Contributions to Finance and Accounting

Antonio Scalia *Editor*

Financial Risk Management and Climate Change Risk

The Experience in a Central Bank

Springer

Contributions to Finance and Accounting

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For Chiara and Giuseppe, in memoriam

Foreword

This volume presents the most recent studies by the experts of the Bank of Italy on financial risk management for monetary policy and the integration of sustainability principles and climate change risk in the investment choices. These studies are of interest, in the first place, to those readers who would like to take an inside look at the central banks' strategic thinking on the above themes. The book describes in a non-technical language the conceptual and methodological underpinnings for some policy choices made by the Eurosystem in the recent past and enables to understand the sustainable investment strategy of the Bank of Italy. In the second place, from an 'external' viewpoint, the book might appeal to financial market players and investors who seek a yardstick in the fast-evolving field of sustainable finance.

The first part of the book hinges around monetary policy implementation and financial risk management, with a focus on the credit assessment of security issuers and borrowers performed by rating agencies and the central bank. The essays in the second part tackle several issues concerning environmental and climate-related risks, advancing the comprehension of their macroeconomic and financial impacts. A light is thrown on the investment opportunities provided by sustainable finance instruments, with a view to stimulating financial intermediaries, investors, and savers to take into account climate risks, possibly beyond strictly financial criteria. The correct measurement of these risks, a prerequisite for their management, is not straightforward, owing mainly to data gaps.

The book reflects the Bank of Italy's commitment to address climate change and integrate environmental, social, and governance (ESG) principles and risks in its activities. Since 2010, the Environment Report documents the effectiveness of the initiatives taken towards reducing the Bank's environmental footprint. As of 2019, sustainability criteria have been introduced into the Bank's investment management. In July 2021, by publishing the Responsible Investment Charter, the Bank made three commitments: to promote ESG sustainability in the financial system, also by means of greater information disclosure; to integrate ESG principles into the management of its investments and of financial risks; and to publish analyses and results on sustainable finance on a regular basis. In 2021, these commitments inspired the

Bank's active involvement in the work of the G20 Italian Presidency. In 2022, the Bank started the publication of the Annual Report on Sustainable Investments and Climate-Related Risks.

I believe that the contents of this book may contribute to the knowledge and correct evaluation of the impacts of climate change, in the spirit of the solemn wish made by William Nordhaus in his Nobel Lecture.

Bank of Italy, Rome, Italy Paolo Angelini

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Contents

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About the Editor

Antonio Scalia graduated with honours in Economics at LUISS University, Rome; he obtained an M.Sc. in Economics from the LSE and a Ph.D. from the London Business School. As of 2020, he is the Head of the Financial Risk Management Directorate at the Bank of Italy and a member of the ECB's Risk Management Committee. He had joined the Bank of Italy's Research Department as an Adviser in the Financial Markets Division. He was appointed as the Bank of Italy's representative in several missions with the IMF and working groups at the Bank for International Settlements. At the ECB, he was formerly a member of the Market Operations Committee. His research, published in leading academic journals, concerns prudential regulation and banks' behaviour, information asymmetries in financial markets, the Treasury bond market, the Eurosystem operations, the effectiveness of foreign exchange intervention, and the management of foreign exchange reserves.

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Financial Risk Management and Climate Change Risk

Antonio Scalia

This book presents the recent studies conducted by the experts of the Bank of Italy in two fields: (1) the challenges for financial risk management posed by the growth of the central bank balance sheet, as a result of the unconventional monetary policy measures (Part I); (2) the integration of climate risk and sustainability principles into the investment policy (Part II). The management of the Bank's assets takes place within the general framework of the Eurosystem's policies.

Since 2020, partly following the Covid-19 pandemic, some major developments have taken place in the above fields. The co-authors of this book have been engaged in the underlying debate with the other central banks of the euro area and have contributed to defining the Bank of Italy's policy choices on its sustainable investment strategy. The essays in the book show the underlying analyses and illustrate some avenues for future work, based on the Bank's commitments as well as on the Eurosystem's work programme on climate change and monetary policy implementation.

The publication of this volume is inspired by the general idea that central banks should base their climate-related investment policies, to the extent possible, on predetermined, objective, and transparent principles (Signorini 2020b).

The risks faced by central banks reflect their mandate. The main risk source is thus the possibility that the institutional objectives, namely, price stability and financial stability, are not achieved (Goodhart 2010; Borio 2019). This *strategic policy risk* is overarching with respect to other risk sources, like financial risk and climate-related risk. The protection of financial soundness is conducive to financial independence, which in turn grants credibility to the central bank. This supports public confidence in its policy effectiveness (Passacantando 2013; Rossi 2013).

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Therefore, the central bank's financial management should not be evaluated on the basis of the traditional risk-return criteria adopted by any private investor. Central banks are risk-averse in normal conditions. Under exceptional circumstances, with a view to preserving the stability of the financial system, they may choose to take even large risks (Mersch 2017). Therefore, the central banks' ability to estimate and manage financial risks is crucial. They derive from the policy tasks, the management of foreign exchange reserves, and the investment activity. These circumstances call for an integrated risk management view, which may encompass the entire range of assets and liabilities (Liikanen 2017; Gelsomino 2017). The investment strategy should take a long-term perspective, in view of the possibility to face and absorb extreme events (Signorini 2020a).

In the past decade, all major central banks have adopted unconventional monetary policy measures on an unprecedented scale. While the economy has benefited from a massive liquidity injection and low interest rates, central banks have purchased a huge amount of public sector securities and corporate securities. Similar securities, plus bank loans, have been pledged in large amounts as collateral against refinancing operations. To widen the scope of these operations, central banks have also extended the range of eligible collateral. Following the economic downturn related to the Covid-19 outbreak, at the beginning of 2020, the monetary authorities have adopted further expansionary measures. At the end of 2020, the size of the US Federal Reserve balance sheet was equivalent to 35% of domestic GDP, 10% points above the level of 2015; the size of the Eurosystem balance sheet was equivalent to 60% of the euro area GDP, with an increase of 35 points from 2015. The abundant liquidity in the economic system has tempered the tensions on the markets and favoured the easing of financial conditions (Bank of Italy 2021a).

While the pandemic risk seems to be fading, the main global threat is related to climate change. There is widespread agreement on the notion that the dimension of climate risks calls for a global coordination and that governments are responsible for the fundamental policy choices to tackle such risks (Visco 2021a). At the same time, central banks can play their part as well, by pursuing their price stability mandate in an effective manner even in the presence of these risks (Buch and Signorini 2021). The action against climate change and the pursuit of environmental sustainability may also affect other competencies of central banks, like banking supervision (Lagarde 2021).

In recent years, the central bank community has intensified the efforts towards environmental sustainability and the fight to climate change in several directions, as shown in 2017 by the establishment of the Network for Greening the Financial System (NGFS), a global forum of central banks and supervisory authorities. The NGFS aims at sharing best practices, contributing to the development of climate risk management in the financial system, and promoting environmental sustainability initiatives in finance (Bernardini et al. 2021). In 2015, the Financial Stability Board established the Task Force on Climate-Related Financial Disclosures (TCFD). The TCFD has set common standards and encouraged firms to publish the information on the exposure of their activities to climate risk on a voluntary basis. These actions by central banks reflect their ambition to raise the public awareness on sustainability risks, promote the circulation of information on environmental risks, and foster sound climate risk management practices on the part of financial intermediaries (Visco 2020). Finance can crucially support the reduction of carbon emissions by channelling a growing amount of funds towards sustainable investments. However, progress in this area is restrained by substantial data gaps. It is thus of key importance to fill these gaps, first of all by promoting common standards of disclosure on firms' sustainability at the international level (Visco 2021b).

In the review of monetary policy strategy of July 2021, the Governing Council of the ECB stated that it is strongly committed to further incorporating climate change considerations into its monetary policy framework. A comprehensive action plan has been undertaken, with an ambitious roadmap (ECB 2021). The review recognises that climate change and the carbon transition may affect the value and risk profile of the central bank assets, potentially leading central banks to accumulate an unwarranted amount of climate-change-related risk. The 2021–2024 action plan on the monetary policy implementation framework foresees four work streams dealing, respectively, with information disclosure, risk assessment, collateral rules, and the corporate sector purchase programme. The Governing Council has mandated the ECB's Committees to work out the implementation details to allow the introduction of new operational rules by 2024 (Panetta 2021). As part of this process, the Eurosystem has conducted the first climate stress test on its own balance sheet; it is assessing the transparency of rating agencies about the integration of climate risk into their rating methodologies; and it is developing new approaches for the incorporation of climate risk into its own internal ratings.

In March 2023, the ECB published the first climate-related financial disclosures, providing information on the Eurosystem portfolio of the Corporate Sector Purchase Programme and on the ECB's euro-denominated non-monetary policy portfolio. These documents show the carbon footprint and exposure to climate risks, as well as information on climate-related governance, strategy, and risk management. In the same month, several other National Central Banks (NCBs) in the Eurosystem, including the Bank of Italy, published their own climate-related reports on the non-monetary policy portfolios.

The risk management framework of the Bank of Italy is based on a strategic investment allocation model, operational guidelines, and ex-post controls. The allocation model follows an integrated asset-and-liability approach for the management of the foreign exchange reserves and the euro-denominated own-fund portfolio. The guidelines set the size, composition, and risk limits of the portfolios. The risk tolerance of the Bank drives the choice of the short-term financial risk budget (Fanari and Palazzo 2020). The respect of individual issue- and issuer-level limits is controlled on a regular basis. Ex-post controls include risk measures at portfolio level.

The risk management framework for the monetary policy activities is based on the Eurosystem rules, which foresee eligibility requirements for counterparties and collateral, as well as a margin system. The risk guidelines for the monetary policy purchase programmes include eligibility requirements for the issuers, issue limits, and the regular monitoring of market and credit risk.

Since 2019, the Bank of Italy integrates sustainability criteria in its investment choices. These criteria are combined with the general principle of market neutrality (Visco 2019). In July 2021, the Bank published the Responsible Investment Charter, which lays out its vision of sustainable finance, takes on commitments to promote it and explains, in its role as a long-term investor, the principles underlying its management of the financial portfolio and foreign exchange reserves.

The principles and criteria spelled out in the Charter will guide the future integration of sustainability evaluations with financial considerations in the investment activity. The more general ambition is to stimulate awareness in the financial community about these issues and the risks that may arise, encourage firms to manage them in a way that is respectful of the environment and society, and compliant with the best corporate governance practices (Angelini 2021).

In this rapidly evolving landscape, financial risk management by central banks faces new challenges. Part I of this volume deals with *Monetary policy and financial risk management*. Chapter "The Cost of Unconventional Monetary Policy Measures. A Risk Manager's Perspective", by M. Fruzzetti, G. Gariano, G. Palazzo, and A. Scalia, examines the evolution in the years 2010–2022 of credit risk arising from monetary policy operations and emergency liquidity assistance in the Eurosystem balance sheet. The risk model is dynamic and based on the expected default frequencies of sovereign issuers, banks, and corporates estimated by Moody's Analytics. This innovative, market-driven approach, complementary to the one employed by the ECB, yields interesting results. In 2022, shortly after the Eurosystem ended net asset purchases under its long-standing quantitative easing programmes, the risk was approximately equal to less than half of the value measured at the peak of the sovereign debt crisis in 2012, notwithstanding the almost threefold increase in the Eurosystem monetary policy exposure occurred since then. This shows the effectiveness of the Outright Monetary Transactions (OMT) Programme and the Pandemic Emergency Purchase Programme (PEPP) in quelling market turmoil, thereby reducing the Eurosystem's own balance sheet risk. The OMT in particular has had a lasting effect in reducing sovereign risk in the euro area. These findings support the view that, in periods of severe financial distress, financial risk for a central bank is largely endogenous.

Chapter "The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency", by P. Antilici, G. Gariano, F. Monterisi, A. Picone, and L. Russo, examines the measures adopted by the ECB and the Bank of Italy to address the pandemic emergency in 2020, showing their effects for Italian banks. The Eurosystem conducts lending operations against adequate collateral. As a consequence, the rules on asset eligibility as collateral play a central role in monetary policy implementation and become pivotal in periods of economic distress, when banks increase their reliance on central bank refinancing. In response to the crisis triggered by the Covid-19 pandemic, the Eurosystem adapted its collateral and risk control frameworks to widen collateral availability and enable banks to benefit from ample central bank liquidity, thus safeguarding credit supply to the real economy. Italian banks have also benefited from the broader rules on the eligibility of loans under the so-called *additional credit claims* scheme. Since 2022, collateral eligibility rules have been gradually brought back to normal conditions.

Is it possible to take an inside look at the process employed by rating agencies to assess sovereign issuers? Chapter “Sovereign Ratings”, by A.M. Di Gioia and R. Imperato, gives an affirmative answer. The methodologies with which the four agencies recognised by the Eurosystem (DBRS, Fitch, Moody’s, and S&P) assign their rating to sovereign issuers share some common features. A quantitative *model rating* is assigned first, employing economic and financial variables for the country; then the rating committee introduces other, mainly qualitative, considerations and produces the official rating. The ratings for the same sovereign may thus diverge across the four agencies. In the case of Italy, the most favourable quantitative driver of the rating is the economy’s size as measured by GDP; additional economic strengths are the balanced external position and the solid institutional framework. The qualitative part of the rating is instead driven by Italy’s risk factors. The chapter shows that the model rating can be replicated fairly well by an outside analyst. In the agencies’ models, some significant indicators for a sovereign issuer (e.g. the primary budget surplus, the wealth and indebtedness of the private sector, and the share of derivative instruments in the banks’ balance sheets), in which Italy performs well, have a low or nil weight.

The Bank of Italy’s internal rating system for non-financial companies (*In-house credit assessment system*, ICAS) is described in chapter “The Bank of Italy’s In-House Credit Assessment System for Non-Financial Firms”, by F. Giovannelli, A. Iannamorelli, A. Levy, and M. Orlandi. The Bank’s ICAS is one of the sources for the valuation of collateral within the Eurosystem monetary policy framework. It helps to provide liquidity to those Italian banks that cannot rely on an internal model. Its role has become all the more important in the aftermath of the financial crisis related to the Covid-19 pandemic in 2020. The chapter outlines the collateral framework and illustrates the ICAS’ architecture, governance, statistical model, and validation process. It provides information on the amount of collateral pledged and the probability of default of the Italian non-financial companies rated by the system. Since 2020 the Bank’s ICAS has enabled Italian banks to fully exploit the easing of collateral eligibility rules for bank loans, thus addressing one of the adverse impacts of the pandemic for the transmission of monetary policy, namely, the dry-up of funding sources.

Following the recommendations of the Financial Stability Board, in recent years the Eurosystem has made some progress towards reducing the reliance of monetary policy implementation on the assessments of credit rating agencies, which may cause unwarranted pro-cyclical effects for the financial system. Chapter “The Role of Rating Agencies: Implications for the Financial System and Central Banks’ Efforts to Reduce their Reliance”, by P. Alessandri, M. Bignami, F. Corsello, A. Levy, G. Marseglia, A. Miglietta, A. Puorro, L. Russo, and M. Taboga, analyses the channels through which sovereign downgrades have an impact on sovereigns themselves, on banks and other financial institutions, on non-financial firms and, ultimately, on the real economy. It remains true that credit assessments are required for monetary policy implementation. Ratings are ‘hardwired’ in the Eurosystem’s and other major central banks' collateral frameworks, and most of the financial risks borne by the Eurosystem arise from assets assessed by rating agencies. The chapter provides an overview of the recent academic and policy debate, including the idea that the Eurosystem should rely on the assessment of sovereign risk developed internally or provided by another European public institution. In April 2020, the Governing Council of the ECB, as part of the measures to address the pandemic emergency, decided to 'freeze' the rating level of eligible security issuers to mitigate the adverse impact on collateral from possible credit downgrades. This measure was unwound as of July 2022.

In July 2022, the Governing Council of the ECB decided to take further steps to include climate change considerations in the Eurosystem's monetary policy framework, following the strategy review of July 2021. Chapter "The Incorporation of Climate Change Risk in the Eurosystem Monetary Policy Framework and the Decarbonisation of the Corporate Bond Portfolio" provides an overview of the conceptual underpinnings and the ensuing operational steps, with a focus on the actions aimed at decarbonising the corporate holdings acquired with the Asset Purchase Programme and the PEPP. In particular, the ECB decided to reconsider the general market neutrality principle, adjusting the benchmark that guides the corporate bond purchases to integrate climate considerations. This step supports the green transition of the economy in line with the EU's climate neutrality objectives, by providing incentives to companies and financial institutions to be more transparent about their carbon emissions and to reduce them. As a result, the weighted average carbon intensity of the corporate bond purchases carried out after the implementation of the new benchmark in October 2022 is lower by 65% with respect to the purchases conducted during the first 9 months of 2022.

Part II of the book is devoted to *The integration of climate change in financial risk management*. Chapter "The Commitment to Sustainability in Financial Investments", by E. Bernardini, M. Fanari, and F. Panfili, deals with the integration of sustainability principles and climate-related risks into the Bank of Italy's financial risk management framework. In a broad vision, according to the report of the United Nations' Brundtland Commission in 1987:

> sustainable development is [. . .] a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs.

This vision, based on a commitment to social equity between generations, over time has evolved to encompass the pursuit of environmental objectives and parity of access for all persons to schooling and health services, as well as to fundamental political rights, as stated in the UN 2030 Agenda. In the economic and financial system, sustainability is declined along the three key *environmental, social, and governance* dimensions, which form the well-known ESG acronym. Yet, the main dimension, in view of its global scale and impacts, is that of environmental sustainability and climate change. In 2015, the signatory governments of the Paris Agreement on Climate Change committed to limiting the rise in global temperature to 'well below' 2 degrees centigrade with respect to pre-industrial levels. In 2018, the

European Commission approved the Action Plan on Sustainable Finance. Climate issues have become a priority for the G20 agenda as well. In 2021, under the Italian Presidency, the G20 has re-established the Sustainable Finance Study Group, which has been transformed into a permanent working group. Its tasks are the identification of institutional and market barriers to sustainable finance, the development of options to overcome such barriers, and the contribution to the alignment of the international financial system to the objectives of the 2030 Agenda and the Paris Agreement. The chapter discusses the role of central banks in scaling up sustainable and green finance, owing in particular to the potential impact of climate risks on the central banks' ability to pursue their institutional goals.

The share of sustainable instruments in finance is enjoying a rapid growth in supply and demand. Investors are becoming aware of the risks and opportunities inherent in sustainability and the transition towards climate neutrality, which have a bearing on the value of financial portfolios. The Bank of Italy has developed analyses on the management of sustainability risks for its own balance sheet. In 2020, the pandemic-related shock in the financial markets has confirmed the view that companies that are attentive to ESG issues are generally more resilient to sharp market downturns, as the greater stability and resilience of the activities of such companies attract the investment flows (Bank of Italy 2021b).

The sustainable investment policy of the Bank of Italy and its integration in the strategic asset allocation process are the subject of chapter "The Strategic Allocation and Sustainability of Central Bank Investments", by D. Di Zio, M. Fanari, S. Letta, T. Perez, and G. Secondin. The authors present the optimisation methodology, the robustness tests, and the criteria for security selection. Since 2019 the integration of sustainability criteria in the framework for portfolio selection has brought about a significant improvement in the environmental impact of the Bank's investments and in risk management practices, in the face of an increasing exposure related to unconventional monetary policy measures. The Bank has raised the size of the asset classes, like equities and foreign exchange reserves, that have favourable diversification properties vis-à-vis the rise in sovereign bonds under the monetary policy programmes. Stocks and corporate bonds with better ESG scores and a lower carbon footprint have been over-weighted.

Is it possible to evaluate the performance of a sustainable portfolio against that of a standard one? The existing empirical studies show that the risk-adjusted performance of sustainable portfolios has generally been superior to that of the market portfolio. Yet, the ESG scores of an issuer may significantly differ between the specialised providers. Sometimes a bias is observed in favour of the largest companies or of those operating in certain sectors or geographical areas. Chapter "Machine Learning, ESG Indicators, and Sustainable Investment", by A.A.G. Lanza, E. Bernardini, and I. Faiella, takes a closer look at the role of the information contained in ESG scores for stock returns. The study disentangles the underlying E, S, and G variables to ascertain whether any of them has a significant explanatory power for the performance of stocks in the euro area. The empirical analysis hinges on machine learning techniques. By crunching more than 200 ESG variables provided by two leading scoring agencies, the authors show that it is possible to construct optimal ESG portfolios such that, if an investor had employed the same techniques in 2016, he or she would have obtained a significant over-performance relative to the Eurostoxx index in the following years, even controlling for the contribution of the leading factor models of the stock market.

Chapter “The Global Green Bond Market”, by D. Liberati and G. Marinelli, is a comprehensive statistical study on the global ESG bond market. The supply of such bonds is growing steadily due also to the wide interest of investors and to the market initiatives of the main financial centres. The issuance of sustainable bonds in Italy has kept the pace of global issuance; ESG bonds make up 4% of the total value of outstanding corporate bonds. On the demand side, Italian banks and insurance companies hold the largest shares of ESG bonds, mostly issued by foreign entities. The study documents empirically the existence of a *greenium* (from green premium), namely, a negative differential in the yield of sustainable bonds relative to standard bonds with similar financial features.

The heterogeneity of indicators about the environmental and climate-related sustainability calls for a taxonomy among the available methodologies. The last chapter in this book “The Exposure of Investments to Climate and Environmental Risks”, by I. Faiella, E. Bernardini, J. Di Giampaolo, M. Fruzzetti, and S. Letta, presents the key measures of environmental and climate-related risks for sovereign issuers and corporate issuers, respectively. The focus is on the so-called climate transition risks. Although the availability of a set of coherent and comparable indicators is incomplete, the chapter shows that investors may to a large extent measure and manage the climate risks of the portfolio by employing public information yet to be fully exploited, which is instead systematically used by financial data providers. A forward-looking evaluation of climate risk for individual countries may be conducted by employing historical data, the country’s commitments, and the climate scenarios developed by the NGFS. The evaluation of climate risk for corporate issuers is complicated by the partial coverage and the relatively low correlation between the indicators of carbon emissions from the existing data providers; in some cases, there is a significant divergence in the underlying data. These facts suggest a cautious approach for climate risk evaluation, consisting in the use of indicators from different sources, to achieve a larger coverage of the investment universe and detect potential anomalies in the data.

The chapter finally presents an application of environmental and climate risk measurement for the investment portfolio and the foreign currency reserves of the Bank of Italy. The improvement in the climate risk profile of the Bank derives from the introduction of ESG principles in the investment strategy for the euro-denominated portfolio (see chapter “The Strategic Allocation and Sustainability of Central Bank Investments”). After the implementation of the ESG criteria on the equity portfolio in 2019, which brought about a fall in the carbon footprint by 30%, in 2020 the scope of the ESG strategy was extended to the equity investments in the USA and Japan conducted via exchange-traded funds and to the corporate bond portfolio. Since 2021 the share of green bonds issued by sovereigns and supranational entities has been raised steadily. The methodological analysis presented in chapter “The Exposure of Investments to Climate and Environmental Risks” has paved the way for the Bank of Italy's Report on Sustainable Investments and Climate-Related Risks, first issued in May 2022.

Two general caveats may help the reader to put the following chapters in the right perspective. The strong interest in sustainable finance has stimulated new equilibrium models of the capital market that integrate the preference for sustainability and the awareness about climate risk with the traditional financial objectives (e.g. Pástor et al. 2021; Pedersen et al. 2021). If the ESG preference is widespread, in equilibrium the risk premium and expected return of sustainable stocks will be lower than average. In practice, though, it is difficult to distinguish the impact of sustainability preference on equity returns by observing them during a period in which such preference changes swiftly, i.e. outside of capital market equilibrium, like in recent years. This book shows some empirical results on the relationship between the returns on sustainable stocks and bonds and those on standard securities (see Chaps. 10 and 11). The first caveat is thus the very well-known notice in finance: the estimated relationships may change over time and the results shown may not necessarily repeat themselves in the future.

The second caveat is about the state of our knowledge. While the essays in this volume reflect up-to-date information and the current debate on sustainable finance, the general context (policy choices, regulation, market developments, etc.) is likely to continue its rapid evolution in the near future. I would therefore suggest to view the subject matter of this volume as work in progress in a field that will continue to engage monetary authorities, market players, and financial analysts for the years to come.

The experts at the Bank of Italy maintain their active involvement on climate change and sustainability issues in all the relevant fora in which they participate, and in particular in the technical work related to the action plan for the monetary policy strategy of the Eurosystem. Some of the topics dealt with in the book will thus be subject to further analysis, which might contribute to the decision-making process of the ECB.

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Part I
Monetary Policy and Financial Risk Management

The Cost of Unconventional Monetary Policy Measures. A Risk Manager's Perspective

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1 Introduction

After the inception of the Great financial crisis, the Eurosystem and other major central banks adopted unprecedented programmes of long-term lending and large-scale asset purchases, which stemmed the threats to price stability and financial stability.[1] The *'whatever it takes'* statement by President Draghi and the ECB's decision on the Outright Monetary Transactions (OMT) programme in 2012 clearly showed that the Eurosystem's commitment to act as a potential buyer of last resort is in itself capable of shifting expectations in the economy (Altavilla et al. 2016). These

[1] For the Eurosystem, the full list includes the Securities Market Programme (SMP), the Very Long-Term Refinancing Operations (VLTROs; see the list of abbreviations at the end of the book), 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).

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unconventional measures, though, raised some criticism and concerns that their costs and side effects might have been sizeable.[2]

While the effectiveness of the unconventional measures in terms of the achievement of the price stability mandate is the subject of a wide empirical literature, their consequences for the financial risk borne by the Eurosystem are less explored, partly owing 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 (see e.g. Jeanne and Svensson 2007; BIS 2013).[3]

The credit risk embedded in 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 as 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 study by Caballero et al. (2020). Using a novel risk measurement framework, they show that unconventional monetary policy operations generated beneficial risk spillovers for the Eurosystem, causing risk to be nonlinear in exposures.

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 on a consolidated basis, i.e. taking into account the balance sheet items of the ECB and all national central banks in the euro area, over the period January 2010 to August 2022. During this period, the central bank balance sheet experienced a major expansion, as a consequence of several monetary policy purchase programmes, from the SMP to the Pandemic Emergency Purchase

[2]Recurring concerns relate to the following issues: (1) unconventional policies (UPs) may reduce bank profitability (Borio et al. 2015); (2) they may lead to the build-up of asset-price deviations from their fundamentals and trigger a sharp asset-price correction (Borio 2014); (3) UPs may induce financial intermediaries to move toward riskier assets (Rajan 2005; Borio and Zhu 2012); (4) UPs expose monetary authorities to political interference (Taylor 2016); (5) they have undesirable income and wealth redistribution effects (Lenza and Slacalek 2018); (6) they may increase wage pressure, inflation, and undermine the competitiveness of the industry sector (Sinn 2019, 2021); and (7) 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.

[3]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 about the central bank's ability to deliver on policy targets and expose it to political pressure. Del Negro and Sims (2015) discuss the general conditions under which support from the fiscal authority would be optimal for the central bank policies. The capital strength of the central bank is a key notion in general equilibrium models of the effectiveness of monetary policy regimes (see e.g. Reis 2017; Benigno and Nisticò 2020). Goncharov et al. (2023) examine a large sample of central banks spanning more than 20 years and show that central banks are much more likely to report slightly positive profits than slightly negative profits, especially amid greater political pressure.

Programme (PEPP).[4] Net asset purchases under the PEPP were discontinued at the end of March 2022, while for the Asset Purchase Programme (APP) they ended in July 2022. We aim to further the empirical literature on the impact and costs of the unconventional measures, by investigating the notion of risk endogeneity for monetary policy. 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 is similar to the one of Caballero et al. (2020). We employ a dynamic, market-driven risk model, and 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 corporate and bank issuers (as their expected default frequency, or EDF) as well as sovereign issuers (CDS-Implied EDF, or CDS-I-EDF). 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. From a statistical viewpoint, we model dependence between issuers/counterparties using a multivariate Student-*t* distribution with time-varying parameters, which 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% (ES99) confidence level, i.e. the average loss occurring in the worst 1% of the scenarios. We track the risk at a weekly frequency. Our results exhibit a high degree of robustness to different parameter specifications.

We extend the work of Caballero et al. (2020) along several dimensions. First, the period under analysis is from 2010 to 2022, encompassing all measures from SMP to PEPP, and we include the ELA operations. Second, we widen the perimeter of the entities and instruments: in addition to banks and to the five sovereigns purchased under the SMP, we include the instruments issued by all other euro-area sovereigns as well as all euro-area corporate issuers and structured finance instruments (covered bonds and ABS). Third, we employ detailed and confidential data on exposures arising from monetary policy credit operations (i.e. lending via open market operations, OMOs) which account for counterparty and collateral risk. 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 employs a 3-year rolling window of weekly data, thus providing fully out-of-sample (instead of in-sample) risk estimates.

Our main findings may be summarised as follows. First, while from 2010 to 2022 the Eurosystem exposure from monetary policy operations grew from around 2000 billion euros to almost 8000 billion euros, at the end of August 2022 financial risk estimated with our model was broadly equivalent to the average level observed in

[4] Risk originating from the holding of foreign reserves and own funds is not considered.

2011 (70–80 billion euros) and corresponded to only 43% of the risk measured at the peak of the sovereign debt crisis in 2012 (182 billion euros). We attribute the trend in risk reduction mainly to the launch of OMT: with this programme the ECB made it clear that it considers supporting sovereign issuers that experience financial distress as being, under well-defined conditions, within its mandate.[5] This clarification filled a void that previously existed in the institutional set-up of the euro area and has had a long-lasting effect in lowering sovereign risk in the euro area.

Second, 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 highly distressed periods financial risks, especially credit risk arising from sovereign holdings, are largely endogenous for the central bank.[6] 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. Though such market failures can occur anywhere, countries in a monetary union are particularly vulnerable.[7]

Third, 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. Therefore, the Eurosystem financial risk mainly accrues from outright purchase holdings (APP and PEPP),

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[5] Draghi (2012) and ECB (2012).

[6] Our evidence is consistent with the argument put forward by Danielsson and Shin (2003), that in normal conditions, when expectations are heterogeneous, market agents are price takers and asset prices only depend on the financial and economic fundamentals, treating risk as exogenous is appropriate. In this case, the use of the standard risk measurement tools, 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, asset prices not only depend on financial and economic fundamentals but, to a large extent, they are also affected by the response of individual agents to the unfolding events: market distress can feed on itself. 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 (Brunnermeier and Pedersen 2009; Danielsson et al. 2010, 2012).

[7] In particular, with reference to government debt markets, the presence of self-fulfilling defaults is widely studied in the 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; see also Cole and Kehoe (2000). de Grauwe (2011), de Grauwe and Yuemei (2012, 2013), Corsetti and Dedola (2016), and Orphanides (2017) apply this notion to the euro area. Reis (2017) shows that quantitative easing can be an effective tool for the central bank during a fiscal crisis, by reducing the sensitivity of inflation to fiscal shocks and preventing a credit crunch.

which produced 90% of total risk at the end of August 2022. Risk from public sector purchases accounted for 58% of total risk.

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 the major policy announcements in the last decade, we find that OMT and PEPP, activated amid severely deteriorating market conditions, had been powerful circuit breakers (the result for OMT being broadly in line with Caballero et al. 2020). The SMP's effectiveness 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, so its risk efficiency is relatively small and mainly connected to the price stability objective.

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 can withstand the materialisation of an extreme ES99-sized credit loss. We find that the Eurosystem as a whole had relatively large capital buffers, defined as the sum of capital and reserves, revaluation accounts, and risk provisions. At individual NCB level, comparing the buffers with our risk estimates, for the major NCBs, the buffers were larger than 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.

The remainder of the chapter is organised as follows. Section 2 describes the input data used for the risk estimation, namely, the exposures and the probabilities of default. Section 3 describes the methodology underlying our estimates. Section 4 presents our results. Section 5 concludes. The Appendix provides further methodology details.

2 Data

This section describes the input data used for the analysis, namely, the exposures and the probability of default.

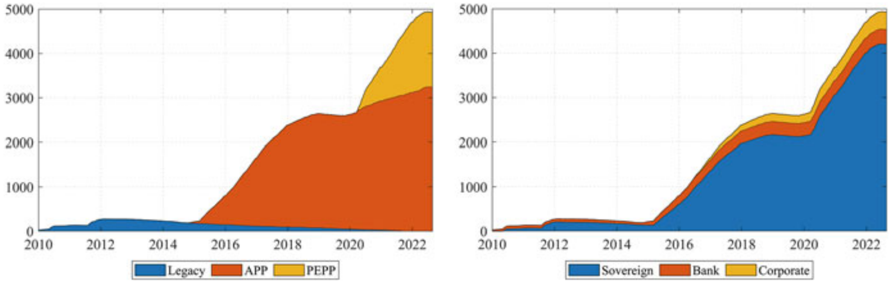

Fig. 1 Monetary policy securities holdings (**2010–2022**, book value, billion euros). The left panel shows the composition by category: the legacy programmes (CBPP1&2, SMP), the Asset Purchase Programme (APP, which includes the Covered Bond, ABS, Public Sector and Corporate Sector Purchase Programmes) and the Pandemic Emergency Purchase Programme (PEPP). The right panel shows the breakdown by sector: public, corporate and bank (i.e. covered bonds and ABS). Source: ECB and own calculations

2.1 Exposure

While aggregated figures for monetary policy and ELA exposures are publicly available, detailed data at the level of individual issuer/counterparty can only be retrieved from the Eurosystem non-public database.

For the purchase programme portfolios, our dataset contains each single transaction from 5 July 2013 onwards. For the purpose of risk estimation, transaction amounts (book and face values) can be aggregated at the level of individual financial instruments. For the period January 2010 to June 2013, which is not covered in our database, we estimate exposures of the Covered Bond Purchase Programmes 1&2 (CBPP1&2) and of the Securities Market Programme (SMP) from the total (publicly available) outstanding portfolio. We assume the same composition by issuer as that observed on 5 July 2013 for CBPP1&2, while for the SMP we take into account the different country composition during the two waves of the programme.[8]

Figure 1 shows the evolution over time of the monetary policy purchase programme holdings, which significantly increased after the launch of the APP at the end of 2014, and especially during its first 3 years of operations (with monthly net purchases of 60–80 billion euros). Net asset purchases under the PEPP were discontinued at the end of March 2022, while for APP they ended in July 2022; in both cases, only the reinvestment of redemptions remained in place.

For credit operations, our dataset contains collateral amounts (collateral face value, collateral value before and after haircuts) for each date, counterparty and financial instrument, from 17 September 2010 onwards. For the period 1 January

[8] SMP purchases were conducted by Eurosystem central banks in two main waves. The first one (May 2010 to 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.

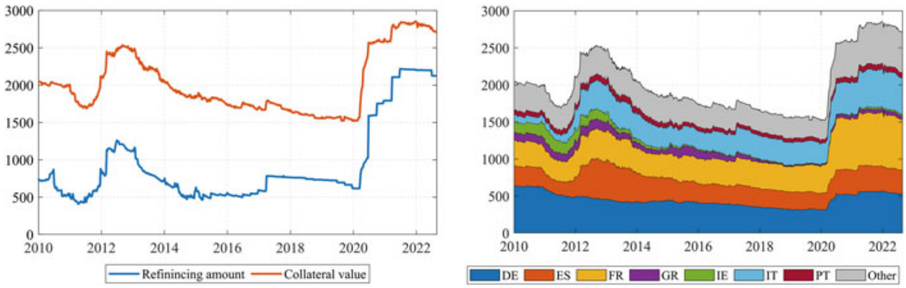

Fig. 2 Credit operations (2010–2022, refinancing amount and collateral value, billion euros). The left panel compares the actual refinancing amount (blue line) with the value of collateral after haircut (red line), which is its upper bound. For simplicity, the refinancing amount only includes the monetary 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, which covers all the outstanding operations (see Sect. 3 for the exposure-at-default assumptions). The right panel shows the distribution of collateral by jurisdiction. Source: ECB and own calculations

2010 to 17 September 2010, we estimate detailed collateral data from aggregated collateral amounts, as recorded in internal archives, assuming the same composition by issuer as that observed on 17 September 2010. Figure 2 shows the evolution over time of the monetary policy refinancing amount and collateral value.

Both the value of collateral after haircut and the actual refinancing amount 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 amounted to 27% of collateral value as of August 2022, on some dates in the first half of 2011 it was around 300%.

For ELA operations, exposures are again obtained from internal data sources.[9]

2.2 *Probability of Default*

This section describes the 1-year probabilities of default used as input for our risk estimation. We use the PDs computed by Moody's as expected default frequencies (EDFs). They are widely employed in the financial sector in counterparty

[9]Some public information regarding ELA may be found on the website of the relevant NCB. Mourmouras (2017) reports some evidence regarding ELA exposures of the Eurosystem over time. 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). Calomiris et al. (2016) provide a thorough discussion of the lender-of-last-resort role of the Eurosystem and other central banks.

Table 1 EDF sample: number of debtors by sector

Sovereign & Supranational	19
Bank	184
Corporate—Invest. Grade	197
Corporate—High Yield	181

assessment, early warning systems and portfolio monitoring, internal risk rating systems, and loss provisioning. These market-driven EDFs, which are independent of agency ratings, enable us to investigate the behaviour of financial risks around some major monetary policy announcements of the sample period.

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, in the absence of the latter input, EDFs are derived from CDS premia (CDS-I-EDF), with a methodology that relies on two equations: a spread valuation equation, which converts CDS premia into 'risk-neutral' PDs, and a translation equation, which converts risk-neutral PDs into 'physical' PDs. The parameters of the translation equation are calibrated so that CDS-I-EDFs are—on average—consistent with standard EDFs.[10]

Both types of EDFs, for corporates and sovereigns, are physical PDs (as opposed to risk-neutral PDs), and thus require no adjustment to disentangle the quantity of risk from the market price of risk for use in credit risk estimation.[11]

Our sample comprises 581 debtors, distributed by sector as reported in Table 1.

We use high-yield EDFs for credit claims pledged as collateral with non-investment grade credit quality.[12] Table 2 reports some EDF statistics.

Our EDFs sample does not cover all the entities employed in our risk estimation, which amount to around 7000 distinct debtors (including counterparties, purchase programme issuers and collateral issuers). To make this large number tractable, we create country-sector EDF indices, which are assigned to debtors without an EDF in the sample. More specifically, we cluster debtors by country and sector, and for each

[10] Moody's Analytics (2010). The approach is used to derive the 5-year CDS-I-EDFs. The EDFs for different horizons, such as the 1-year horizon that is used in this chapter, are derived from the 5-year ones employing a model of the relationship between credit risk and time horizons that relies on three components: an asymptotic default tendency, a systemic factor and a firm-specific factor (see Moody's Analytics 2017 for further details).

[11] 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 et al. (2005).

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

Table 2 EDF statistics by sector and time period (2010–2022, percentage values). Sectors are: Sovereign & Supra; Bank; Corporate Investment Grade; Corporate High Yield

			Percentiles				
		Avg.	5th	25th	50th	75th	95th
2010–2012	Sovereign	0.80	0.01	0.01	0.07	0.30	3.07
	Bank	2.60	0.15	0.38	0.58	1.41	14.73
	Corp. IG	0.46	0.02	0.04	0.12	0.38	1.32
	Corp. HY	0.97	0.03	0.06	0.20	0.87	4.28
2013–2017	Sovereign	0.17	0.01	0.01	0.01	0.03	0.62
	Bank	1.46	0.09	0.31	0.60	1.30	5.58
	Corp. IG	0.14	0.01	0.02	0.04	0.14	0.50
	Corp. HY	1.19	0.01	0.03	0.09	0.41	4.83
2018–2022	Sovereign	0.02	0.01	0.01	0.01	0.01	0.04
	Bank	0.66	0.01	0.15	0.34	0.62	2.64
	Corp. IG	0.15	0.01	0.02	0.03	0.11	0.57
	Corp. HY	1.15	0.01	0.03	0.11	0.51	5.42

Table 3 Country-sector EDF indices

Sovereign & Supra (19)	Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Portugal, Slovakia, Slovenia, Spain, the Netherlands,[a] 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

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

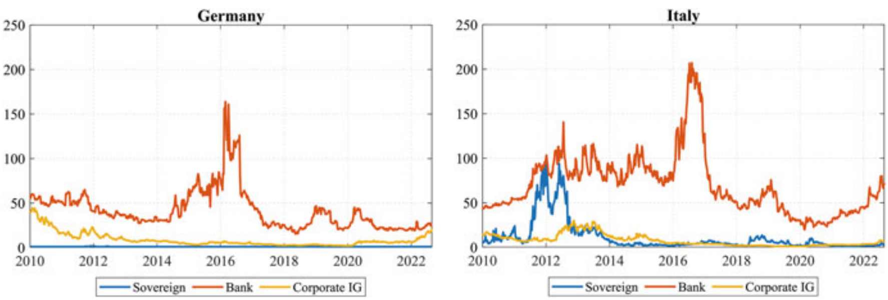

Fig. 3 Country-sector EDF indices for Germany and Italy (2010–2022, basis points). Source: Moody's Credit Edge and own calculations

cluster we compute the median of all available EDFs, which is then assigned to all the entities in the cluster without an EDF. We chose the median rather than the average EDF since the former is less sensitive to outliers, in line with Caballero et al.

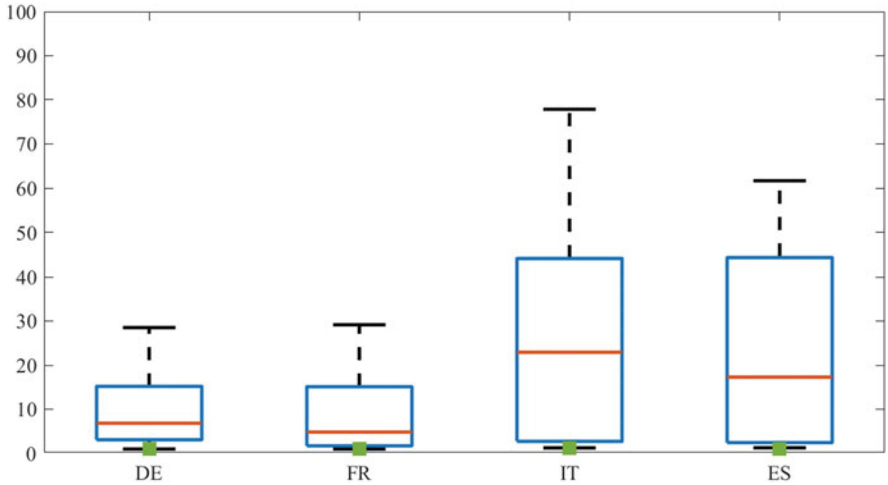

Fig. 4 Sovereign EDF (green squares) and corporate EDFs (boxplots) for the major jurisdictions in the euro area (average in Q4 2021, basis points). For the largest countries of the euro area, the sovereign issuer is perceived as less risky than the safest domestic firm. Source: Moody's Credit Edge and own calculations

(2020). Since there is a single sovereign for each country,[13] sovereign indices correspond to the individual EDFs (and not to a median of several EDFs). In all, we calculate 36 indices (Table 3).

Figure 3 shows EDF indices for Germany and Italy.

A robustness check of CDS-I-EDFs is challenging, because very few sovereign defaults are available. A possible course of action consists in checking that the value of the sovereign CDS-I-EDF in each country is consistent with domestic corporate EDFs (financial and non-financial), under the assumption that the former should be lower. Figure 4 shows that this is indeed the case for the largest countries of the euro area.

3 Methodology

This section describes how we estimate the financial risk of the Eurosystem. Input data consist of (1) monetary policy and ELA exposures and (2) probability of default of issuers and counterparties, both described in Sect. 2. The output is a measure of risk for the whole Eurosystem over a 1-year horizon.

We estimate risks by means of a Monte Carlo simulation in which over 100,000 scenarios are drawn at any date, with the exact number (which may be as large as

[13] 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.

200,000) depending on the fulfilment of a convergence criterion.[14] In any scenario, losses arising from purchase programmes and monetary policy and ELA refinancing operations are computed and aggregated. Risks are calculated as the expected shortfall at the 99% confidence level (ES99), i.e. taking the average of the 1% most adverse losses realised in the simulated scenarios at any particular date.

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 materialise only subordinately to the default of the counterparty. This implies that we calculate losses conditionally on the default of one or more debtors whom the Eurosystem is exposed to.[15]

The methodology has three building blocks: (1) the calculation of losses for the entire Eurosystem (Sect. 3.1); (2) the simulation of the default indicator for issuers and counterparties (Sect. 3.2); and (3) the calibration of the parameters of the multivariate distribution on market data (Sect. 3.3).

3.1 Calculation of Losses

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[16] and a fixed percentage of the nominal value, as follows:

$$L = \sum\nolimits_a \delta_{\text{issuer}(a)} \cdot (\mathrm{BV}_a - \mathrm{RR}_a \cdot \mathrm{FV}_a)$$

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 value and the face value of the asset, and RR is the recovery rate.

Our recovery rate assumptions are 60% for structured finance instruments (covered bonds and ABS) and 30% for all other assets. These values are conservatively based on historical recovery data from Moody's and complementary internal analyses for structured finance instruments.[17]

In the previous formula, book values and face values, which proxy for the exposure-at-default (EAD), are those observed at the reference date, and do not include the net purchases which were already defined and known to take place within the 1-year horizon. Risk estimates under this approach thus ignore the fact that the EAD over a 1-year horizon would be larger than that implied by current exposure.

[14] After the first 50,000 simulations, 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% for five consecutive times.

[15] Potential losses arising from market prices movements are therefore not considered.

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

[17] See Moody's (2021a, b).

This potential underestimation of risk, however, is absorbed over time, since our analysis spans a very long period (more than 12 years) and ends at a point where all net purchases were discontinued: the programmes eventually reach their target amount (envelope), and from that moment on exposure at the reference date is a good proxy of EAD.

The calculation of losses arising from monetary policy credit operations (i.e. lending via open market operations) takes into account the double layer of protection offered by the counterparty and the collateral pledged. First, 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 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,[18] as follows:

$$L = \sum\nolimits_c \delta_c \cdot \max\left(0, \mathrm{EAD}_c - \sum\nolimits_{a \text{ in collateral}(c)} (\delta_a \cdot \mathrm{FV}_a \cdot \mathrm{RR}_a + (1 - \delta_a) \cdot \mathrm{BH}_a)\right)$$

where c is the counterparty index, a is the collateral instrument index, EAD is the assumed exposure-at-default, δs are the binary default indicators for the counterparties and the collateral asset issuers, BHs are the values before haircut, FVs are the face values, and RRs 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 have increased 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,[19] assuming that banks under stressful conditions would have increased their monetary policy exposure up to the maximum allowed amount, given by the value of collateral they had pledged (net of the haircuts).[20] 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 26 August 2022, the total refinancing exposure was 2100 billion euros, while the total net collateral value—which we use as EAD—was 2700 billion euros (+27%).

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

[18] 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.

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

[20] 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.

$$L = \sum\nolimits_c \delta_c \cdot \max\left(0, \sum\nolimits_{a \text{ in collateral}(c)} (\text{AH}_a - \delta_a \cdot \text{FV}_a \cdot \text{RR}_a - (1 - \delta_a) \cdot \text{BH}_a)\right)$$

where AHs are the values after haircut.

Since collateral value before haircuts is always larger than collateral value after haircut, collateral assets that do not default add a negative contribution to losses, which offsets the positive contribution originated by collateral assets that do default. Thus, we take into account both the diversification effect in the collateral pool and the protection offered by the haircuts.

Regarding ELA operations, losses could in principle be computed 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, exposure is likely to be of worse quality than exposure via 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 operations conducted in the sample period (see Appendix, Section B for more details).

3.2 *Simulation*

In the formula of the previous subsection, exposures (book values, face values, values before haircuts, and 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 debtors for each scenario:

1. issuers of assets held in the purchase programme portfolios;
2. counterparties in monetary policy and ELA operations; and
3. issuers of assets pledged as collateral by counterparties.

These debtors are jointly simulated according to a multivariate Student-*t* distribution, which is a standard choice for this kind of risk estimation.[21]

In practice, for each debtor *I,* we define a Student-*t* random variable X_i as:

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

$$X_i = \sqrt{\frac{\nu}{u}} \cdot Z_i$$

where u and Z_i are independent with u distributed as a chi-square (with ν degrees of freedom) and Z_i as a standard normal. In turn, Z_i is calculated as:

$$Z_i = \sum\nolimits_{k=1}^{m} \beta_{i,k} \cdot F_k + \sqrt{1 - \sum\nolimits_{k=1}^{m} \beta_{i,k}^2} \cdot \varepsilon_i$$

where F_i and ε_i are independent and distributed as a standard normal. Since the factors F_i are common to all debtors, the correlations are given by:

$$\rho(X_i, X_j) = \rho(Z_i, Z_j) = \sum\nolimits_{k=1}^{m} \beta_{i,k} \cdot \beta_{j,k}$$

The coefficients β can be obtained via the Cholesky decomposition of the correlation matrix (Ω) of the Student-t variables.

Thus, two parameters (the scalar ν and the matrix Ω) must be estimated before the simulation. This process is described in Sect. 3.3.

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

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

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

$$T_i = Q(\mathrm{PD}_i)$$

This yields a simulated default rate equal to the PD, up to the Monte Carlo error. 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. Nevertheless, the distribution determines the simulated joint default rates (i.e. the number of scenarios where many debtors jointly default, leading to the largest losses).

Finally, we point out that, while issuers in the purchase programme portfolios and counterparties are simulated over a 1-year horizon (namely, the risk horizon),[22] 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

[22] 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 seems acceptable if one considers the practice of reinvestment which has taken place until the end of the sample period.

counterparty default. In practice, this means that PDs must be scaled down for collateral assets.

For more details, see Appendix, Section B.

3.3 Calibration

The simulation described in the previous subsection requires the calibration of the degrees of freedom ν (a scalar) and the correlation matrix Ω (a matrix).

The estimation is performed in two steps:

1. Estimation of the correlation matrix;
2. Estimation of the degrees of freedom, conditionally on the previously estimated correlation matrix.

The correlation matrix (Ω) required for our analysis has a very large dimension since on each date we must simulate over 7000 debtors. Therefore, we cannot estimate it directly. We address this issue by working with block equicorrelations within and across clusters. With this approach, we can define the correlation matrix Ω as a function of a much smaller correlation matrix Σ: $\Omega = \Omega(\Sigma)$, with $\Omega \in R^{N,N}$, $\Sigma \in R^{D,D}$, and $D << N$. D is the number of clusters, while N is the number of debtors. The mapping of matrix elements is surjective but not injective (i.e. any element of Σ typically appears multiple times in Ω):

$$\Omega_{i,j} = \Sigma_{\text{cluster}(i),\text{cluster}(j)}$$

We define as clusters the country-sector group defined in Table 3 (Sect. 2.2), so that $|D| = 36$.

The within-cluster correlations (i.e. the off-diagonal diagonal elements in the diagonal blocks of Ω) cannot be read directly from Σ.[23] In line with Caballero et al. (2020), we proceed by assuming that the within-cluster correlations are equal to the maximum correlation observed for the relevant sector (e.g. the correlation between corporates in the same country is equal to the maximum correlation between corporates in that country with corporates of all other countries). For sovereign clusters, correlations within cluster can be safely set to 1, since there is a single sovereign for each country.

As in Caballero et al. (2020), we fit Σ to the weekly log-changes of the EDF indices. The log-changes function maps the domain of the EDF, which is the [0, 1]

[23] As otherwise it would imply perfect correlation within cluster: $\Sigma_{\text{cluster}(i),\text{cluster}(j)} = \Sigma_{\text{c,c}} = 1$.

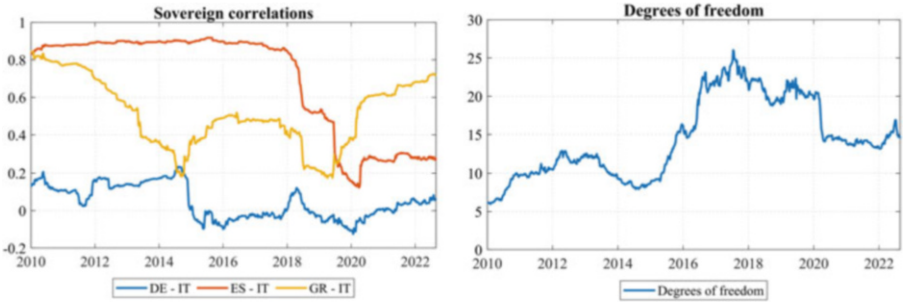

Fig. 5 Time-varying Student-*t* parameters (2010–2022). This figure plots the time series of the estimated correlations between Italy and Germany, Italy and Spain, Italy and Greece (left panel) and the degrees of freedom (right panel). Source: own calculations

interval, to the real axis, where the Student-*t* distribution is defined. We also check that other transformations have a negligible impact on the results.[24]

The same data, namely, weekly log-changes of the EDF indices, are also used for the estimation of the degrees of freedom, which are obtained by means of maximum likelihood estimation:

$$\nu = \text{argmax}_\theta \sum_{i=1}^{\text{nobs}} \log f(\theta; Y_i, \Sigma)$$

where f denotes the multivariate Student-*t* density function, θ and ν denote the degrees of freedom (to be estimated), Y are the log-changes of the country-sector EDF indices, and Σ is the correlation matrix previously estimated.

Both parameters (ν and Σ) are estimated with a moving average rolling approach using the last 3 years of weekly data (with a number of observations equal to 156). This means that on each date risks are estimated using a different correlation matrix and a different value for the degrees of freedom. The resulting risk estimates are thus fully out-of-sample, i.e. they reflect the 'true' market risk perception at any date.

The left panel of Fig. 5 shows the time series of three relevant sovereign correlations: Italy and Germany, Italy and Spain, and Italy and Greece. It shows that Italy was highly correlated (>80%) with Spain for the years 2010–2017. From 2018 onwards, the correlation between Italy and Spain decreased due to Spain being upgraded and leaving the 'BBB' group.[25] From 2020 onwards, Italy was highly correlated with Greece instead. Finally, correlation between Italy and Germany had always been small, and sometimes even negative.

The right panel of Fig. 5 shows the time series of the degrees of freedom. The estimated degrees of freedom were mostly below 10 until 2015 and larger in the

[24] More specifically, we test an alternative estimation based on the changes in normal quantiles of the EDF indices, which is another common transformation (the normal quantile of the probability of default is sometimes referred to as distance-to-default).

[25] In the first quarter of 2018 Spain were upgraded from BBB to A by both Fitch and S&P.

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).

Section A in Appendix reports robustness analysis for both the correlation matrix and the degrees of freedom.

4 Results

This section presents our risk estimates. Risk is estimated for the entire Eurosystem as the expected shortfall at the 99% confidence level (ES99) with the methodology described in Sect. 3, for the period between January 2010 and August 2022.

Figure 6 summarises the main results. Aggregate exposure increased from around 2000 billion euros at the beginning of 2010 to almost 8000 billion euros at the end of August 2022. Risk reached an overall maximum around 182 billion euros in June 2012, even though monetary policy exposure widely increased since then, following the APP in 2014 and PEPP in 2020. We attribute this trend in risk reduction mainly to the launch of OMT. With this programme, the ECB made it clear that it considers supporting sovereign issuers that experience financial distress as being, under well-defined conditions, within its mandate. After June 2012, risk reached local highs on the following occasions: (a) the ELA provision to Greek banks in 2015; (b) the political tensions in Italy surrounding the formation of the new government in May 2018; (c) 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. The increase in risk

Fig. 6 Risk and Exposure (2010–2022, billion euros). Risk and exposure at weekly frequency from 1 January 2010 to 26 August 2022. Source: own calculations

Fig. 7 Absolute risk and relative risk (2010–2022, billion euros and percentage of exposure. Risk in absolute terms (billion euros) and relative terms (percentage of exposure) at weekly frequency from 1 January 2010 to 26 August 2022. Source: own calculations

in 2022 was mainly a consequence of the increase in the exposure to sovereigns, while PDs had reached a floor (1 basis point; see Figs. 3 and 4).

As discussed in the next subsections, financial risks 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 highly distressed periods financial risks, especially credit risk arising from sovereign holdings, are largely endogenous for the central bank. This point is made even more clear in Fig. 7, which shows absolute risk (billion euros) and relative risk (as a percentage of exposure).

Figure 8 shows the breakdown of risk by sector. The contribution to risk of monetary policy credit operations was rather small and less sensitive to financial market developments, due to the collateralised nature of refinancing to commercial banks. The risk profile of the Eurosystem changed after the launch of the purchase programmes, becoming 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 was quite significant.[26] As of August 2022, the public sector accounted for 58% of total risk, while the corporate sector and the bank sector accounted for 25 and 17%, respectively.

Next, we examine what would have happened if an ES99-sized credit loss had materialised: would capital buffers have withstood 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,

[26]Figure 8 does not show the breakdown for confidentiality reasons.

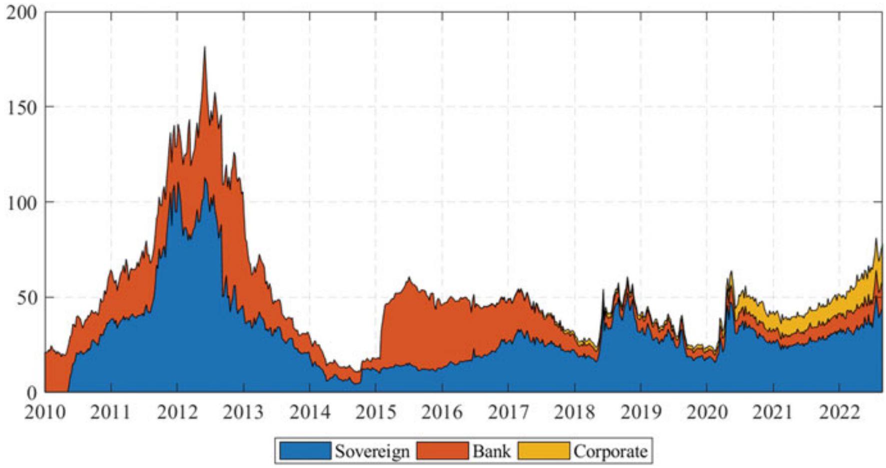

Fig. 8 Risk breakdown by sector (2010–2022, billion euros). The sovereign sector and the corporate sector take into account the risk of the corresponding purchase programmes. The bank sector, in addition to risk arising from purchase programmes (covered bonds and ABS), also includes the risk of monetary policy refinancing and ELA operations. Source: own calculations

legal reserves and other reserves), revaluation accounts (i.e., unrealised gains on certain assets like gold), and risk provisions.

We find that for all major NCBs the buffers were larger than 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.[27]

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.

Next, we look more closely at the evolution of risk during four time periods encompassing the launch of the major purchase programmes for sovereign bonds: SMP, OMT, PSPP, and PEPP. To examine these monetary policy measures under a cost-benefit perspective, we show two indicators (Fig. 9) related to the central bank price stability mandate and the financial stability function, respectively: (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 (this indicator ranges between 0 and 1).[28]

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[27] The individual NCB figures are not provided for confidentiality reasons.

[28] Garcia-de-Andoain and Kremer (2018) and Holló et al. (2012).

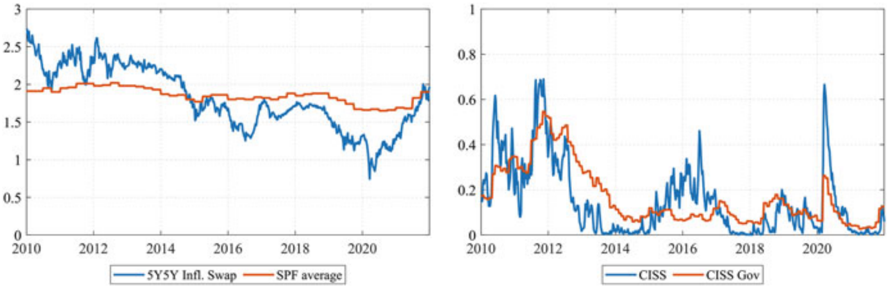

Fig. 9 Inflation expectations and systemic stress indicator (2010–2021). The left panel plots the 5-year, 5-year forward euro inflation swap rate (blue line) and, for comparison, the long-term inflation expectations from the Survey of Professional Forecasters (red line). The right panel plots the CISS index (blue line) and its sovereign component (red line). Source: ECB

We cannot perform a proper event study analysis. Such an approach rests on the assumption that markets are informationally efficient. In our context, this would imply that the impact of the ECB's decisions materialises on the exact date of announcement, while in the cases under review expectations had been shaped over a period of time, during which the views and actions of financial market participants, including the central bank, had 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 and the first half of 2015.

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

4.1 Securities Market Programme (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.[29] Yet the market tensions that had led to the launch of the SMP had been going on since the end of 2009, when difficulties with public finances in Greece had come into the focus of financial market participants.

[29] ECB (2010a).

In launching the SMP, as well as in subsequent official speeches by the President of the ECB, the communication was very cautious.[30] On 10 May, the ECB did not announce any key features of the SMP, such as which securities it would target, the amount that would be purchased, and how long the programme would last.[31] Furthermore, it became evident that the ECB was not acting decisively also on account 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 rose 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.[32]

The sovereign crisis did not abate after the launch of the second wave of the SMP, as shown in Fig. 10.[33]

[30] 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).

[31] 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'*.

[32] ECB (2011).

[33] 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.

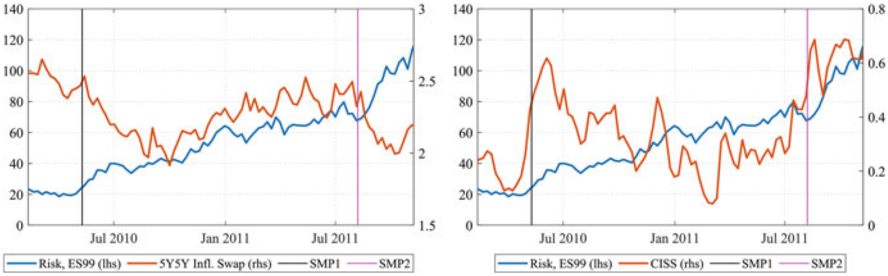

Fig. 10 Risk (left and right panels, billion euros), Inflation expectations (left panel, percentage values), and Systemic stress indicator (right panel) around the two relevant SMP dates (10 May 2010 and 7 August 2011). Risk is on the left y-axis, while inflation expectations and systemic stress indicators are on the right y-axis. Source: ECB and own calculations

4.2 Outright Monetary Transactions (OMT)

The two 3-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.

At their summits in the first half of 2012, the 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, in January, and of the Single Supervisory Mechanism, in June.

As a further intervention to avoid impairment 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.[34] On 2 August 2012, at the press conference following the Governing Council meeting, the ECB announced that it *'may undertake outright open market operations of a size adequate to reach its objective'*.[35] On 6 September, the ECB eventually announced a number of technical features of the OMT programme.

[34] 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.

[35] 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: (1) explicit conditionality; (2) full transparency about the countries where OMT

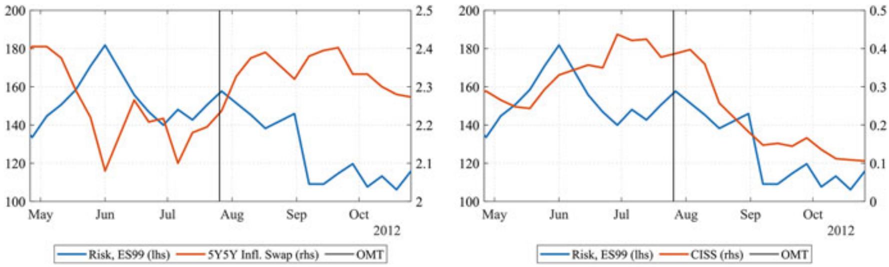

Fig. 11 Risk (left and right panels, billion euros), Inflation expectations (left panel, percentage values) and Systemic stress indicator (right panel) around the *'whatever it takes'* statement (26 July 2012). Risk is on the left *y*-axis, while inflation expectations and systemic stress indicators are on the right *y*-axis. Source: ECB and own calculations

The announcement of the OMT signalled determination and strength, and succeeded in easing market tensions (Fig. 11). The effectiveness of the announcement of OMT in affecting 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.[36] In the following years, risk has never reached the level of 2012, despite the huge increase of the Eurosystem's balance sheet.

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.[37] The decision to launch the OMT was later challenged before the German Constitutional court by members of the German Bundestag.

4.3 Asset Purchase Programme (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 (Fig. 12). In the face of weaker-than-expected inflation dynamics and signs of decrease of inflation expectations even at long horizons, on

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would be undertaken and about the amounts; (3) focus on the shorter part of the yield curve; and (4) review of the issue of the seniority of the Eurosystem claims.

[36] Altavilla et al. (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 et al. (2017) show significantly positive effects on banks' equity prices after the OMT announcement.

[37] 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.

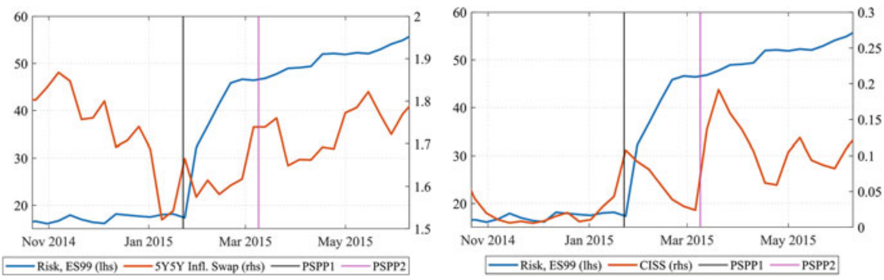

Fig. 12 Risk (left and right panels, billion euros), inflation expectations (left panel, percentage values), and systemic stress indicator (right panel) around the extension of APP to the public sector (22 January 2015, PSPP1) and the actual start of the purchases (9 march 2015, PSPP2). Risk is on the left y-axis, while inflation expectations and systemic stress indicators are on the right y-axis. Source: ECB and own calculations

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, agencies, and EU institutions (Public Sector Purchase Programme, PSPP).[38] 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. The evolution of risk around 22 January 2015 was affected by the large ELA operations in Greece, that started just a few days later.

As with the OMT, also the launch of the APP was challenged in court.[39]

4.4 *Pandemic Emergency Purchase Programme (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

[38]For an analysis of the macroeconomic effects of the APP in counteracting the falling inflation expectations, see Neri (2021).

[39]The complainants—a group of about 1750 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.

March an official statement by the President of the ECB did not point to any concrete action and merely signalled that the central bank *'stands ready to take appropriate and targeted measures, as necessary and commensurate with the underlying risks'*.[40] The first measures to address the effect of the pandemic were announced on 12 March. These included additional LTROs, more favourable terms applied to TLTRO III operations and a temporary envelope of additional net asset purchases for the APP, by 120 billion euros, until the end of 2020.[41]

After some stress indicators 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 flexible implementation of the purchases over time, across asset classes and among jurisdictions, reinforced the perception of the ECB's determination to act.[42] 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 subsequent rating downgrades on collateral availability for euro area counterparties.[43]

However, after an initial positive market reaction, intra-EMU credit spreads rapidly surged 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.[44] PEPP started to be seen as unable to address re-emerging 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 euros of spending power. Italian and Greek government bonds sharply rallied after the announcement, sending their yields to 3-month lows. Before

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[40] 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%) and the discount rate from 2.25 to 1.75%.

[41] ECB (2020b).

[42] Time-wise flexibility allows the central bank to adjust the pace of asset purchases to market conditions. Bernardini and Conti (2021) show that this type of flexibility in the implementation of the programme significantly contributed to its effectiveness.

[43] 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.

[44] 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.

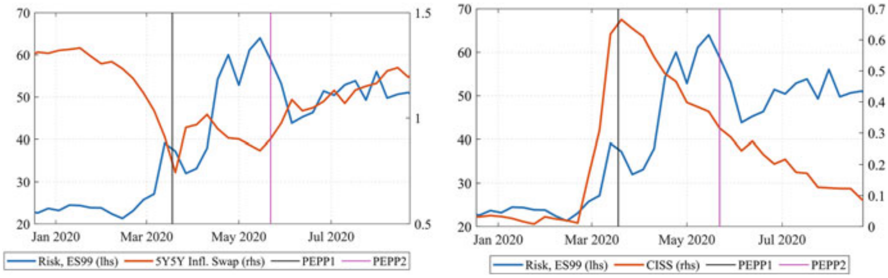

Fig. 13 Risk (left and right panels, billion euros), inflation expectations (left panel, percentage values), and systemic stress indicator (right panel) around the PEPP announcement and follow-up (PEPP1: 18 March; PEPP2: 22 May 2020). Risk is on the left *y*-axis, while inflation expectations and systemic stress indicators are on the right *y*-axis. Source: ECB and own calculations

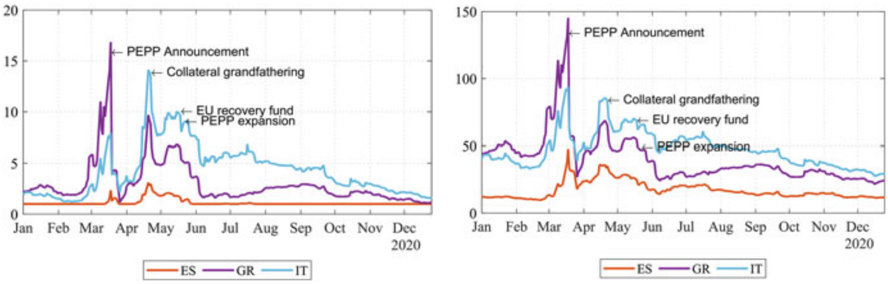

Fig. 14 1-year (left panel) and 5-year (right panel) CDS-I-EDF of Spain, Greece, and Italy (basis points) during 2020. Source: Moody's Credit Edge

then, Eurosystem risk had peaked at 62 billion on 15 May 2020, based on our estimates.

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 would have bought an extra 600 billion euros of bonds, a move larger than most economists' expectations, taking the PEPP financial envelope to 1.35 trillion euros in total. Italian and Greek government bonds rallied after the announcement (Figs. 13 and 14).

Table 4 summarizes the change in risk, inflation expectations, and the financial stability indicator 3 weeks after the monetary policy announcements described in this section.

Table 4 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)	+33	−14	+33
SMP2 (7 August 2011)	+15	−18	+3
OMT (26 July 2012)	−11	+16	−29
PSPP1 (22 January 2015)	+134	−6	−36
PSPP2 (9 March 2015)	+5	−8	+106
PEPP1 (18 March 2020)	−3	+21	−14
PEPP2 (22 May 2020)	−23	+13	−13

4.5 Trasmission Protection Instrument (TPI)

On 21 July 2022, the ECB introduced the Transmission Protection Instrument under which it will be able to purchase euro area countries' bonds under certain conditions; a previous statement of the ECB on 15 June 2022 had already made clear that the ECB services were accelerating the completion of the design of such an instrument.[45] The TPI addresses the risk that the higher monetary policy rates needed in response to higher inflation could cause yields for some sovereigns to rise sharply, bringing about fragmentation in the financial system of the eurozone and destabilising monetary policy transmission.

The TPI can be activated to counter what the ECB considers unwarranted, namely disorderly market dynamics that seriously threaten the transmission of monetary policy. To be eligible for the TPI, countries should be compliant with the EU fiscal framework, have a sustainable public debt trajectory, and have sound and sustainable macroeconomic policies, with no severe macroeconomic imbalances. Eligibility will be decided by the ECB's Governing Council. The scale of purchases will depend on the severity of the risks to transmission and is not restricted ex-ante.

Preliminary evidence (Fig. 15) suggests that the TPI announcement was effective at addressing fragmentation in the euro area and compressed the risk on the Eurosystem balance sheet around the two reference dates (15 June and 21 July 2022).

[45] ECB (2022a).

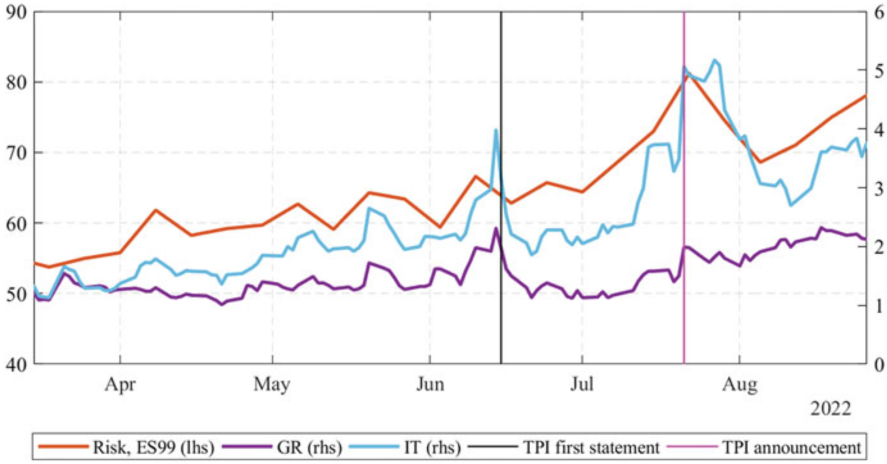

Fig. 15 Risk (billion euros, left *y*-axis) and 1-year CDS-I-EDF of Greece and Italy around two reference dates 15 June and 21 July 2022 (basis points, right *y*-axis) from 15 March 2022 to 26 August 2022. Source: Moody's Credit Edge, own calculations

5 Conclusions

We show the evolution of financial risk on the monetary policy and ELA operations of the Eurosystem since 2010 using a methodology that relies on probabilities of default inferred from real-time market data.

While from 2010 to 2022 the Eurosystem exposure arising from monetary policy operations grew almost by a factor of four, financial risk estimated with our model at the end of the period was broadly equivalent to the average level observed in 2011 and corresponded to only 43% of the risk 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 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 mindset 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 Eurosystem risk from 2012 onwards, provide a clear indication about the risk-efficiency of these monetary policy measures. Our results are robust under different methodological assumptions regarding exposures, probabilities of default, and default co-dependency structure.

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 exposure 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.

Appendix

A. Robustness Analysis

This section provides a robustness analysis of our results. First, we focus on the default co-dependency model. Figure 16 shows the impact on risk of different copula specifications, comparing the proposed fat-tail approach (Student-*t*) with the Gaussian approach. While accounting for fat tails leads to higher estimated risk (the average risk level of the Student-*t* copula is larger by 9% with respect to the Gaussian copula), the risk profile is basically the same under the two approaches. This is partly due to the fact that our estimates for the degrees of freedom of the Student-*t* are moderately high (see Fig. 5, Sect. 3.3).

Second, Fig. 17 compares our risk estimates with those obtained under the assumption of very fat tails. The latter are obtained by artificially setting the degrees of freedom to very low levels (down to 1) at all dates, rather than using our estimated values.[46] The number of degrees of freedom affects the tail behaviour: the smaller its value, the heavier the tails. Fatter tails lead to higher estimated risk; e.g. setting the degrees of freedom equal to 1 would imply an average risk level larger by 37% than in our approach. However, the risk profile over time is broadly the same.

Figure 18 compares our risk estimates with those obtained under the assumption of very high correlations. The latter are obtained by artificially raising the correlations to very high—and rather unrealistic—levels (up to 100%) for all pairs of debtors at all dates. High correlations have a larger impact on the absolute level of risk than the degrees of freedom (a constant correlation equal to 100% implies an

[46]The moments of the Student distribution are undefined for low values of the degrees of freedom parameter (for example, the variance is defined only for a number of degrees of freedom above 2).

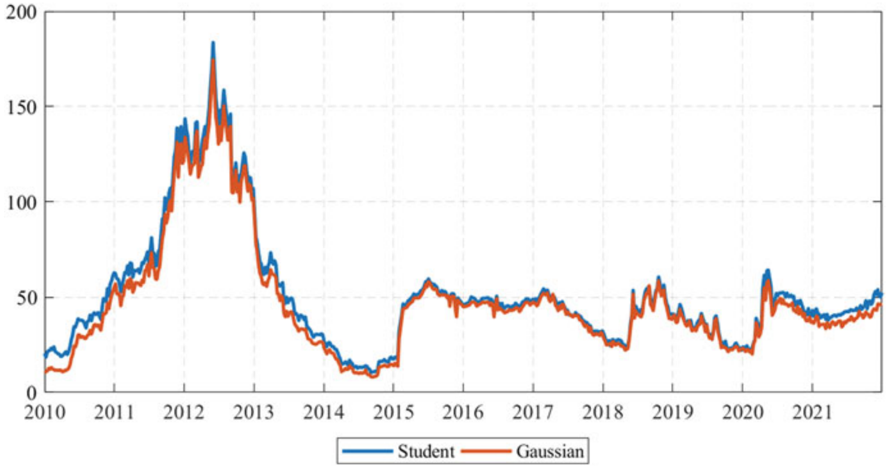

Fig. 16 Risk; Student-*t* *vs* Gaussian copula (2010–2021, billion euros). This figure compares risk estimated with the fat-tail approach (Student-*t*) against that estimated with the Gaussian approach. Source: own calculations

average risk increase by 82% with respect to our approach). Even in this case, however, the risk profile remains broadly unchanged.

Next, Fig. 19 shows that the effect on the risk measure of a different rolling window for the parameter estimation, namely, the 3-year window compared with the alternative 2-year and 1-year windows. The alternative parameters do not affect our results in a significant way.

We then examine more closely the PDs. Since sovereign PDs are by far the most important input of our model, we have also considered as an alternative the methodology proposed by Heyndericks et al. (2016), which is also employed by Caballero et al. (2020). Even this alternative method employs physical PDs obtained from CDS quotes.

Figure 20 compares the 1-year CDS-I-EDF for Italy with the PD computed with the Heyndericks method. The latter yields a much larger volatility for the estimated PDs compared with Moody's EDFs. We attribute this to the fact that Moody's CDS-I-EDF involves the daily recalibration of the relevant parameters, which allows for the adjustment (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. The parameters proposed by Heyndericks et al. for converting risk-neutral PDs into physical PDs are constant over time, hence market noise incorporated in risk-neutral PDs is filtered out to a lesser extent.

Figure 21 shows the impact on risk of these two different PD specifications for the sovereign. The volatility of the PD with the alternative method affects the volatility of the corresponding risk estimate, which shows a larger peak-to-trough difference.

Our interpretation of this check is that, while alternative parameter choices may affect the absolute level of the risk estimates, the evolution of risk over time looks

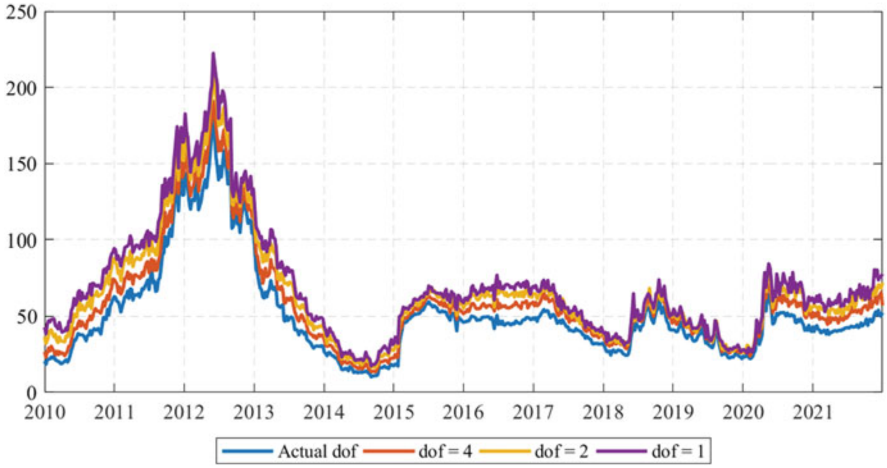

Fig. 17 Risk; actual degrees of freedom *vs* very low degrees of freedom (2010–2021, billion euros). The blue line represents our estimated risk measure (based on the estimated degrees of freedom), while the other lines are obtained by setting the degrees of freedom equal to 4, 2, and 1 (constant for all dates). Source: own calculations

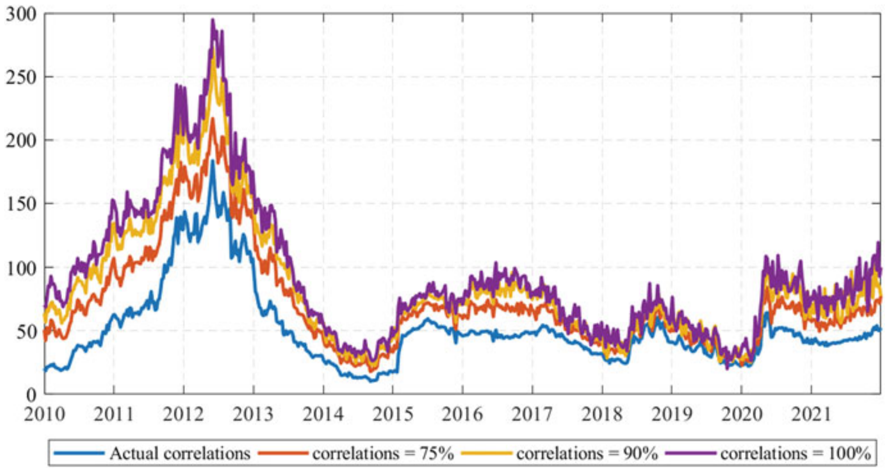

Fig. 18 Risk; actual correlation *vs* very high correlation (2010–2021, billion euros). The blue line represents our estimated risk measure (based on the estimated correlations), while the other lines are obtained by setting all correlations equal to 75, 90, and 100% (constant for all dates and for all pairs of debtors). Source: own calculations

broadly similar in all cases. This supports our general conclusion, namely, that at the end of August 2022 financial risk is broadly equivalent to the average level observed in 2011 and corresponds to less than half of the risk measured at the peak of the

Fig. 19 Risk; different rolling window lengths (2010–2021, billion euros). The blue line represents our estimated risk measure (based on a 3-year window), while the other lines are obtained by using 2-year and 1-year windows. Source: own calculations

sovereign debt crisis in 2012, despite monetary policy and ELA exposure have grown by almost a factor of four during the entire period.

B. Further Methodology Details

Simulation of Collateral

While risk on purchase programme holdings and counterparties is simulated over a 1-year horizon, collateral is simulated over a much shorter horizon, since collateral 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,[47] 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.

In order to simulate collateral over a time horizon equal to the assumed T2L, the default thresholds (T_i, see Sect. 3.2) must be calculated on the T2L PDs (e.g. the

[47] 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.

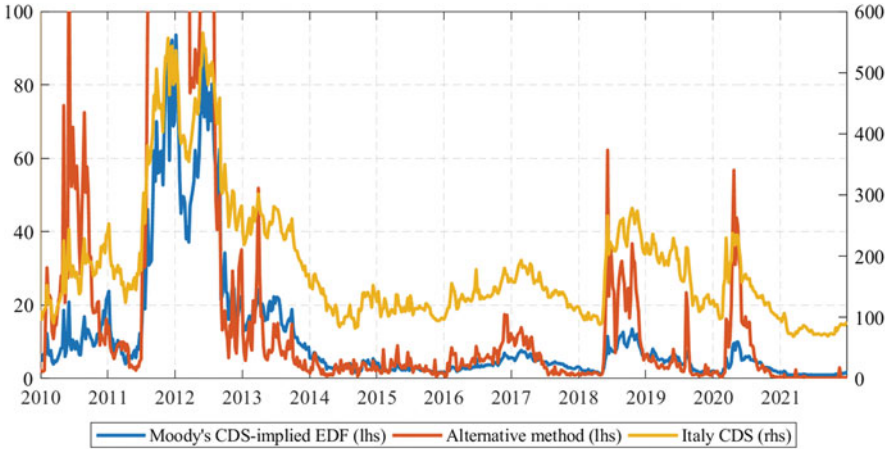

Fig. 20 1-year probability of default of Italy and Italy's CDS (2010–2021, basis points). This figure compares the 1-year probability of default of Italy retrieved from the Credit Edge platform provided by Moody's Analytics (CDS-I-EDF, blue line) with that obtained with an alternative method also based on CDS (red line). For comparison, the yellow line represents the Italian CDS (right *y*-axis). Source: Moody's Credit Edge, CMA, own calculations

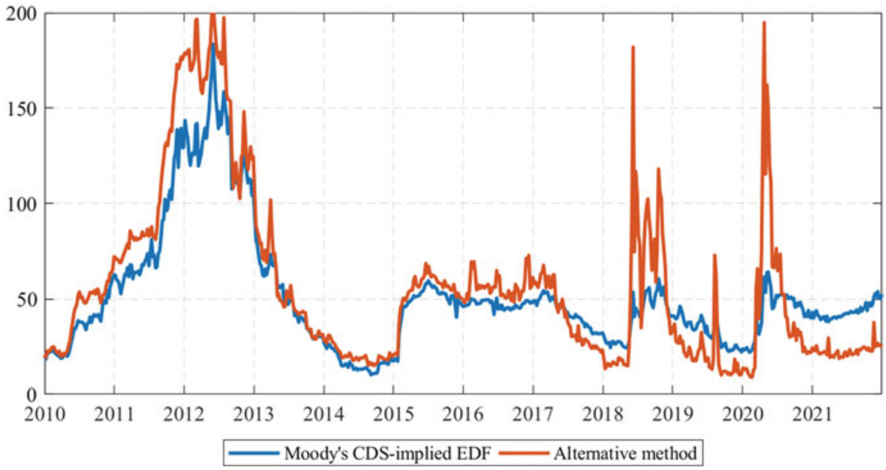

Fig. 21 Risk; Moody's EDFs *vs* alternative PDs (2010–2021, billion euros). This figure compares the risk estimates based on Moody's EDF (blue line) with those obtained using for all sovereigns the alternative specification based on Heynderickx et al. (2016) (red line). Source: own calculations

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:

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

Central governments	1
Local governments	2
Agencies and supranational	2
Covered bonds	3
ABS	6
Uncovered bank bonds	6
Corporate and other	6
Own-used collateral	52
Credit claims	52

$$\mathrm{PD}_{\mathrm{T2L}} = 1 - \left(1 - \mathrm{PD}_{1-\mathrm{year}}\right)^{\mathrm{T2L}}$$

We note that the same asset might be included in the purchase programme holdings as well as in the collateral pool. In such cases, 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 a quality comparable to investment grade, and one containing the remaining credit claims.[48] 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 hundreds of thousands (the actual number of distinct debtors) to below 1000. The approximation leans on the conservative side, since it reduces the degree of diversification within the collateral pool.

ELA Operations

In theory, losses arising from ELA operations could be calculated with the same formula employed for monetary policy credit operations (see Sect. 3). In practice, however, risks from ELA exposures should 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 banks, should be taken into account.

As a first assumption, we set the EAD equal to the current exposure. This makes sense since in the ELA operations the exposure 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:

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

$$\mathrm{EAD} = \sum\nolimits_{a \text{ in collateral}} \mathrm{AH}_a = \text{actual exposure}$$

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 number of banks in the same jurisdiction resort to ELA. Both types are in turn divided into two different subtypes. More specifically we consider:

1. 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;
2. 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;
3. 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;
4. 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 3 and 4 above), where the collateral composition is not considered, the loss (if any) is computed as:

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

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

Probability of Default for Covered Bonds and ABS

For covered bonds and ABS,[49] 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,[50] 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 ABS. These 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)[51] with those implied by the rating of their issuers. In spite of the same average level of rating, we estimate a lower divisor (3.06) for ABS than for covered bonds since ABS default rates are generally higher than non-ABS default rates, for any given rating level.

C. 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 661, the number of portfolios ranges from 0 to 9 depending on the date,[52] and the average number of issuers for any portfolio is 120, yielding a total number of records approximately equal to 360,000;
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 661, the average number of counterparties by date is 1500, and 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 13 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 8000;
4. probability of default table: each record contains the PD for any given combination of date/debtor. The number of dates is 661, the number of debtors (either

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

[50] Covered bonds and ABS have almost always an AA rating.

[51] For covered bonds, we use the 'Global Corporates' default rates, since no covered bonds default was ever experienced in the past. For ABS, we use the 'Structured Finance' default rates.

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

issuers or monetary policy counterparties) is approximately 9000, yielding a total number of records around six 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.

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The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency

Paola Antilici, Giulio Gariano, Francesco Monterisi, Alessandro Picone, and Luigi Russo

1 The Role of Collateral in Monetary Policy Transmission

The European Central Bank (ECB), like most other central banks, steers the short-term money market interest rates by setting the policy rates, which correspond to the price paid by commercial banks for borrowing funds from National Central Banks (NCBs) on behalf of the Eurosystem.[1] The interest rates charged by the Eurosystem on the money lent to banks—an alternative for them to market-based funding—affect interest rates in the interbank market, where banks lend funds to each other. Changes in interbank rates, together with market participants' expectations of their future level, affect short-term and longer-term bond rates which, in turn, affect consumption and investment decisions of households and firms, thereby ensuring the transmission of changes in central bank policy rates to the real economy.[2]

When borrowing from the Eurosystem, banks need to provide adequate collateral. In this context, the concept of collateral adequacy has a twofold interpretation: on the one hand, it refers to the need to protect the Eurosystem from incurring losses in the

[1] See ECB (2011).

[2] The implementation of monetary policy in the euro area assigns a central role to credit operations with banks to manage liquidity in the money market and influence interbank rates; this is due to different reasons: (1) the inability to purchase or sell very short-term securities owing to the lack of a sufficiently developed market (like the US Treasury Bill market); (2) the greater reliance of the real economy on bank lending relative to market funding.

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event a counterparty fails to repay the borrowed amount according to the agreed terms. On the other hand, collateral adequacy means that banks should be in a position to pledge as collateral the assets that originated in their core business activities, thereby mitigating the risk that potential collateral shortages may impair the access to central bank liquidity and ultimately undermine the transmission of monetary policy to the real economy.

Therefore the rules on the assets the Eurosystem accepts as collateral play a central role in the monetary policy operational framework and are pivotal in periods of financial stress.[3]

Since 2007 the Eurosystem has developed a harmonised framework for eligible assets (the so-called 'single list')[4] that replaced the former dual system, in place since 1999, which included: (1) tier one collateral, accepted by all NCBs and subject to a loss-sharing regime, and (2) tier two collateral, specific to each NCB and subject to a no loss-sharing regime. Since 2011, in response to the euro area sovereign debt crisis, the Governing Council of the ECB has again allowed NCBs to accept as collateral, in a no loss-sharing scheme, a set of assets with specific features (the so-called Additional Credit Claims—ACCs—frameworks, see Sect. 2), in practice re-establishing a dual system, albeit temporarily.

During the global financial crisis of 2008, severe tensions emerged in interbank markets worldwide, which no longer ensured an efficient redistribution of liquidity from banks with a surplus of funds to banks with a liquidity shortage; as a result, credit institutions' needs for central bank funding increased. In this context, the Eurosystem has adopted a liquidity-providing mechanism, which is still in place, that offers banks as many funds as they need at a fixed interest rate (the so-called fixed rate tender with full allotment mechanism).[5] Under this regime, banks' collateral availability effectively limits the access to central bank liquidity. To enable counterparties to take full advantage of the expansionary measures introduced by the ECB in the aftermath of the global financial crisis, the range of eligible assets has been expanded several times, thereby mitigating the risk of banks reducing credit supply to the real economy.[6]

As a result of these measures, the value of the collateral pledged by Italian banks and their refinancing with the Eurosystem have considerably increased over time. By February 2020, before the outbreak of the pandemic, the refinancing granted to Italian banks reached 213 billion euros, while the value of the collateral pool, net of haircuts (see Sect. 3), was approximately 287 billion euros (Fig. 1).

[3] See Bindseil (2014).

[4] See ECB (2006).

[5] Prior to 2008, the amount of liquidity to be offered to banks was defined *ex ante* by the ECB and was distributed to the counterparties participating in monetary policy operations through a competitive tender system.

[6] See Koulischer and Struyven (2014).

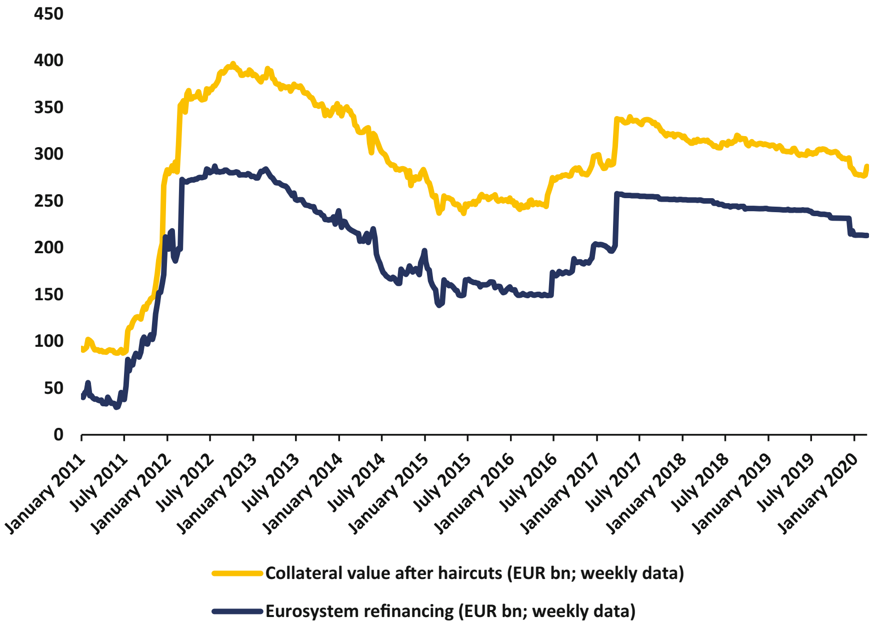

Fig. 1 Eurosystem refinancing and collateral in Italy

2 The Eligibility Criteria for Collateral and the Credit Assessment Sources

The Eurosystem accepts a wide range of assets as collateral, including marketable debt instruments (public sector securities, corporate and bank bonds, ABSs) and non-marketable assets (credit claims). The choice to accept a wide range of assets as collateral was made in 1999 consistently with the decision that credit operations would be offered to all banks operating in the euro area, provided they are supervised. This creates the need to ensure that adequate collateral is available to a large number of banks which feature rather different business models.[7]

To be considered eligible as collateral for Eurosystem liquidity-providing transactions, assets must fulfil a number of criteria, which are uniform to all Eurosystem credit operations across the euro area. The only exception is represented by the criteria for the ACC frameworks, which are defined by each NCB following a minimum set of rules (see Sect. 4). Notably, the type of instrument, the place of issue, the currency of denomination, the country of residence of issuers/debtors/guarantors, the absence of subordination of the rights to principal and interest, and

[7] See Bindseil et al. (2017).

the creditworthiness are all crucial elements for determining the eligibility of Eurosystem collateral.[8]

To assess the creditworthiness of potentially eligible assets, the Eurosystem has developed the Eurosystem Credit Assessment Framework (ECAF), which defines the procedures, rules and techniques to ensure that eligible assets meet the requirement of high credit standards. In particular, the Eurosystem relies on information—ratings or probabilities of default (PDs)—provided by the following three sources of credit assessment:

(a) the external credit assessment institutions (ECAIs);
(b) the NCBs' In-House Credit Assessment Systems (ICASs; see chapter "The Bank of Italy's In-House Credit Assessment System for Non-Financial Firms");
(c) the counterparties' Internal Ratings-Based (IRB) systems.

Ratings and PDs are mapped into the credit quality steps (CQSs) defined by the Eurosystem harmonised rating scale. All assets accepted by the Eurosystem as eligible collateral in the general framework must have a minimum credit assessment of CQS 3, which is equivalent to a rating not lower than BBB-[9] or to an annual PD of the obligor/issuer less than or equal to 0.40%. Under its ACC framework, the Bank of Italy accepts as collateral credit claims with higher PDs: for individually pledged loans it requires an annual PD of less than or equal to 1.5% (CQS 5), while the threshold is set at 99% for loans mobilised within portfolios of credit claims (see Sect. 3). In any case, only performing loans are accepted as collateral.

The Eurosystem uses the ratings assigned by the recognised ECAIs to assess the credit quality of marketable assets, while the PDs provided by ICASs and IRBs are also used to assess the credit quality of debtors whose credit claims are pledged as collateral. The ratings provided by IRBs are mostly used by larger banks, while ICAS ratings are mainly used by smaller banks, which do not have internal credit assessment systems. The ICASs therefore play a crucial role in allowing small banks to refinance their loans with the central bank, thus increasing their capacity to access the Eurosystem liquidity. Since 2008, the share of counterparties using the IRBs and the ICASs to pledge credit claims as collateral has steadily increased.

On an annual basis, the Eurosystem runs a performance monitoring exercise by comparing the default rate observed at the end of each year for all potentially eligible debtors/issuers/instruments and the ratings/PDs assigned to them by each credit assessment system at the beginning of the year. The objective of this exercise is to check that each credit assessment system is able to predict with sufficient accuracy the defaults in the sample of the rated entities and to ensure that the mapping of the

[8] With regard to marketable assets, the ECB publishes on its website the list of the eligible assets, which is updated daily by the NCB of the country where the asset is admitted to trading on both regulated or recognised non-regulated markets. The eligibility of credit claims is self-assessed by the counterparties on the basis of pre-defined public criteria. The self-assessment is followed by ex-post checks performed by the competent NCB.

[9] Where the same bond has more than one rating issued by the recognised rating agencies, the Eurosystem considers the best rating; for ABSs it requires two ratings not lower than A.

rating/PD classes with the Eurosystem's CQSs remains adequate. In the event of a significant deviation between the observed default rate and the maximum PD associated with each CQS, the Eurosystem engages with the credit assessment system provider in order to analyse the reasons for the deviation; as a result, the Eurosystem may require corrective actions and, ultimately, may also impose restrictive measures.

3 The Risk Control Framework

When implementing monetary policy via liquidity-providing operations, the Eurosystem is exposed to the risk of a counterparty default and, in this scenario, to the credit, market, and liquidity risks associated with the assets pledged by that counterparty as collateral. As a first layer of risk protection, the Eurosystem has therefore defined a set of rules aimed at ensuring the financial soundness of banks that can act as counterparties in credit operations. In addition, the Eurosystem applies a set of risk control measures on the assets pledged as collateral, which constitute the second layer of protection.[10] These measures include limits on the use of certain assets and the application of valuation haircuts on the value of the eligible assets.

The Limits A counterparty may not pledge as collateral an asset issued by itself or by any other entity with which the counterparty has close links, i.e. ownership relationships (direct, indirect, or through third parties) equal to or greater than 20% of the capital. The prohibition on the own-used assets does not apply to covered bonds and ABSs. In addition, the Eurosystem applies limits to the use of unsecured bank bonds. The aim is to mitigate the risk associated with the correlation between the counterparty's default and the default of the issuer of the pledged asset.

Valuation Haircuts The Eurosystem applies reductions to the value of the eligible assets for the calculation of the net value of the collateral. The valuation haircuts cover potential losses in the value of the assets in the event of the default of counterparties, over the period required to liquidate them on the market.[11] Since haircuts cover credit and market risks of the collateral, they are not differentiated by the counterparty. This ensures a level playing field among market participants. The haircuts are calibrated using an Expected Shortfall at 99% confidence level[12] and

[10] See ECB (2015).

[11] In theory, haircuts would not be necessary if the instantaneous liquidation of collateral were feasible. However, this is not the case, as a certain amount of time is required to sell the collateral in the market, even for the most liquid assets. More illiquid collateral might require weeks or even months to be smoothly sold in the market. Thus, the valuation haircuts depend primarily on the liquidity of the assets, which determines the length of time required to sell them on the markets. The liquidation period is estimated on the basis of the observed market liquidity.

[12] The Expected Shortfall at 99% confidence level is the expected loss in the worst 1% of cases.

adopting a through-the-cycle approach.[13] The haircut is proportional to the level of risk of each asset,[14] so that the residual risk is the same for all eligible assets (the so-called risk equivalence principle). The level of the haircut applied to each asset depends on a number of instrument features (such as residual maturity, coupon type, and asset type) and on its credit quality, but it is not affected by the maturity of the refinancing operation, as collateral is evaluated on a daily basis.[15]

Other Risk Mitigation Measures The valuation haircuts applied to own-used covered bonds are increased by a mark-up. Furthermore, in order to mitigate model risk, the Eurosystem applies a mark-down to securities that do not have a reliable market price (mostly ABSs and covered bonds) and for which a theoretical valuation is used.

Under the ACC frameworks, credit claims may be pledged as collateral in two distinct ways: either individually or in homogenous portfolios. For individually pledged loans, as in the case of marketable assets, to each credit claim the Eurosystem applies a haircut that depends on the asset characteristics. For portfolios of ACCs, a single haircut is applied to the portfolio as a whole, taking into account the features of each credit claim as well as the risk diversification effect within the portfolio.[16]

Table 1 shows the current valuation haircuts for two important asset types, namely, government bonds and credit claims.[17]

Valuation haircuts are applied to the market value of marketable assets and to the nominal value of non-marketable assets.[18] For example, consider an Italian government bond (with a first-best rating of BBB+) and a credit claim, both with a residual maturity between 7 and 10 years and a nominal value of ten million euros. Suppose

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[13] This means that very long time windows of historical data are used in the calibration.

[14] Marketable assets have much lower valuation haircuts than non-marketable assets. Among marketable assets, the lowest haircuts are assigned to government bonds, while ABSs and unsecured bank bonds are subject to the highest haircuts.

[15] The Common Eurosystem Pricing Hub (CEPH) calculates a theoretical price for all assets for which a market price is not available. If the value of the collateral falls below the value of the outstanding refinancing operations (this may occur, for example, in case of decrease in prices or rating downgrades) the competent NCB requests to the counterparty to pledge additional collateral (so-called margin call).

[16] The risk of a set of assets is smaller than the sum of the risks of the individual assets (unless the assets are perfectly correlated). The haircuts applied to loan portfolios follow this principle: they are calibrated on a portfolio-wide basis, rather than as a sum of the risks of individual loans.

[17] For the sake of simplicity, the table only reports valuation haircuts applied to fixed rate instruments. Lower valuation haircuts are applied to floating rate credit claims and higher haircuts are applied to zero-coupon instruments. The haircuts for portfolios of credit claims differ from those shown in the table.

[18] The haircuts applied to credit claims are appropriately increased to take into account the absence of a market price.

Table 1 Valuation haircuts for government bonds and individually pledged credit claims (in percentages points; source: ECB)

	Government bonds		Loans to NFCs (individually pledged)			
Credit Quality Step (CQS)	CQS 1&2	CQS 3	CQS 1&2	CQS 3	CQS 4	CQS 5
Maturity [years]	Rating from AAA to A−	Rating from BBB+ to BBB−	PD $\leq$ 0.1%	0.1% < PD $\leq$ 0.4%	0.4% < PD $\leq$ 1%	1% < PD $\leq$ 1.5%
0, 1	0.5	5.0	8.0	16.0	46.0	54.0
1, 3	1.0	6.0	11.5	25.0	57.0	62.0
3, 5	1.5	8.5	15.0	35.0	59.0	64.0
5, 7	2.0	10.0	20.0	42.0	61.0	66.0
7, 10	3.0	11.5	26.0	46.0	63.0	68.0
10, 15	4.0	12.5	33.0	48.0	64.0	69.0
15, 30	5.0	13.5	38.0	50.0	65.0	70.0
> 30	6.0	14.0	40.0	52.0	65.0	70.0

the price of the government bond is 101.75 and the annual PD of the loan is 0.40%.[19] The liquidity that can be obtained with the Italian government bond amounts to ten million * 101.75% * (1–11.5%) = nine million euros. In the case of the credit claim, the amount of liquidity would be: ten million * (1–46%) = 5.4 million euros.

4 The Use of Credit Claims as Collateral for Eurosystem Credit Operations

Credit claims play an important role in the Eurosystem's collateral framework as their use enables banks to refinance non-liquid assets with the central bank and fosters the provision of credit to the real economy at favourable conditions.[20]

Owing to the importance of bank loans as a funding source for the euro area economy, in December 2011 the Governing Council of the ECB decided to allow NCBs to accept the ACCs as collateral; loans eligible under this framework do not meet the Eurosystem ordinary eligibility criteria but fulfil less restrictive criteria defined by each NCB, which bears the associated financial risks. The national frameworks have to be authorised by the Governing Council and must comply with minimum common Eurosystem rules. The ACC framework expanded the scope of eligible assets and it was also introduced to facilitate banks' access to the first two very long-term refinancing operations (with a 3-year maturity) conducted by the Eurosystem between the end of 2011 and the beginning of 2012.

The Bank of Italy has made full recourse to this additional scheme since its introduction, by accepting as collateral loans granted to lower-rated debtors and enlarging the scope of its ACC framework on several occasions. In September 2014, the Bank of Italy expanded its framework by accepting portfolios of homogenous loans comprising those to private households secured by residential properties and those to non-financial corporations (NFCs). The possibility of pledging credit claims within portfolios has allowed counterparties to benefit from lower valuation haircuts. At the same time, it has enabled them to refinance with the central bank loans other than corporate ones, thereby ensuring greater flexibility in the use of credit claims. These results have also been achieved thanks to significant IT investments and the development of ad-hoc procedures for the management of a large number of credit claims made both by the Bank of Italy and by the Italian counterparties. As to corporate loan portfolios, an additional factor that enabled Italian banks to increase their recourse was the possibility to resort to the statistical module of the Bank of Italy's ICAS, which ensures a high degree of coverage of small and medium-sized enterprises (SMEs, see also chapter "The Bank of Italy's In-House Credit Assessment System for Non-Financial Firms"). For residential mortgage portfolios, an

[19] It is assumed that, on the basis of the Eurosystem's harmonised rating scale, the credit quality of the Italian government bond and that of the loan are the same.

[20] See Tamura and Tabakis (2013) and Mésonnier et al. (2022).

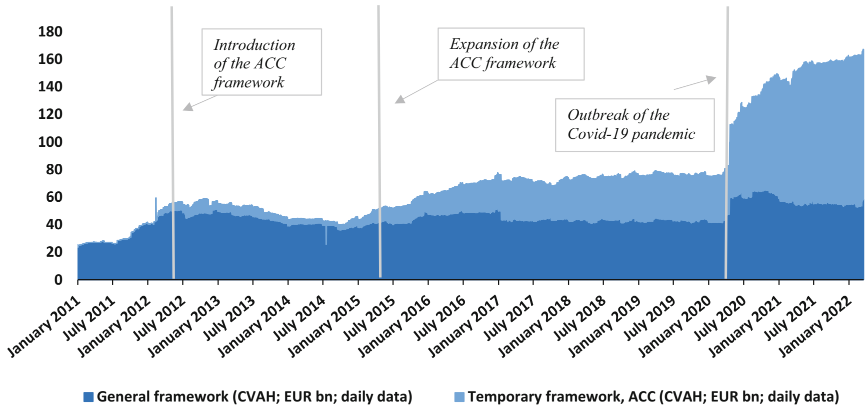

Fig. 2 The use of credit claims as collateral by Italian banks

ad-hoc valuation methodology has been developed since their introduction, based on loan and borrower characteristics, which banks can use in the absence of alternative sources.

The possibility of using a larger share of credit claims as collateral is particularly important for Italian banks, whose assets account for around 38% of loans granted to households and NFCs, compared with 34% in the euro area as of June 2022.

Between the beginning of 2012 and February 2020, i.e. prior to the outbreak of the Covid-19 pandemic, the net value of the credit claims pledged as collateral in Italy almost doubled, from 40 billion euros to 76 billion (see Fig. 2).

As of February 2020, 26% of the total value of collateral pledged by Italian banks was represented by credit claims, almost half of which were pledged under the temporary ACC framework. The share of credit claims rises to 71% when including structured finance instruments (ABSs and covered bonds), whose underlying assets are loans originated by banks.

5 The Measures Adopted by the ECB During the Covid-19 Crisis

In response to the economic crisis caused by the outbreak of the Covid-19 pandemic, the Governing Council of the ECB took extraordinary measures to support the provision of credit to households and NFCs and to stimulate the demand for goods, services, and investment. The Eurosystem introduced additional longer-term refinancing operations (LTROs) and other operations specifically aimed at countering the adverse effects of the pandemic crisis (Pandemic Emergency Longer-Term Refinancing Operations, PELTRO); in addition, the terms and conditions applied to targeted longer-term refinancing operations (TLTROs)—which foresee favourable pricing conditions for banks that increase credit to the real economy—became more advantageous.[21]

As a result of the economic crisis triggered by the pandemic, the decline in asset prices and the downgrades by rating agencies reduced the value and availability of Eurosystem-eligible collateral. This, in turn, reduced the possibility for counterparties to access central bank liquidity. Without concrete actions by the ECB, counterparties could have reduced lending to households and firms, thus exacerbating the severity of the crisis.[22] To avoid the possible collateral shortage, the Governing Council of the ECB has increased its risk tolerance level through the adoption of a package of collateral measures along three directions:

1. easing of the risk control measures, to increase the value of collateral in a timely manner and offset potential loss of collateral value in a scenario of economic and financial stress;
2. extension of the range of eligible assets, with special reference to credit claims, to stimulate the provision of credit to the real economy;
3. lowering of the minimum credit quality threshold for eligible assets, to increase the resilience of the banking system to potential rating downgrades by credit rating agencies.[23]

In particular, on 7 April 2020, the ECB reduced the valuation haircuts applied to all eligible assets (marketable assets and credit claims) by a fixed factor of 20%. Some additional measures for specific asset classes were introduced, thereby reducing haircut add-ons applied to own-used covered bonds and lowering mark-downs for assets valued with a theoretical price. For marketable assets, these measures were linked to the duration of the pandemic crisis; for credit claims, in addition to the 20% temporary haircut reduction, the ECB decided to fine-tune some of the haircut parameters. All these measures jointly led to an immediate increase in the value of the collateral pledged by Italian banks by 36 billion euros. Over 80% of such increase was due to the reduction in valuation haircuts applied to credit claims.[24]

In addition, the ECB removed the minimum size threshold for credit claims (which was set at 25.000 € until April 2020) to facilitate the use as collateral of loans granted to smaller NFCs and increased the concentration limit for unsecured bank bonds (from 2.5 to 10% of the total collateral pool of each counterparty).[25]

[21] See Lagarde (2020).

[22] See de Guindos and Schnabel (2020).

[23] See, in this regard, Bank of Italy (2020a, b, 2021) and Benigno et al. (2021).

[24] Valuation haircuts for marketable assets were reduced by 20% (on average from 9.1 to 7.3%) and by 42% for non-marketable assets (on average from 44.6 to 25.8%).

[25] Other measures included the expansion of credit assessment sources for the NCBs' ACCs frameworks, including IRB systems only approved by the Supervisory Authority for the purposes of calculating capital requirements and not also by the Eurosystem and the simplification of reporting requirements on loans included in the portfolios of ACCs. Moreover, as at the time of the outbreak of the Covid-19 pandemic the Greek government bonds were not eligible as collateral in Eurosystem liquidity operations because their credit rating did not meet the minimum

To mitigate the negative impact of potential rating downgrades on collateral availability and value, on 22 April 2020 the Governing Council also decided to 'freeze' the eligibility of the marketable assets which were eligible as of 7 April 2020, provided that their rating remained above BB (except for ABSs, for which the threshold was set at BB+). With regard to Italian Government bonds—which at the time of the decision had a first best rating of BBB+ and represented around 30% of the collateral pledged by Italian counterparties—this measure increased the distance from the minimum rating threshold for eligibility from two to four notches.

The comprehensive collateral easing packages adopted by the Governing Council of the ECB has avoided a potential lack of collateral for Eurosystem counterparties, thus preventing liquidity shortages in the euro area banking system and offsetting the risks of fragmentation in funding conditions. Similar measures have been adopted by other central banks worldwide, thus supporting bank lending to the real economy.[26]

The ECB's flexible and targeted policy response hence supported a sustained economic recovery following the pandemic. In addition, the increased risk tolerance by the ECB contributed to stop adverse procyclical effects from asset price drops and rating downgrades, thereby avoiding a potential impairment of euro area funding conditions.

6 The Expansion of the Bank of Italy's ACC Framework in Response to the Covid-19 Emergency

In addition to the measures described above, on 7 April 2020, the Governing Council of the ECB also announced the possibility for NCBs to further extend their ACC frameworks to include, among others, loans to SMEs or self-employed individuals that benefit from the Government guarantee schemes introduced to specifically address the Covid-19 emergency. Following the announcement, the Bank of Italy defined a set of measures to expand the scope of its ACC framework, which was approved by the Governing Council. Overall, the expansion of the Italian framework followed three directions.

Government-Guaranteed Loans Italian banks can pledge as collateral loans benefiting from the Government guarantees introduced by Decree-Law No 23/2020. The guarantees shall be granted by SACE (the Italian export credit agency) and the Guarantee Fund for SMEs (*Fondo di garanzia per le piccole e medie imprese*). These loans were accepted under the enlarged ACC framework as the guarantee in most cases covers only partially the size of the loans, thus not complying with the ordinary eligibility criteria which require a full coverage of the loan. The

requirements, the ECB decided to temporarily waive the minimum rating requirement for Greek government bonds.

[26] See International Monetary Fund (2020) and Bank for International Settlements (2021).

haircut applied to each credit claim takes into account the rating of the guarantor (equivalent to that of the Republic of Italy), for the share of the loan covered by the guarantee, and the credit quality of the borrower, for the remaining part.

Loans to Non-financial Corporations The Bank of Italy raised from 10 to 99% the maximum eligible PD for loans granted to NFCs pledged within portfolios, while maintaining the general requirement for loans to be performing. The list of accepted loan types was expanded to include recourse factoring; in addition, the scope of eligible debtors was widened to include loans to smaller firms (partnerships, limited liability companies, producer households, and artisans). To assess the creditworthiness of these debtors, the Bank of Italy extended the scope of its ICAS and developed new credit assessment methods.

Loans to Households The Bank of Italy also raised from 80 to 100% the maximum original loan-to-value (LTV) limit for residential mortgages granted to households. Furthermore, the ACC framework was expanded to include a new type of portfolio, which consists of loans granted to households for consumer credit.

These measures, together with those described in Sect. 5, were introduced on a temporary basis with the aim of maintaining them for as long as needed to ensure adequate collateral availability for counterparties (see also Sect. 9 for their phasing-out).

7 The Effects of the Collateral Easing Measures in Italy

The collateral easing measures introduced by the ECB and the Bank of Italy to mitigate the economic impact of the pandemic enabled Italian banks to retain full access to the ample liquidity provided by the Eurosystem. Between March 2020 and June 2022, the collateral value after haircuts of assets pledged by Italian counterparties increased by 209 billion euros (to 497 billion euros), compared with an increased recourse to Eurosystem financing by 212 billion euros (to 425 billion euros, Fig. 3). As a result, on aggregate the overcollateralisation of Italian counterparties decreased from 26 to 14%.[27]

Between March 2020 and June 2022, the increase in the value of the collateral pool deriving from the introduction of the collateral easing measures amounts to 85 billion euros (17% of the total value of collateral pledged by Italian counterparties, see Fig. 4). Such increase includes the haircut reduction and the measures introduced by the Bank of Italy to expand the scope of its ACC framework. The remaining 124 billion euros increase in the value of the collateral pool is due to the larger recourse to assets already eligible before the outbreak of the pandemic.

[27] The overcollateralisation rate is the ratio of the amount of unencumbered assets pledged in the collateral pool to the total collateral pledged and can be interpreted as a proxy for collateral availability.

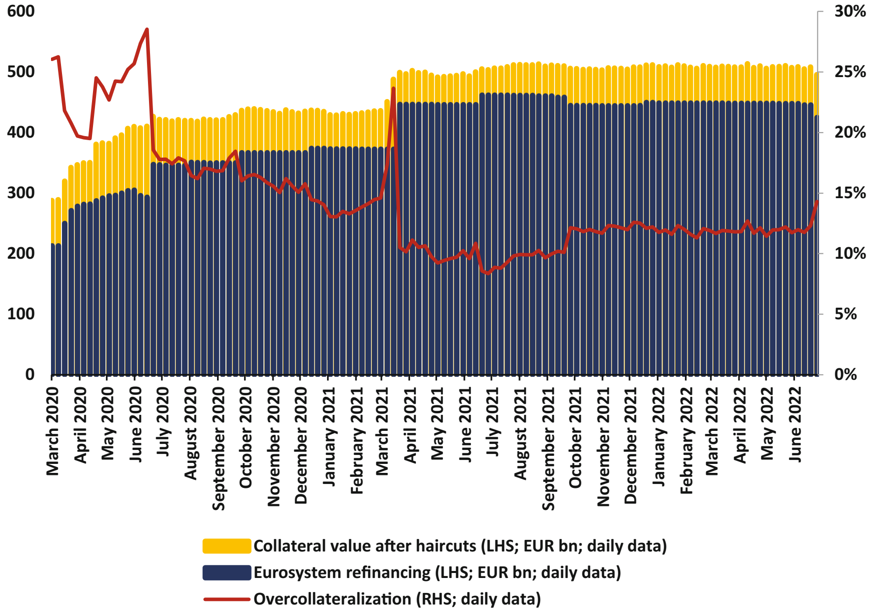

Fig. 3 Eurosystem credit and collateral in Italy after the outbreak of the pandemic

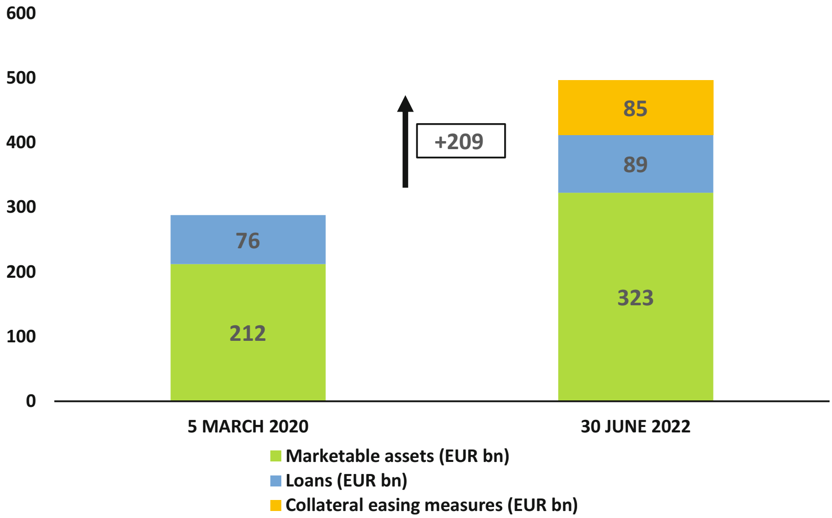

Fig. 4 The increase in the collateral value of assets pledged by Italian counterparties

The largest part (90%, or 77 billion euros) of the increase of the value of the pool of Italian banks related to the easing measures (85 billion euros) is due to the easing of the conditions for the use of credit claims as collateral. In particular, the loans

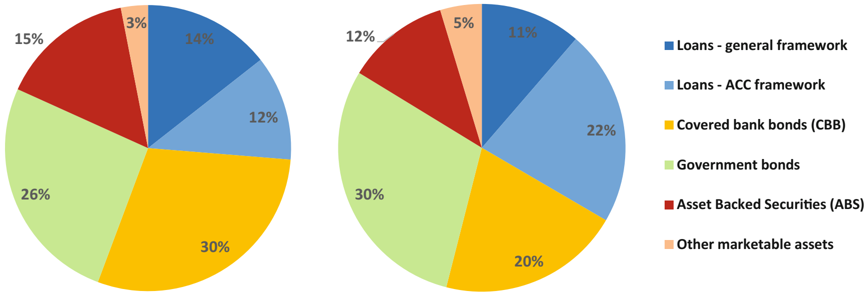

Fig. 5 The collateral pool composition of Italian counterparties (left: data as of March 2020; right: data as of June 2022)

backed by the Government guarantee schemes played a pivotal role in ensuring the access to central bank liquidity in Italy.[28] As of June 2022, 51 counterparties (out of 69 banks using credit claims as collateral) relied on such loans to collateralise the Eurosystem refinancing, resulting in an increase of 31 billion euros in the net collateral value.[29]

Together with the increase of the overall value of the collateral pool, the distribution of asset classes pledged by Italian counterparties has markedly changed over the pandemic period (Fig. 5). In particular, the share of credit claims and government bonds increased, while the share of covered bonds and ABSs decreased.

In the whole euro area, the collateral pool increased by 76% (or 1.2 trillion euros)[30] from March 2020 to June 2022. One-third of the increase was driven by a larger use of credit claims pledged under the national ACC frameworks, which significantly increased in all jurisdictions. Several NCBs introduced this scheme for the first time in 2020.[31]

8 The Benefits and Costs for Italian Counterparties

The haircut reduction applied to all eligible assets produced an immediate increase in the collateral value, thereby allowing banks to meet their increased need for central bank funding without incurring in additional operational costs.

By contrast, counterparties took longer to take advantage of the measures introduced to foster the use of credit claims as collateral, namely, the expansion of the

[28] For a general analysis on the use of government guarantees, see ECB (2020).

[29] On the basis of a weekly survey conducted by the Bank of Italy on a sample of banks that lend about 90% of the loans to companies, as of 15 June 2022 the requests for the Guarantee Fund for SMEs amounted approximately to 250 billion euros loans. The loans granted under the SACE guarantee scheme amounted approximately to 36 billion euros.

[30] In the same period, the increase in the collateral value after haircuts in Italy was 73%.

[31] See ECB (2021).

ACC framework. In general, the banks' willingness to refinance credit claims with the central bank is mainly driven by two factors:

- the availability of IT systems for the automated identification of the loans fulfilling the Eurosystem eligibility criteria for collateral pledge;
- the operational costs related to the handling of credit claims pledged as collateral and to their on-going monitoring required by the Eurosystem rules.

The operational costs related to the handling of credit claims as collateral are carefully weighed against alternative options to mobilise credit claims; for instance, large banks may use loans as underlying assets of securitised instruments (ABSs and covered bonds).

Since April 2020 a higher number of counterparties has pledged credit claims as collateral. The importance of the use of credit claims lies in the fact that loans are relatively illiquid assets and as such they are not suitable for repo transactions among private entities. Together with smaller banks, counterparties endowed with agile internal processes have benefited more from the expansion of the ACC framework.

9 The Gradual Phasing-Out of the Pandemic Collateral Easing Measures

On 24 March 2022, the Governing Council of the ECB announced its decision to gradually phase out the pandemic collateral easing measures.

The decision reflected the expected decline over time of banks' demand for liquidity, as TLTRO-III operations will gradually mature. The ECB also assessed the efficiency of the different measures from a financial risk perspective, weighing the additional collateral made available to banks against the increased risk exposure borne by the Eurosystem for each of the collateral easing measures.[32]

The gradual phasing-out is scheduled to take place in three steps and it has been designed in a forward-looking perspective to give banks sufficient time to adapt their financing strategy to the adjustments to the collateral framework.

In the first step, in July 2022, the ECB halved the temporary reduction in collateral valuation haircuts across all assets from 20 to 10%. By reducing the financial risk associated with the haircut reduction, this measure allowed a gradual comeback to pre-pandemic risk tolerance levels while continuing to ensure sufficient collateral availability. The ECB also phased out a set of measures with more limited impact and scope by: (1) removing the eligibility freeze for downgraded marketable assets; (2) restoring the limit on unsecured debt instruments issued by any other banking group in a credit institution's collateral pool from 10 to 2.5%; (3) restoring several technical requirements for the eligibility of ACCs which were in force before the pandemic easing measures.

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[32] See ECB (2022).

In the second step, in June 2023, the ECB implemented a new haircut schedule based on its pre-pandemic risk tolerance level for credit operations, phasing out the temporary reduction in collateral valuation haircuts completely.

In the third step, in March 2024, the ECB will, in principle, phase out the remaining pandemic collateral easing measures. The Governing Council will take the final decision following a comprehensive review of the ACC frameworks, taking into account banks' collateral needs for continuing to participate in Eurosystem credit operations, including TLTRO-III operations which will be running until December 2024. The measures in place until March 2024 include those on the ACC frameworks introduced during the pandemic, in particular loans benefitting from Government guarantee schemes, which have significantly contributed to collateral availability since the outbreak of Covid-19.

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Sovereign Ratings

Anna Michelina Di Gioia and Roberto Imperato

1 Introduction

Ratings represent an agency's opinion about the creditworthiness of an issuer or a debtor. As such, they matter for investors, financial markets, and the Eurosystem too, as the latter normally accepts, in its credit operations and purchase programmes, only bonds with a rating of BBB- or better.[1]

In this chapter, we investigate how sovereign ratings are obtained by the four rating agencies recognised by the Eurosystem for the purpose of monetary policy implementation, namely, DBRS, Fitch, Moody's, and S&P. Our analysis covers the methodological issues and the empirical results, with a focus on Italy's sovereign ratings.

We find that rating processes and baseline methodologies are similar across the four agencies, whereas specific methodological choices (on indicators, weights, and rating computation rules) largely differ across the four, which leads to differences in the model ratings and, potentially, also in the final ratings.

In the rating process, the four agencies follow a two-step approach, whereby a 'model rating' is first derived from a proprietary, mostly data-driven model; the model rating is then adjusted by the internal rating committee's qualitative assessment, usually in the range of +/−3 notches from the model rating, in order to obtain the official rating. The agencies focus on the same sources of risk for the sovereign creditworthiness, namely: (1) the country's *economic strength*, (2) its *public finance*, (3) the *external balance*, (4) the outlook as regards *monetary and financial stability*, and (5) the country's *institutional framework.*

[1] For ease of reading, the rating notation from Fitch/S&P is used in the paper for all four rating agencies (e.g. we use 'AA+' rather than 'AA(H)' from DBRS or 'Aa1' from Moody's).

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As of January 2023, the official ratings assigned by DBRS, S&P, Fitch, and Moody's to the Republic of Italy were BBB+/BBB/BBB/BBB−, respectively; they were lower than their respective model ratings by 2 notches (DBRS, Fitch) and 1 notch (S&P and Moody's). These differentials, i.e. the impact of the qualitative assessment on the ratings, were larger than those applied on average to the other euro area countries. Countries with similar official ratings were Bulgaria, Romania, Colombia, and Mexico which are arguably not comparable with Italy in terms of financial wealth/borrowing capacity and rule of law.

In recent years, the four agencies have significantly improved their transparency on the assessment of sovereign issuers. All four agencies regularly publish detailed reports on each of their rated sovereigns, including the model inputs and outputs (the quantitative drivers of the official rating) and the reasons behind the judgmental adjustments (the qualitative drivers of the official rating), if any. The available documentation allows rating agencies' model rating to be simulated. As an illustrative exercise, in this chapter, we replicate the four model ratings of Italy as of December 2020.

This simulation exercise—where we apply each agency's model, indicators, scores, and rules—shows that the most favourable driver of Italy's ratings is the large size of the economy—as measured by GDP—which results in an AAA or equivalent score. Additional economic strengths are the balanced external position and the sound institutional framework, as measured by Italy's place in the ranking of the World Bank governance indicators. On the downside, the rating suffers from the public debt burden, with a high debt-to-GDP ratio. Regarding the qualitative drivers of the ratings—which we draw from the agencies' public reports on Italy—the four agencies mainly focus on Italy's risk factors (e.g. the uncertainty around the economic and public finance outlook) which lead the four agencies to set the final rating lower than their respective model rating.

We find that the quantitative models appear to overlook some economic and financial variables that are important for the creditworthiness of a sovereign, like the government primary balance, the commercial banks' exposure to financial derivatives, and the private sector debt and savings. In the case of Italy, these factors are a point of strength for the country, as also recognised by the four agencies in their reports; since these factors do not improve the rating in the qualitative assessment, it could be argued that their contribution in the final rating is negligible or absent.

The chapter is organised as follows. Section 2 provides an overview on Italy's sovereign ratings. In Sec. 3, we compare the sovereign rating methodologies employed by DBRS, Fitch, Moody's, and S&P. Section 4 discusses the quantitative and qualitative drivers of the ratings assigned to Italy. Section 5 concludes.

Table 1 Republic of Italy: long-term local and foreign currency ratings as of January 2023

	DBRS	S&P	Fitch	Moody's
Official rating Outlook	**BBB+** stable	**BBB** stable	**BBB** stable	**BBB−** negative
Previous rating change	−1 notch 13.1.2017	+1 notch 27.10.2017	+1 notch 3.12.2021	−1 notch 19.10.2018

Source: Rating agencies

2 Italian Sovereign Ratings: An Overview

As of January 2023, the long-term ratings assigned to the Republic of Italy by DBRS, Fitch, S&P, and Moody's, on both local and foreign currency debt, ranged between BBB+ and BBB− (Table 1).

These ratings are the outcome of a sequence of downgrades carried out by all four agencies over the past few years, in some cases with multiple notch downgrades within the same rating decision.[2] Between the onset of the financial crisis in August 2007 and December 2020, the Republic of Italy was downgraded by seven notches by Moody's (from AA to BBB−); five notches overall by Fitch (from AA− to BBB− in April 2020, before being upgraded to BBB in December 2021); four notches by DBRS (from AA− to BBB+); and four notches overall by S&P (from A+ to BBB−, before being upgraded to BBB in 2017).

As of January 2023, other sovereigns with official ratings similar to that of Italy were Bulgaria, Romania, Colombia, and Mexico. All these countries markedly differ from Italy in terms of economic fundamentals, financial strength, and institutional structure.

DBRS, Fitch, Moody's, and S&P are credit assessment sources recognised by the Eurosystem; as a result, their rating decisions directly affect the Eurosystem monetary policy implementation. Bond ratings are used to establish whether a bond is eligible as collateral in the Eurosystem refinancing operations and whether it may be purchased in the context of the bond purchase programmes, where only bonds rated at BBB− or better are accepted. Ratings also affect collateral valuation. If, following a rating change, the first best rating falls in a different 'Credit Quality Step' (CQS) of the harmonised Eurosystem rating scale (Table 2), this results in a change in the haircuts applied to the bonds.[3]

This was the case with the DBRS downgrade of Italy from A− to BBB+ in January 2017, which lowered the first best rating on Italian government bonds (i.e. the best out of the four accepted agencies' ratings) from CQS 2 (which includes A−) to CQS 3 (BBB+) which in January 2023, at the time of writing this chapter,

[2]The multiple notch decisions were the following: from Moody's, −3 notches on 4 October 2011 and −2 notches on 13 July 2012; from Fitch, −2 notches on 27 January 2012; from S&P, −2 notches on 13 January 2012.

[3]The Eurosystem applies the 'first best rating rule', therefore the change of CQS occurs when the first best rating (or the only available rating) moves to a different CQS.

Table 2 Eurosystem's harmonised rating scale as of January 2023

CQS	Equivalent probability of default (PD, at 1 year)	DBRS	Fitch/S&P	Moody's
CQS 1	PD <= 0.04%	AAA AA(high)/ AA/ AA(low)	AAA AA+/AA/ AA-	Aaa Aa1/Aa2/ Aa3
CQS 2	PD in]0.04%, 0.10%]	A(high)/A/ A(low)	A+/A/A-	A1/A2/A3
CQS 3	PD in]0.10%, 0.40%]	BBB(high)/ BBB/ BBB(low)	BBB+/ BBB/ BBB−	Baa1/Baa2/ Baa3
CQS 4[1]	PD in]0.40%, 1%]	BB(high)	BB+	Ba1
CQS 5[1]	PD in]1%, 1.5%]	BB	BB	Ba2

Source: Rating agencies. Notes: 1) Assets in CQS 4 and 5 are accepted as collateral only within the national frameworks of those national central banks of the Eurosystem (among which Banca d'Italia) which accept additional types of asset classes (the so-called 'Additional Credit Claims', ACC) compared with the standard framework applied throughout the Eurosystem, where the minimum threshold is BBB-, i.e. CQS 3

was the CQS haircut class the Italian sovereign belonged to. Likewise, the rating downgrades applied to Greece during the sovereign debt crisis, which resulted in the country's first best rating falling below the BBB− threshold in 2011, led to the automatic exclusion of Greek sovereign bonds from the list of the Eurosystem eligible collateral. Greek government bonds remained eligible as collateral only due to a special waiver granted by the ECB's Governing Council, which was conditional on the Republic of Greece's compliance with the economic recovery programme set out by the European Commission, the IMF, and the ECB.

3 Sovereign Rating Methodologies[4]

All four agencies formulate their sovereign rating by combining quantitative and qualitative elements. This section compares the methodologies (Sect. 3.1) and examines some specific issues that arise when assessing countries belonging to a monetary union (Sect. 3.2).

[4]We performed our analysis on the methodologies in force in 2020. Up to January 2023, credit rating agencies have performed only technical updates which do not affect the substance and conclusions of our work. More precisely, the reference documentation for our analysis is the following: DBRS Morningstar (2020a, 2021), Fitch (2020l, 2021), Moody's (2019, 2021), S&P (2017, 2021b).

3.1 Models, Indicators, Rules

Rating agencies adopt ad hoc assessment criteria for sovereigns, owing to the distinctive features of a sovereign as a debtor, including the taxation power, legislative power and monetary policy, where applicable, which imply a high survival probability even after an event of default. Models, indicators, and rules present some similarities as well as differences across the four agencies (see also Table 3).

- **Rating definition.** The four agencies define a rating as a forward-looking assessment of the capacity and willingness of an issuer to honour its financial obligations in full and on time. The agencies point out that the rating (in general, not just for sovereigns) is an 'opinion' on the creditworthiness of the rated entity, and not a recommendation to buy the issuer's securities or a guarantee about their performance. The agencies also point out that ratings are defined in ordinal terms—rather than in cardinal terms, as is the case for the probability of default—and that they are comparable across sectors and countries owing to the use of a uniform rating scale.[5]
- **Sovereign rating process.** To determine a sovereign rating, all four agencies follow a two-step approach. First, a model-based rating is obtained from a proprietary model (mostly or fully quantitative), which may be refined (through ad hoc adjustments) by the analysts in charge of the issuer. A qualitative assessment is subsequently performed by the rating committee, which may deviate from the model rating in deciding on the official rating.

  The qualitative assessment is meant to incorporate into the final rating: (1) the data that are not (fully) factored into the model (e.g. comparison with peers, omitted variables, confidential information, and forward-looking perspective); (2) the personal view of each rating committee member about the current and perspective solvency of the sovereign. All agencies specify that the model rating is only a starting point in their rating analysis, rather than an exhaustive representation of all information that is relevant and available on a sovereign issuer.

  DBRS specifies that, typically, it will not deviate by more than +/−2 notches from the 'indicative rating range' that stems from the 'model rating range', possibly adjusted by the analysts. Fitch states that the rating adjustment is normally expected to be in a range of +/−3 notches from the model rating. The S&P foreign currency rating would usually deviate by no more than +/−1 notch from the model rating; while the local currency rating would be set by applying a 1 notch uplift over the foreign currency rating, for euro area countries the two ratings are the same. Moody's does not specify the range of the qualitative deviation.[6]

[5] Moody's, in particular, explains that expressing rating in cardinal terms would imply a higher rating volatility, while S&P explains that only in the long term would default frequencies be similar across similarly rated issuers from different sectors. See Moody's (2021), p 37. See S&P (2021b) p 57.

[6] See DBRS Morningstar (2020a) p 3, p 19; Fitch (2020l) p 7; S&P (2017) pp. 4–5, p 33.

Table 3 Key features of the four agencies' sovereign models

	DBRS	Fitch	Moody's	S&P
Model type	Scorecard	Econometric	Scorecard	Scorecard
Indicator type	Quantitative	Quantitative	Quali-quantitative	Quali-quantitative
Indicator grouping	6 Blocks[a]	4 Pillars[b]	4 Factors[c]	5 Assessments[d]
Indicators (N.)	23	18	22	39[e]
Model approach[f]	Modular	Multiple linear regression	Modular (waterfall)	Modular (matrix)
Model mechanics[f]	Simple average of the 6 block scores:	Combination of the 18 indicators based on a regression equation:	Combination of the 4 Factors in pairs, progressively:	Combination of the 5 Assessments into 2 Profiles, then combined in a matrix:
	$y = \mu(B1, B2, B3, B4, B5, B6)$	$y = \alpha + \beta_1 x_1 + \ldots + \beta_{18} x_{18}$	$y = \{[(F1, F2), F3], F4\}$	$y = (Pr1, Pr2)$
Risk drivers[g]	**Key indicators[h]**			
Economic strength	GDP per capita	GDP per capita	GDP per capita	GDP per capita
	GDP nominal amount	Share in world GDP	GDP nominal amount	
	GDP growth volatility	GDP growth volatility	*GDP growth volatility*	*GDP growth vs peers*
		GDP growth	*GDP growth*	
Sovereign public finance	Gross Govt debt/GDP	Gross Govt debt/GDP	Gross Govt debt/GDP	Net Govt debt/GDP
			Gross Govt debt/Revenues	
	Interests/GDP		Interests/GDP	
		Interests/Revenues	Interests/Revenues	Interests/Revenues
	Fiscal balance/GDP	Fiscal balance/GDP	*Debt/GDP trend*	Debt/GDP trend
External balance	Exch. rate classif. (floating, currency union member, etc.)			Currency status (reserve, actively traded, etc.)
	Share of global fx turnover	Reserve currency status (curr. Share in global fx ptf.)	Access to fx market and qualitative assessment	Narrow net ext. debt/Current acc. Receipts
	Net intern. Invest. position/GDP	Sovereign net foreign assets/GDP	Net external liabilities	*(Net intern. Invest. posit. - Narrow net ext. debt)/Curr. acc. Receipts*

(continued)

Table 3 (continued)

	DBRS	Fitch	Moody's	S&P
	Curr. acc. Balance /GDP	*(Curr. acc. Balance + Net foreign direct inv.)/ GDP*	Curr. acc. Balance/GDP	*Curr. acc. Balance / GDP*
Monetary and financial strength	Consumer price inflation	Consumer price inflation	Monetary and macroecon. Policy effectiveness (qualit.)	Exchange rate regime (reserve, actively traded, etc.)
	Property price growth/GDP			*Central bank independ. and credibility*
	Domestic Savings/GDP			*Membership in a monetary union*
	Credit growth/ GDP		Total bank assets/GDP	
	NPL/Total capital		Average banks' baseline rating	*Banks' exposure to Govt*
Institutional assessment[i]			Transparency and quality of government accounts (qualitative)	Transparency and accountability of institutions, data and processes (quality)
	WB: Rule of law	WB: Rule of law	*WB: Rule of law*	
	WB: Voice and accountability	WB: Voice and accountability	*WB: Voice and accountability*	
	WB: Government effectiveness	WB: Government effectiveness	*WB: Government effectiveness*	
		WB: Control of corruption	*WB: Control of corruption*	
		WB: Regulatory quality	*WB: Regulatory quality*	
		WB: Political stability and absence of violence	*WB: Political stability and absence of violence*	
		Years since default or restructuring	*Years since default or restructuring*	

Source: Rating agencies' methodologies in force in October 2020

[a]*Fiscal management and policy; Debt and liquidity; Economic structure and performance; Monetary policy and financial stability; Balance of payments; Political environment.* The six blocks have equal weights in the model rating

[b]*Structural features* (weighs 53.7% on the model rating); *Macroeconomic performance, policies and prospects* (10.9%); *Public finances* (18%); *External finances* (17.4%)

(continued)

[c]*Economic strength; Institutions and governance strength; Fiscal strength; Susceptibility to event risk*. The last Factor applies a neutral or negative adjustment in the rating process: the lower the score assigned to the combination of the first three Factors (which yields the *Government financial strength*), the stronger the negative correction from the last Factor
[d]*Institutional assessment; Economic assessment; External assessment; Fiscal assessment; Monetary assessment.* The first two Assessments are combined under the *Institutional and economic profile;* the other three Assessments are combined under the *Flexibility and performance profile.* The first Profile weighs more on the model rating: assuming the same scores in two different combinations—e.g. (1,6) and (6,1), where 1 is the best and 6 the worst score on S&P's scale, if 6 is assigned to the *Institutional and economic profile*, the rating returned by the matrix is lower than the other way round
[e]Our own estimate based on S&P description of the scorecard (lacking a table summarising all scorecard indicators)
[f]Model approach and formulae on the model mechanics, with 'y' representing the model rating, are our own representation of the four models
[g]The list of indicators reported in this table under each of the five risk drivers may differ from the grouping adopted in the four agencies' models since the four models do not necessarily match in terms of indicator breakdown
[h]Italic font for the indicators weighing less in the model computation or explicitly defined by the agency as secondary or adjustment indicators
[i]'WB' stands for World Bank

The minutes of the rating committee meetings are not published. However, for each rated sovereign all agencies publish detailed reports and rating announcements which include the quantitative drivers (model inputs and outputs) and the qualitative drivers of the final rating. When a rating review is published (at least twice a year, as required by the European regulation on credit rating agencies),[7] all four agencies report the rationale for the decision and, if a rating adjustment is applied, the reasons behind it.

- **Model mechanics.** To structure their models, the rating agencies first identify the sources of risk for the sovereign creditworthiness, namely: (1) the country's *economic strength*, to assess the country's resilience to shocks; (2) its *public finance*, to assess the public debt burden and affordability; (3) its *external balance*, to evaluate the ability to repay the debt denominated in foreign currency; (4) the outlook as regards *monetary and financial stability*, for the assessment of price and financial vulnerability; and (5) the country's *institutional framework*, to examine the stability and predictability of policymaking.

  For each of these areas, the agencies use a set of indicators (the same for all issuers) that are considered as predictive of the potential stress or default of an issuer (e.g. GDP and the public sector deficit/GDP ratio). While the models of DBRS and Fitch purely rely on quantitative indicators, the models of Moody's and S&P also employ qualitative ones. Regarding the model type, Fitch employs

[7]Regulation (EU) No. 462/2013 of the European Parliament and of the Council of 21 May 2013 amending Regulation (EC) No. 1060/2009 on credit rating agencies.

a regression model,[8] while the other three agencies employ a 'scorecard', where the indicators are combined on the basis of a set of weights and rules.

The interplay of model indicators yields the model rating (or a range of ratings). Indicators largely differ across the agencies, and so do the aggregation rules. As a result of these methodological differences, the model ratings for the same sovereign issuer may diverge across the four agencies: as of December 2020, Italy's model ratings were in a 3-notch range (between A and BBB).

3.2 Membership of a Monetary Union

An important issue in the sovereign rating methodology is the treatment of countries belonging to a monetary union. The four agencies follow a similar approach: in the monetary assessment of sovereigns that belong to a monetary union, all member countries are treated identically for monetary policy, but only some of them are assigned a 'reserve currency status'.

In the scorecard assessment of a sovereign, *DBRS* assigns the same currency ranking to all euro area countries ('currency union members', which corresponds to 5, the worst score) to highlight 'some meaningful restrictions on sovereigns operating within the union'.[9] DBRS then differentiates among countries by using two indicators: the share of the country's economy of the whole area's GDP and the correlation between growth in the country and the area.

Similarly, *Fitch* assigns the same score for Reserve currency flexibility (RCF) to each country, but it makes ad hoc adjustments in the ensuing qualitative overlay 'to recognize that not all countries in the Eurozone have the same degree of RCF'.[10,11] In its rating actions on Italy in 2019 and early 2020, Fitch applied a 1-notch penalty to the External Finances pillar due to the 'high net external debt' compared with

[8] The independent variables of the regression equation are the 18 economic and financial indicators of the model; the estimated coefficients of the regression are the same for all sovereigns and represent the weights of the variables in the equation. The dependent variable is a numerical score that provides, via a proprietary matching table, the model rating for the sovereign under assessment (e.g. a value between 6.5 and 7.5 corresponds to BBB-). The regression is estimated from the application of Ordinary Least Squares (OLS) to the set of the 18 variables for all sovereigns rated by Fitch over 2000–18 inclusive and is re-estimated and reviewed annually to incorporate additional data into the estimation period and to test for new potential variables. See Fitch (2020l), p 6.

[9] See DBRS Morningstar (2020a), p 27.

[10] See Fitch (2020l), p 23, footnote 1.

[11] The adjustments, within +/−2 notches, are applied to the score assigned by the model to the 'External finances' section where the 'Reserve currency flexibility' is comprised. The adjustments are based on the assessment of the resilience and range of external financing sources, the external debt sustainability and the vulnerability to external shocks. See Fitch (2020l), Section 'IV. External Finances'.

Italy's peers, i.e. countries at BBB level[12] (in 2019 Italy's net external debt—NED—amounted to 48.3% of GDP, against a BBB median value of 6.6% according to Fitch).[13] The 1-notch penalty, which was removed in July 2020, put Italy in the same group as Cyprus and Greece. Greece, whose penalty was also removed in July 2020, was penalised on account of the high NED (133.5% of GDP), much larger than those of Greece's BB peers (whose median value was 9.6%) and almost three times as large as Italy's. Cyprus, instead, was penalised because of its recent history of external and banking crises, the large share of non-resident deposits, and the lack of diversification. It should be noted that, while Cyprus NED, at 421.2% of GDP in 2019, was nine times larger than Italy, the penalty for External Finances was the same for the two countries. No penalty was instead applied to France, even though its NED (42.1% of GDP in 2019) was close to Italy's and very far from those of its AA peers (whose median credit amounted to 8.3% of GDP). Also, France was running a current account deficit (0.7% of GDP in 2019), compared with Italy's solid surplus (3% of GDP), and its net international investment position (NIIP) was deeply negative (−22.9% of GDP at the end of 2019), compared with Italy's almost balanced position (−1.5% of GDP). These findings became stronger at the end of 2020, when Italy's NIIP turned positive (+1.8% of GDP), while France's NIIP remained around the 2019 level (−26.7%).[14]

One remark is in order: from a methodological viewpoint, choosing NED, rather than the NIIP,[15] as the main indicator of the qualitative assessment for external solvency, also aimed at differentiating countries within a currency union, may raise some issues. Indeed, while the NIIP is given by the difference between *all* financial assets and liabilities of a country's residents towards non-residents, NED is not as comprehensive, as it provides a partial view of a country's external exposure. Specifically, NED only includes 'debt instruments' and excludes, among others, residents' holdings of investment funds (covering money market and bond funds), even though a large part of these are typically invested in debt instruments.[16] Hence,

[12] While Fitch's methodology specifies that peers refer to both the countries in the quantitative rating category (A in the case of Italy) and those in the official rating category (BBB) as the issuer under assessment, Fitch's announcements on rating decisions on Italy refer only to the BBB category as peer countries for Italy.

[13] Fitch defines the 'Net external debt' as 'the difference between gross external debt and residents' debt claims on non-residents' (see Fitch (2020l), p 26). Based on the IMF definition of the net external debt, this includes only debt instruments, i.e. instruments that require payments of principal and/or interests by the debtor. See IMF (2013).

[14] Source of the figures reported in the text: (i) Eurostat, for the net international investment position; (ii) FitchRatings reports, for the net external debt: Fitch (2020h), p 5; Fitch (2020i); Fitch (2020j), p 4; Fitch (2020f), p 5; Fitch (2020g), p 4; Fitch (2020a), p 2; Fitch (2020d), pp. 2–4; Fitch (2020c). For some countries we considered two different reports since their 2019 NED figures were updated by Fitch in the second half of 2020; instead, the 2019 peer median was available only in the 2020 first-half reports. We used Finland report to retrieve the 2019 NED for France's AA peer median.

[15] See Fitch (2020l), p 26.

[16] More precisely, the NIIP is the difference between (a) financial assets of residents of an economy that are claims on non-residents and gold bullion held as reserve assets, and (b) liabilities of

using NED implies an asymmetry in the treatment of the asset and liability sides of a country's external exposure. In the case of Italy, this asymmetry is pronounced and likely to impact the outcome of Fitch's quantitative assessment.

Moody's scorecard does not include any indicators about the currency regime of the sovereign. To differentiate across euro area countries, Moody's upgrades the 'Fiscal Strength' score only for France and Germany: 'Whilst the euro is considered a reserve currency, only the two largest member states, Germany and France, are considered to benefit from reserve-currency status'.[17] For these two countries, the weights of the debt burden indicators (including the debt-to-GDP ratio) and debt affordability indicators (including the interest-to-GDP ratio) in the 'Fiscal Strength' score are 0.1 and 0.9, respectively, vs. 0.5 and 0.5 for all other euro area countries.[18] If the former weights were applied to Italy, its scorecard rating would improve by 1 notch.

S&P assigns a score to the monetary union as such; such score can imply a penalty relative to countries with their own central bank: in the case of the euro area countries, this penalty is applied. Next, S&P may decide to lower the initial score in case the country's economy is out of synch with the bulk of the union (this occurs when price and wage trends are deemed to diverge from the monetary union average), monetary policy transmission is ineffective or capital controls are in place. In the case of Greece, for example, all three penalties were applied until early 2020; starting in April 2020, only one penalty has been applied, because of the ineffective transmission of monetary policy, as the result of a high level of non-performing bank loans.

Between 2019 and 2020, S&P applied to Italy a penalty for 'weak monetary policy transmission' as inferred from the low GDP growth and the level of non-performing loans; the penalty, which is likely to have caused a 1 notch reduction of the quantitative rating (hence, other things being equal, also of the official one) was removed in October 2020, reflecting the fall in non-performing loans and the support provided by the Eurosystem's purchase programmes. In October 2020, the score of Italy as member of a monetary union was the same as that of France and Germany.[19]

In short, all four agencies share a similar approach in the assessment of sovereigns within a monetary union: (1) the union is seen as a 'whole', as far as monetary policy is concerned; (2) for each member state the flexibility of monetary action is deemed to be lower than that of jurisdictions with their own central bank; and (3) differences

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residents of an economy to non-residents. The difference can be positive or negative and is calculated from the asset perspective (assets minus liabilities). The NED refers only to 'debt instruments'; it is calculated from the liability perspective as the difference between an economy's external liabilities and assets in debt instruments (instruments that require payments of principal and/or interests by the debtor). For more details, see: IMF (2009, 2013).

[17] See Moody's (2019), p 27.

[18] At the end of 2019, France debt-to-GDP ratio was 98.1% against 59.6% for Germany. See Eurostat database (2020).

[19] See S&P (2020a, 2020b).

in the size of the economy (the smaller the country, the lesser the influence on the union's monetary policy), as well as country-specific penalties, may result in pronounced rating differences among members of the same monetary union.

4 The Drivers of the Ratings Assigned to Italy

To illustrate how the rating process works in practice, we examine the actual ratings assigned to Italy by DBRS, Fitch, Moody's and S&P. Section 4.1 describes the quantitative and qualitative inputs of the four ratings. Section 4.2 investigates the reasons why the scores assigned to Italy for the same or similar indicators may differ across the four models. Variables that are not included in the agencies' analyses, but are arguably important in assessing the sovereign's creditworthiness, are reviewed in Sect. 4.3. Then, Sect. 4.4 compares the official and model ratings of euro area countries.

4.1 The Quantitative and Qualitative Drivers of Sovereign Ratings for Italy

As of December 2020, the official ratings assigned to Italy by DBRS, S&P, Fitch, and Moody's were BBB+/BBB/BBB−/BBB−, respectively (Table 4). These were lower than the respective model ratings by 3 notches in the case of Fitch, by 2 in the case of DBRS, and by 1 for S&P and Moody's. In January 2023, the sequence of ratings had become BBB+/BBB/BBB/BBB− (following the upgrade by Fitch in December 2021). These ratings were still lower than the respective model ratings: by 2 notches for DBRS and Fitch, and 1 notch for S&P and Moody's.

In what follows we examine the quantitative and qualitative drivers of the official ratings assigned to Italy. The qualitative drivers are taken from the public agencies' reports; the quantitative drivers are identified by means of a simulation exercise that replicates each agency's sovereign methodology to obtain their model rating. The quantitative drivers are also available in the public rating agencies' reports; in fact, over time all four agencies have significantly increased their transparency about the sovereign ratings they assign to individual issuers, so they regularly publish detailed

Table 4 Official and model ratings for Italy as of December 2020

	DBRS	S&P	Fitch	Moody's
Official rating	**BBB+**	**BBB**	**BBB−**	**BBB−**
Model rating/rating range	[A+: A−]	BBB+	A−	[BBB+: BBB-]
Central rating (in case of a range)	A			BBB
Notch differential	**−2**	**−1**	**−3**	**−1**

Source: Moody's DBRS, Fitch, and S&P

reports on the rated sovereigns, including the scorecard/model rating, i.e. the sovereign-specific values and scores used for the indicators included in the model rating. Although the quantitative drivers of Italy's ratings are already in these reports, the purpose of our simulation is to better understand the mechanics of the four methodologies and to single out the impact of the various indicators and rules in the final ratings.[20]

The simulations are run for three different dates. In all cases and for all agencies, the simulations deliver the same ratings as those published by the four agencies for the same reference dates. Below we present the results of the simulation exercise (see also Annex 1 to Annex 4) based on the data and the agencies' methodologies as of December 2020.

DBRS—*Quantitative drivers* (see Annex 1). In the simulation of the (totally quantitative) DBRS model, our final score equals 67.2 (on a range from zero to 100) which, based on DBRS' score-rating equivalence table, corresponds to a model rating range of [A+: A−]: such score is a good proxy of DBRS' published score on Italy as of October 2020 (65.9), which also corresponds to the rating range [A+: A−].[21] Following the qualitative adjustment applied by the agency, the final rating turns out to be BBB+ (i.e. 2 notches below the central rating in the quantitative range).[22]

The simulation results show that all areas included in the DBRS template are assigned scores in the upper-intermediate level. The blocks of indicators that get the best score in the simulation are 'Economic structure and performance' (16.7, in a range from zero to 20)[23] and 'Monetary policy and financial stability' (19.8). Some indicators in these areas reach the top score (20); among them are: economic size as measured by the total nominal GDP, inflation performance, domestic savings, credit growth, and property price growth. The 'Net NPL-to-Banks' capital ratio' (18.8) is also not far from the top score. Next in the ranking are the block scores for the

[20] We conduct the simulation for each of the four agencies as follows. First, in the agency's published methodology we identify the list of quantitative indicators that are included in the agency's model. Second, we identify the most suitable data source, if not already specified in the methodology, to get Italy-specific data to be used as input for the model indicators (we use data from the Bank of Italy, BIS, Eurostat, IMF, Italian National Institute of Statistics (Istat), Ministry of Economic and Finance of the Republic of Italy, OECD, World Bank, and World Economic Forum). We then compute the value of each model indicator following the rules specified in the methodology. Next, we attach, based on the indicator value, the corresponding score in the scales/tables published in the agency's methodology (e.g. a GDP higher than X gets a Y score). Finally, we combine all model scores according to the aggregation rules specified in the methodology (e.g. average, sum, minimum or maximum function). The resulting (simulated) 'model rating' only relies on the quantitative variables that are included in each agency's model (DBRS and Fitch models are fully quantitative, Moody's and S&P models are quali-quantitative models).

[21] For the four agencies' model simulations, the difference between our simulation's and the respective agency's results depend on differences in the input values for the model indicators. In particular, this happened with those indicators whose model values are also based on forecasts.

[22] See DBRS Morningstar (2020b).

[23] The scoring scale [0, 20] is in turn divided into 11 'categories' which go from 'very weak', corresponding to the interval [0, 0.99] to 'very strong', corresponding to the range [19.00, 20.00].

'Balance of payment' area (14.7), thanks to the current account balance-to-GDP ratio (which is assigned the top score, i.e. 20), and the 'Political environment' area (15.7), which reflects the World Bank governance indicators.

Among the worst performers, the debt level gets the lowest possible score (zero), owing to the high debt-to-GDP ratio (current: 135%; projected 5-y forwards: 157%). The 'fiscal balance' indicator is instead assigned an intermediate score (10.3). 'Exchange rate classification' gets the worst score too, due to the currency union membership (the same as for all euro area countries).

DBRS—Qualitative drivers. The agency's October 2020 report shows that the scorecard result (an [A+: A−] range) was lowered by 2 notches in the qualitative assessment, to the range [A−: BBB]. As a final step, the rating committee decided to pick the central point of that range (BBB+), thus confirming the official rating of the May 2020 review (in that case the model rating range was [AA−: A] and the qualitative adjustment amounted to −3 notches).

In its report, DBRS motivates the 2-notch negative adjustment with the lower GDP growth compared with Italy's peers, the expectation of a rising NPL-to-loans ratio and the political uncertainty.[24] In the report, DBRS does acknowledge some positive factors (the low level of private sector debt, the Eurosystem sovereign bond purchases, and the historically low interest payment), which however are not reflected in the final rating.

Fitch—*Quantitative factors* (see Annex 2). The final score obtained with our simulation is 9.79, which corresponds to an A− rating, the same as the model rating in the Fitch December 2020 report (whose final score is 9.82); the −3 notch qualitative adjustment applied by the agency in December led to a final BBB− rating.[25]

The highest contribution to the 9.79 final score comes from Pillar 1, 'Structural features' (9.54), whose weight is the highest (53.7%)[26]; this pillar includes GDP per capita (weight: 12.3%) and a set of World Bank Governance indicators (with a weight of 20.4%, which makes them the most important variable in the model). The worst contribution comes from Pillar 3 'Public finances' (−3.9), which is the second most important pillar in the model (weight: 18%).

[24] DBRS says that the 2-notch negative adjustment comes from a downward revision applied to 3 out of the 6 blocks of indicators in its model: (i) the 'Economic Structure and performance' area (from 'strong/good' to 'good'), because of a GDP per capita (33,200 US dollars in 2019) lower than euro area peers' and the gap on green and digital transition investments; (ii) the 'Monetary policy and financial stability' area (from 'very strong' to 'strong'), because of the high NPL stock and the low diversification of some small and medium-sized banks; and (iii) the 'Political environment' area (from 'strong/good' to 'good') for the political uncertainty, as shown by the frequent change in governments and the weak appetite for reforms.

[25] See Fitch (2020b, 2020k).

[26] The weights mentioned in the text refer to Fitch's methodology in force at the time of our simulation (October 2020). Little changes were applied by Fitch afterwards with the methodology updates.

Comparing Italy's scores with those assigned to Germany (which we use as a benchmark in our analysis, as we lack indicator scoring scales in Fitch's methodology),[27] Italy's quantitative score is 5 points lower than Germany's 15.19 (which translates into an A− rating for Italy, 5 notches lower than Germany's AA+), reflecting the lower scores for the economic and public finance indicators.[28,29] The final rating difference is even larger (9 notches), as the qualitative assessment lowers Italy's model rating by an additional 3 notches, to BBB-, and raises Germany's model rating by 1 notch, to AAA.

For the 'GDP-per-capita' indicator, Fitch employs the 'percentile rank of per capita GDP in US dollars at market exchange rates in the current year across all Fitch rated sovereigns'.[30] As of October 2020, Italy was in the 77th percentile.

Fitch—Qualitative factors. In December 2020, Fitch applied a −3 notch qualitative adjustment, i.e. the worst possible penalisation foreseen in standard conditions according to its own methodology, resulting in a final rating of BBB-. In the December 2020 report, the agency explains that out of the 3 notch penalisation, 1 notch was due to the very low GDP growth potential and 2 notches to the very high public debt and the sustainability risk, because of the lack of a medium-term fiscal strategy.[31] The 3-notch negative adjustment was based on a peer comparison whereby Italy's scores for the four pillars were compared with a peer group of issuers which would cover, as per Fitch's methodology, both the quantitative rating category (A in the case of Italy) and the 'rating category' (BBB; we note that Fitch's public reports on Italy mention only the BBB peers, not the A peers). Three remarks are in order. First, while the peer comparison results in a sizeable negative

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[27] Fitch uses a linear regression model, hence no scoring scales are available for each indicator to assess the relative position of a sovereign in the regression (e.g. how high is a 3.05 value for the variable GDP-per-capita for Italy, obtained as the product of Italy's GDP-per-capita, as a percentile rank, times the coefficient of 0.040 for that variable in the regression). Lacking a reference scale, for the purpose of this analysis, the scores assigned by Fitch model to Germany are used as a benchmark to assess the scores assigned by Fitch model to Italy. Data on Germany were sourced from Fitch (2020e), p 2.

[28] The −5.4 point difference between Italy's and Germany's quantitative scores derives from: (i) -2.4 points on Pillar 1 (Structural features) which includes, as main indicators, GDP-per-capita and World Bank Governance Indicators; (ii) −2.1 points on Pillar 3 (Public finances), mainly based on the debt-to-GDP ratio; and (iii) around −0.5 points on each of the two remaining pillars in the Fitch model, namely, Pillar 2 (Macroeconomic performance, policies, and prospects), which includes the GDP growth and the inflation indicators, and Pillar 4 (External finances) based on balance of payments indicators.

[29] The Fitch model is structured in such a way that every additional point in the final score (given by the sum of the 4 Pillars' individual scores) corresponds to 1 notch in the implied credit rating. For example, a final regression score between 6.5 and 7.5 corresponds to a BBB- rating; a final score between 7.5 and 8.5 to a BBB rating, and so on. Therefore, the 5 point difference between Italy and Germany yields a 5 notch difference in the model ratings (A− vs. AA+).

[30] See Fitch (2020l), p 11.

[31] Hence the 3-notch penalisation stems from a downward adjustment to 2 analytical pillar scores: 'Macroeconomic performance, policy and prospects' pillar (−1 notch) and the 'Public finances' pillar (−2 notches).

adjustment, no positive adjustment is applied for the pillars where Italy outperformed its peers in the A and/or the BBB category (the ‘Structural features’ and ‘External finances’ pillars).[32] Second, as of December 2020, the BBB peer category included a number of countries that differ sharply from Italy in terms of wealth/borrowing capacity, economic and financial conditions and rule of law; this is the case, for instance, for Colombia, India, Mexico, Romania, Uruguay (the final, official rating being BBB- for all of them, similarly to Italy as of December 2020), and Bulgaria, Indonesia, Kazakhstan, and Panama (all rated BBB). Third, the official rating may not represent an objective basis for comparison as, unlike the quantitative rating, the official rating may include substantial qualitative adjustments.

Moody’s—*Quantitative factors* (see Annex 3). Our simulation yields ‘A− and BB’ as output, where A− is related to the economic, institutional and fiscal factors combined, while BB refers to the ‘Susceptibility to event risk’ factor, which includes four sub-factors: political risk, government liquidity risk, banking sector risk, and external balance risk. From Moody’s methodology tables, the ‘A− and BB’ output is equivalent to a model rating in the [BBB+: BBB−] range. This is the same as the model rating range published by Moody’s in April and in November 2020; in both cases, the agency’s final rating was BBB− (1 notch below the central point of the model rating range).

The most important findings of our simulation are the following:

- the model rating takes shape progressively in the model by combining the assessment ‘factor’ pairwise. First, the economic and institutional[33] factors deliver an A rating (stemming from the excellent scores to GDP (AAA), GDP-per-capita (AA+), and real GDP growth volatility (AA+) which are offset by the low score to real GDP growth (CCC−)). The rating declines marginally (to A−) when public finance factors are included (with a score equal to BB−); the rating further declines in the neighbourhood of BBB, when the susceptibility to event risk is considered (BB, referred to the banking system). The BBB range is the outcome of the model;
- Italy’s external balance, with an AA rating, feeds neither into the model rating nor into the official rating, since this indicator is apparently ignored in the qualitative assessment. Regarding the model, the external balance falls within the last assessment factor (called ‘Susceptibility to event risk’) which, based on Moody’s

[32] The over-performance referred to the following metrics of the model: (i) World Bank Governance indicators, GDP per capita, Share in world GDP, Broad money/GDP ratio (in the ‘Structural features’ pillar) and (ii) Commodity export dependence, Current account balance and Net foreign direct investment, Sovereign net foreign currency debt (in the ‘External finances’ pillar).

[33] Regarding ‘Institutions and governance strength’, Moody’s made this factor mostly qualitative in the methodology review of November 2019, hence it cannot be entirely replicated (formerly, instead, it was based on inflation variables and some World Bank indices). In order to process this factor in our simulation, we take into account the only two quantitative indicators in this area that are also publicly available (namely, the ‘Quality of legislative and executive institutions’ and the ‘Strength of civil society and the judiciary’, both published by the World Bank) which yield an A score. This corresponds to the score assigned by Moody’s in its November 2020 rating review.

methodology, takes the lowest of the scores assigned to its four sub-factors (external finance, political risk, government liquidity risk, and banking sector risk).[34] As a result, this factor gets, in our simulation, the same score as the banking sector risk[35] (BB; as a comparison, the corresponding score for France and Germany is BBB). The other three sub-factors in this category get better scores: political risk (A in our simulation, BBB in Moody's report on Italy, which also includes qualitative components), government liquidity risk (A), and external balance risk (AA).[36] Hence, the latter sub-factor (external finance), which should arguably not be irrelevant in assessing a country's soundness, is altogether ignored in Moody's quantitative score. Since no qualitative upgrade was applied by the rating committee late in 2020 (nor in the following decisions until 2022), the positive contribution of the external finance was ignored in Italy's final rating.

Moody's—Qualitative factors. In the new methodology introduced in 2019, Moody's scorecard has become to a non-negligible extent qualitative; accordingly, the scorecard should arguably require little, if any, further qualitative adjustment. In November 2020, Moody's judgmentally downgraded Italy's score for the fiscal and economic assessment factors, which anyway had no impact on the rating range outcome of the model [BBB+: BBB−].[37] Starting from this, Moody's rating committee finally chose the lower bound of this range, assigning a BBB− official rating to Italy, which implies a differential of −1 notch with respect to the central rating of the range.

S&P—*Quantitative factors* (see Annex 4). Our simulation, which only relies on the quantitative components of the model, yields '3' for the 'Institutional and economic profile' (where we replicate only the 'Economic assessment') and '3.33'

[34] Moody's explains that the choice for the lowest score among those assigned to the four sub-factors depends on the fact that the four sub-factor risks (political, government liquidity, banking sector, and external vulnerability risks) are typically correlated, with the manifestation of one of these risks likely to accelerate the occurrence of other risks'. See Moody's (2019), p 33.

[35] Moody's methodology assesses the 'Banking sector risk' through two indicators: the 'Strength of the banking system' (rating) and the 'Size of the banking system' (total assets-to-GDP). These two indicators are combined through a table also reported in Moody's methodology.

[36] In our simulation, we can replicate only the score on the banking sector risk since this has become the only quantitative sub-factor, within the 'Susceptibility to event risk' factor, in Moody's methodological review of November 2019 which made this factor mostly qualitative. To determine if the banking risk score (BB) is the worst among the four sub-factors, we assess the other three sub-factors as follows: (i) for the political risk, we take into account the only quantitative indicators foreseen by the new methodology for this sub-factor (the World Bank 'Voice and accountability' and 'Political stability' indices and the country income Gini coefficient) which yields an A score, against a BBB reported by Moody's in its November 2020 report on Italy; (ii) for the external vulnerability risk, we take into account also in this case the only quantitative indicator specified in the methodology (the current account balance) whose assessment can be 'scored' based on what described in the methodology: this leads to an AA score, in line with Moody's score in November 2020 report; and (iii) for the liquidity risk, we apply Moody's former, more quantitative methodology which yields an A score, in line with Moody's report of November 2020.

[37] See Moody's (2020a), pp. 3–6.

for the 'Flexibility and performance profile' (S&P's scale ranges from 1, which is the best possible score, to 6). When matched with the proprietary matrix, the '3 and 3.33' score results in a quantitative rating of BBB+, which is consistent with S&P's model rating for Italy as of October 2020.[38] In fact, the addition of the qualitative component of the model (the 'Institutional assessment,' which was given a score of 3 by S&P) does not change the average score of 3 assigned to the 'Institutional and economic profile' in our simulation.

The rating is supported by Italy's high GDP-per-capita (which is part of the 'Economic assessment'), with a score of 2. The 'Monetary assessment' also contributes positively to the overall quantitative assessment, with a score of 2, despite the standard penalisation for the membership in a monetary union. The quantitative rating is dragged down by the 'Fiscal assessment', whose overall score is 5; the score for the debt burden component is 6 (the worst possible one), reflecting two variables: the general government interest payments-to-revenues ratio (7.6% in the simulation) and the net general government debt-to-GDP ratio (149%).[39]

The simulation highlights a noteworthy feature of the S&P's model rating for Italy: the banking sector assessment (captured in the model through the 'Banking sector's exposure to government' and the 'Contingent liabilities from banks') has no impact on Italy's rating. This is because the two banking indicators are used just as a possible reason for a 'negative adjustment' to the debt burden score; since Italy's debt burden score is already the worst (6), the banking sector indicators are not used in the analysis.

S&P—Qualitative factors. In October 2020, the S&P rating committee confirmed Italy's official rating at BBB, thus applying a −1 notch adjustment to the scorecard rating (BBB+), on account of Italy's general government debt being one of the largest among all the rated sovereigns.[40] While Italy's government debt is unquestionably high, we notice that S&P had stated in an earlier commentary on Italy (September 2019) that 'the most useful indicator of sovereign creditworthiness is the country's net external position in relation to the rest of the world, rather than the ratio of debt to GDP and that Italy's external position was essentially in balance and better (sometimes much better) than those of other European countries' (UK, FR, ES, and PT).[41] By late 2020, Italy's external position had further improved (the net international investment position had turned positive, to 1.4% of GDP, from almost 30 years of negative or in-balance values) and was far better than those of the United

[38] See S&P (2020b).

[39] According to S&P methodology, interest payments at the level of Italy's, i.e. between 5 and 10% of the revenues, could lead to a better score on the fiscal assessment (between 2 and 5) for a debt-to-GDP ratio lower than 100%; instead, for interests-to-revenues between 5 and 10% coupled with a debt higher than 100% of the GDP, that combination takes the lowest score (6). This means that, at the current and projected debt level, Italy's assessment in S&P fiscal section could hardly improve.

[40] See S&P (2020a, 2020b).

[41] See S&P (2019).

Kingdom (−17.88% of GDP), France (−30.7%), Spain (−85.7%), and Portugal (−104.6%).[42] It would appear that despite being singled out by S&P itself as 'the most useful indicator of sovereign creditworthiness', the net international investment position is only a secondary indicator in S&P's model.

In the October 2020 review, S&P improved the rating outlook from 'negative' to 'stable', reflecting the Eurosystem's asset purchases (a factor that is not included among the quantitative indicators) and the measures introduced by the Italian government to support economic growth in the midst of the Covid-19 induced uncertainties. S&P also acknowledged the Italian Treasury's ability to carefully manage the public debt (with an increase of the average maturity up to 7 years and a reduction in the refunding risk and the average interest cost). These positive qualitative considerations led to the above-mentioned outlook improvement.

Recap from the simulation To sum up, the quantitative results of our simulation across the four agencies show that the high GDP (in absolute value and per capita), the balanced external account and the World Bank Indicators are Italy's economic strengths. These factors allow Italy to keep its rating in the investment-grade territory. The official ratings are instead penalised by the high government debt and, as far as Moody's is concerned, also by the banking sector rating.

Among the qualitative factors, the four rating agencies motivate the negative adjustments with concerns either about economic growth and the public debt prospects or about political uncertainty.

4.2 Comparison Across Italy's Model Ratings

In what follows, we carry out a comparison across the model ratings we obtained in our simulations, so as to pin down the reasons behind the differences in the scores assigned by the four models. As the results from our simulation exercise are in line with those published by the rating agencies as of December 2020, this comparison refers in practice to the agencies' published model ratings. Fitch cannot be included in the comparison: because of its reliance on a linear regression model, its overall quantitative score, as well as sub-factor scores, cannot be assessed against a ranking scale.

The other three agencies have their own scales for score assignment (DBRS: 0–20; Moody's: AAA-C; S&P: 1–6), hence a score normalisation is necessary to perform a comparison. We adopt the range 0–10, where 0 is the worst and 10 is the best score. The key findings of the comparison are described below and refer to our simulation exercise as of October 2020 (Table 5).

- The choices concerning indicators, calculation methods, and scoring scales (as regards, for instance, the time horizon) may have a significant impact on the

[42] Data sourced from the Eurostat (for the euro area) and the Office for National Statistics (UK), consultation date: 13 January 2023.

Table 5 Comparison across the scores assigned in our simulation to Italy on selected key indicators

	Agency-based score[a]			Normalised score[b]		
	DBRS	Moody's	S&P	DBRS	Moody's	S&P
ECONOMY[c]	**16.7**	**A**	**3**	**8.3**	**7.5**	**6**
Nominal GDP	20	AAA		10	10	
GDP per capita	14.5	AA+	2	7.3	9.5	8
GDP growth		CCC-	+1 point		1	−2 points
GDP growth volatility	15.5	AA+		7.8	9.5	
PUBLIC FINANCE[c]	**6.8**	**BB−**	**5**	**3.4**	**4**	**4**
Debt/GDP	0	CCC	6	0	1.5	0
Fiscal balance or Govt debt/GDP trend	10.3	−1 points	4[d]	5.2	−0.5 points	4
Interests/Revenues		A+	6		8	0
Interests/GDP	3.4	BB		1.7	4.5	
EXTERNAL POSITION[c]	**14.7**	**AA** (no impact)	**3**	**7.4**	**9** (no impact)	**6**
Curr. acc. balance/GDP or/Curr. acc. receipts	20	AA	−1 point	10	9	+2 points
Net intern. invest. position/GDP or /Curr. acc. receipts	16.4		−1 point	8.2		+2 points
Short term debt/Curr. acc. receipts			+1 point			−2 points
Narrow net ext. debt/Curr. acc. receipts			4			4
FINANCIAL POSITION[c]	**19.8**	**BB**	No impact	**9.9**	**4.5**	No impact
Total domestic savings/GDP	20			10		
Credit growth	20			10		
NPL/Banks' capital	18.8			9.4		
Banks' exposure Govt/Total assets			No impact			No impact
Banking system risk		BB			4.5	

Source: own calculations
[a]Rating agencies' scales:
DBRS: 21 scores in the range [0, 20], where 0 = very weak, 20 = very strong
Moody's: 21 scores in the range [AAA, C], where AAA = the best score, C = the worst score
S&P: 6 scores in the range [1, 6], where 1 = the strongest, 6 = the weakest
[b]Range [0, 10], where 0 = the worst score, 10 = the best score
[c]The aggregated score related to each area is not necessarily equal to the average or the sum of the indicator scores reported in the table. This is due in some cases to the specific agency's aggregation rules (e.g. the weights assigned to each indicator in the model computation); in other cases, to the fact that only a sample of indicators (those considered as the most representative for each area) was selected for this table among all indicators used by the agencies in their models
[d]Exceptionally for S&P's indicator 'Govt debt/GDP trend' we use in this table S&P's actual score from October 2020 rating review (which is equal to 4) instead of our simulation score (5). The simulation score is worse than S&P actually assigned score, hence that could alter the results of the comparison across the four agencies (5 corresponds to a normalised score of 2, while 4 corresponds to a normalised score of 4)

score assigned to the same economic variable or block of variables, resulting in some cases in sharply diverging assessments. The most striking case is that of DBRS and Moody's financial assessments (with final normalised scores of 9.9 and 4.5, respectively): while DBRS relies on a wide and diversified set of indicators (domestic savings, credit growth, NPL/Banks' capital, real estate price growth), Moody's focuses almost exclusively on the banking system (banks' size and rating), that is assessed by using the same score as the average rating assigned to Italian banks (BB+).

Unsurprisingly, the agencies' scores for Italy's economic strength (as measured by GDP and GDP-per-capita) are very similar with top scores. However, even in this case, the final scores show non-negligible differences (8.3 according to DBRS, 7.5 for Moody's and 6 for S&P), due to the different weight assigned to economic growth.[43]

As concerns public finance, the three agencies assign the lowest (or nearly the lowest) score to government debt; however, in all cases, the final score improves somewhat thanks to the additional public finance indicators used in the three agencies' models (8 to the interests-to-revenues ratio for Moody's; 5.2 to the fiscal balance in the case of DBRS; 4 to the debt-to-GDP trend for S&P). The different overall scores for the public finance area can be explained by the different weights adopted by the various agencies.[44]

- The rules for combining the model indicators have a major impact on the output. The external balance assessment exemplifies this point. DBRS, Moody's, and S&P assess Italy's external position with good to excellent scores (respectively, 7.4, 9, and 6). However, while DBRS and S&P (and Fitch in the linear regression) always include this score in their model result, Moody's score (9 in the normalised scale, AA in Moody's scale) does not feed into the final rating. As mentioned in Sect. 1, Moody's model chooses only the worst score among the marks assigned to the four variables included in the 'Susceptibility to event risk' area (external balance risk, political risk, liquidity risk, and banking sector risk). For Italy, the worst score (4.5) is the one related to the banking sector risk, so the nearly top score assigned to external balance (9) has no impact on the model rating nor, lacking qualitative upgrades, on the final rating. Two remarks are in

[43] The reason is twofold: (i) DBRS only takes into account GDP growth volatility, instead of GDP growth (S&P) or the combination of growth and volatility (Moody's); (ii) Moody's assigns a higher weight to GDP growth in its computation (25% of the economic strength factor) than to GDP growth volatility (10%). Overall, in the 'GDP growth' area, DBRS normalised score is 7.8; Moody's score is 3.5; S&P assessment is measured as *a* −2 point adjustment.

[44] For this specific assessment area, we analyse also Fitch outcome on Italy by taking Germany as a benchmark (as stated above, a benchmark must be used for cross-comparison absent, in Fitch methodology, a scoring scale at indicator level). In Fitch's model, assuming for Italy the same public finance score assigned by Fitch to Germany, Italy's model-implied rating would improve by 2.4 notches. The same simulation on the three other agencies—all other indicators being equal—results in a rating differential of 2 notches for S&P and 4 notches for DBRS and Moody's. Therefore, the government debt indicator has a more significant rating impact in DBRS and Moody's rating relative to Fitch and S&P.

order: (1) an asymmetrical treatment is applied when processing in the model the political, banking sector, debt liquidity and external risks, because only one of them (the worst one) contributes to the final rating, regardless of the performance of the other three indicators; (2) the minimum score function is applied to very heterogeneous types of risk.

As a result of the differences in indicators and rules, the key drivers of a sovereign model rating may differ markedly across the agencies. For instance, in S&P's model, the economic and the external position assessments receive similar scores, i.e. none of these two specific areas prevails over the others. For DBRS and Moody's, and also for Fitch, the model-implied rating is driven by the positive assessment of economic strength, which prevails over all other indicators.

4.3 Factors Potentially Underweighted in the Four Agencies' Analyses

A remarkable feature of the four agencies' methodologies is the fact that some key indicators—that are arguably important when it comes to assessing sovereign creditworthiness—are not included in their models. These indicators may, or may not, be factored into the final rating through the qualitative assessment of rating committees.

In the case of Italy, these metrics (which would reasonably contribute positively to the country's credit standing) are not explicitly acknowledged in the qualitative assessment. As a result, their contribution to the final rating is nil.

The following indicators are worth mentioning:

- *Economic diversity,* which may be an important factor of economic strength. The S&P's scorecard indirectly considers this aspect, but only as a possible reason for a negative adjustment, in case the economy is highly concentrated in one sector. Italy's economic diversity is a feature that all agencies highlight in their reports. However, it does not appear to affect the final assessment.
- *Government primary balance.* There are reasons to believe that the primary balance should be an important variable in the public finance assessment. However, this variable is absent in the four agencies' models, which cannot therefore differentiate between countries that run a primary surplus (as Italy has done for over 25 years) and countries that show a 'double deficit'.
- *The country's private sector debt level* (i.e. household and corporate debt). This can be viewed as a latent sovereign liability (in the event of a severe and widespread economic recession) and as an intrinsically riskier type of debt relative to public debt (a private debtor has a limited repayment ability, while a sovereign wields taxation power). Italy's private sector debt level is one of the lowest among G7 and Western European countries. The different dynamics of private and public sector debt in different countries may be explained also by the

fact that the cost of a range of 'public good services' (such as health services) may be borne by private individuals or public administrations, and the countries' choices may differ widely. Since the four agencies focus on public, rather than total debt, the assessment of the overall risk level of a country is affected by this choice.

- *Private sector's financial wealth.* This variable only plays a role in DBRS' model (via the 'Total domestic savings-to-GDP ratio'), even though all four agencies underline that it is a credit plus for Italy.
- *The weight of derivatives in banks' balance sheets.* This is a potential source of financial instability for a country, as shown by the events following the great financial crisis, and may be viewed as a latent liability of the sovereign. However, this factor is neglected by all agencies. Conversely, all agencies take into account, in their models or in the judgmental overlay, the risk from non-performing loans. The asymmetric treatment of these two types of banking risk might lead to an asymmetric treatment across jurisdictions, as risk is magnified in countries where financing largely relies on bank lending, whereas it is arguably underestimated in countries where speculative finance is more widespread in the banking sector.

4.4 Official vs. Model Ratings for Euro Area Countries

As of December 2020, the qualitative assessment of the Italian sovereign, as measured by the differential between the official rating and the respective agency model rating, was −3 notches (Fitch), −2 notches (DBRS), and −1 notch (Moody's, S&P). Next, we compare the qualitative adjustments for all euro area countries at that date (Table 6).

- For sovereigns in the AAA-AA space, the final rating tends to be either aligned or up to 2 notches higher than the model rating; the 2-notch positive deviation occurs with Moody's official ratings for Austria, Luxembourg, and The Netherlands, and with Fitch's official ratings for Austria and France. Estonia is an exception, with a −1 notch qualitative adjustment by DBRS, Moody's and S&P. For less creditworthy sovereigns, the official rating is up to 3 notches lower than the model rating, i.e. weaknesses regularly outweigh credit strengths in the qualitative assessment;
- DBRS, Fitch and Moody's qualitative adjustments (2–3 notches) are on average larger than S&P (1 notch);
- Italy's notch differential between official and model ratings (up to −3 notches) is comparable to those of Cyprus and Portugal. Fitch's adjustment for Italy between April and July 2020 (−4 notches) was exceptionally large and unmatched in the sample; it also exceeded the +/−3 notch range which is envisaged as the norm in Fitch's methodology, unless a larger deviation is justified by truly extraordinary events.

Table 6 Official and model rating of euro area sovereigns as of December 2020

	DBRS		Fitch		Moody's		S&P	
Sovereign issuer	Official rating	Distance from model rating[1]	Official rating	Distance from model rating[1]	Official rating	Distance from model rating[1]	Official rating	Distance from model rating[1]
Austria	AAA	0	AA+	+2	AA+	+2	AA+	-1
Germany	AAA	0	AAA	+1	AAA	+1	AAA	0
Luxembourg	AAA	0	AAA	0	AAA	+2	AAA	0
Netherlands	AA+	0	AAA	+1	AAA	+2	AAA	+1
France	AA+	+1	AA	+2	AA	+1	AA	+1
Belgium	AA+	+1	AA-	+1	AA-	0	AA	0
Finland	AA+	0	AA+	0	AA+	+1	AA+	0
Estonia	AA-	-1	AA-	0	A+	-1	AA-	-1
Ireland	A+	+1	A+	-1	A	**-3**	AA-	-1
Malta	A+	-2	A+	0	A	-1	A-	-1
Slovakia	A+	+2	A	+1	A	-1	A+	+1
Lithuania	A	-1	A	0	A-	-1	A+	+1
Slovenia	A+	+1	A	0	A-	0	AA-	0
Spain	A	0	A-	0	BBB+	-2	A	0
Latvia	A-	-1	A-	0	A-	0	A+	+1
Italy	BBB+	-2	BBB-	**-3**	BBB-	-1	BBB	-1
Portugal	BBB+	-1	BBB	-2	BBB-	-2	BBB	-1
Cyprus	BBB-	-1	BBB-	-2	BB	**-3**	BBB-	-1
Greece	BB-	0	BB	-1	BB-	0	BB-	-1

Source: Rating agencies' reports; S&P Global Ratings, S&P (2021a).
[1)]The distance is quantified in notches. For DBRS and Moody's, whose models generate a rating range rather than a single rating, the difference is calculated relative to the central point of the range

To appraise to what extent these diverging qualitative assessments are justified, let us compare Moody's ratings to for the Netherlands and Italy.

In the case of the Netherlands, Moody's official rating (AAA as of November 2020) was 2 notches higher than Moody's scorecard rating (AA, midpoint of the [AA+: AA−] range). As per Moody's report, a +1 notch adjustment was applied to the economic pillar score (raised from A+ to AA−) to account for (1) factors which are not fully captured by the quantitative indicators in the model (the high degree of competitiveness and flexibility) and (2) the diversification of the economy and its sizeable current account surplus. The new model rating range then became [AAA: AA], whose upper bound was finally chosen by the rating committee as the official rating (AAA), implying an additional notch upgrade, hence +2 notches overall for the qualitative adjustment.[45]

It may be argued that, by applying the 2-notch qualitative adjustment, Moody's made up for two potential weaknesses of its quantitative model: (1) some model-omitted variables (competitiveness, diversity, etc.) were factored into the final

[45]See Moody's (2020b), p 2.

assessment; (2) the economy's 'sizeable current account surplus' (a feature that also applies to Italy), which had been ignored in the quantitative assessment because of the model mechanics, was allowed to feed into the final rating.

Conversely, the high private sector debt (which Moody's itself mentioned as a challenge for the Netherlands) did not trigger any negative adjustment. At the end of 2019, the Dutch private sector debt amounted to 234% of GDP which, when added to the public debt (48.7%), leads to a total debt equal to 282.7% of GDP (241.3% for Italy, resulting from a private sector debt at 106.6% and a public debt at 134.7%).[46] In the case of the Netherlands, the high private sector debt was overlooked both in the model and in the qualitative assessment.

Turning to Italy, Moody's official rating (BBB− as of November 2020) was 1 notch lower than the rating of the model (BBB, mid-point of the [BBB+: BBB−] range); the −1 notch adjustment reflected the agency's expectation of the pandemic lasting effect on the fiscal balance. As regards Italy's economic strength, Moody's mentioned that the model score 'reflects the size and diversification of the economy, as well as the relatively low indebtedness of the private sector' as an important strength. Moody's went on to remark that 'Households in particular have low debt and high financial wealth, which provides some buffers against economic shocks'. None of these factors, despite being singled out as important, apparently played a role in shaping Italy's rating: in Moody's scorecard, the economic strength assessment is only based on GDP size and growth; at the same time, no adjustment was subsequently applied in the qualitative assessment.

Two general remarks can be drawn from this comparison:

- the qualitative assessments may lead to a revision of model results and one would argue that they should be used to compensate for omitted variables and known model flaws. Actually, only some of those adjustments seem to fix those issues;
- the qualitative adjustments do not seem to be uniformly applied, and rating agencies appear to be stricter with lower-rated countries.

An econometric study by Vernazza and Nielsen (2015) confirms that the rating agencies' qualitative assessment tends to overrule the 'objective' component of their analyses (i.e. the quantitative indicators), with the risk of what they call the 'damaging bias' of sovereign ratings. The analysis focuses on rating decisions on Eurozone peripheral countries during 2009–11: the rating committees repeatedly overruled the signal coming from fundamentals. As an example, only 2 out of the 6 notches of the Italian rating downgrade by Moody's between 2011 and 2012 could be explained by a deterioration of fundamentals. The study concludes that while the 'objective' component has explanatory power to predict defaults both in the short and long term (1 to 3 years), the 'subjective' component does not help to predict defaults and even biases default predictions in the wrong direction.

[46] Data sourced from Eurostat.

5 Conclusion

This chapter investigates (1) the approaches followed in the assignment of sovereign ratings by the four rating agencies recognised by the Eurosystem for the purpose of monetary policy (DBRS, Fitch, Moody's, and S&P) and (2) the quantitative and qualitative drivers of the ratings assigned to Italy as of December 2020. The main findings may be summarised as follows.

We find that rating processes and baseline methodologies are similar across the four agencies, while significant differences arise in terms of indicators and computational rules. All four agencies follow a two-step approach in the assignment of a sovereign rating, whereby a 'model rating' is first derived from a proprietary, mostly data-driven model; the model rating is then adjusted by the internal rating committee's qualitative assessment, usually in the range of +/−3 notches from the model rating, to obtain the official rating.

To build their models, whose outcome is the starting point of the rating process, the four agencies first identify the sources of risk for the sovereign creditworthiness, namely: (1) the country's *economic strength* (to evaluate the country's resilience to shocks); (2) its *public finance* (to assess the public debt burden and affordability); (3) its *external balance* (to assess the ability to repay the debt denominated in foreign currency); (4) its perspectives as regards *monetary and financial stability* (for the price and financial vulnerability assessment); and (5) the country's *institutional framework* (to examine the stability and predictability of policymaking).

For each of these areas, the agencies use a set of indicators among those that are considered as predictive about the potential stress or default of an issuer (e.g. GDP and the public sector deficit-to-GDP ratio). While the models of DBRS and Fitch are purely quantitative, the models by Moody's and S&P also employ qualitative indicators. As concerns the model type, Fitch employs a regression model, while the other three agencies employ a 'scorecard' where the indicators are combined on the basis of a set of weights and rules. Since indicators and aggregation rules largely differ across the agencies, the model ratings can diverge across the four agencies for a sovereign issuer.

As of December 2020, the official ratings assigned to Italy were BBB+/BBB/BBB−/BBB− by DBRS, S&P, Fitch, and Moody's, respectively. They were lower than the respective model ratings by 3 notches in the case of Fitch, by 2 in the case of DBRS, and by 1 for S&P and Moody's. In January 2023, the sequence of ratings had become BBB+/BBB/BBB/BBB− (following Fitch upgrade in December 2021), i.e. below the respective model ratings by 2 notches for DBRS and Fitch and 1 notch for S&P and Moody's. In the whole period, the qualitative assessment implied that Italy's rating was more punitive than the average for other euro area countries, with an overweight for the risk factors and an underweight (or neglect) for the strengths in the qualitative assessment. Countries with a final rating similar to Italy include Bulgaria, Romania, Colombia, and Mexico, which are arguably not comparable with Italy in terms of economic and financial wealth, rule of law and institutional structure.

In recent years, the four agencies have significantly improved their transparency on the assessment of sovereign issuers. All four agencies regularly publish detailed reports on each of their rated sovereigns, including the model inputs and outputs (the quantitative drivers of the official rating) and the reasons behind the judgmental adjustments (the qualitative drivers of the official rating), if any.

Based on the agencies' published methodologies, in this chapter we replicate the four model ratings (indicators, scores, and rules) to better understand the mechanics of sovereign ratings and to dissect the components of Italy's ratings as of December 2020. In line with the agencies' reported results, we find that the most favourable quantitative driver of the rating is the size of the economy as measured by GDP, which gets an AAA or equivalent score; additional economic strengths are the balanced external position and the solid institutional framework. These drivers allow Italy's ratings to stay above the investment grade threshold. Conversely, the least favourable quantitative driver is the public debt burden. The qualitative part of the rating is driven by Italy's risk factors, especially the slow economic growth and the political uncertainties, while some sources of strength of the Italian economy are apparently overlooked (e.g. the 25-year track record of government primary surpluses and the private sector's high wealth level). This translates into official ratings by 1 to 3 notches lower than the agencies' model ratings.

We think that a way to enhance the credit assessment of a sovereign would be to include additional economic and financial variables in their quantitative models, to cover a wider range of the issuer's credit features (e.g. the government primary balance, the commercial banks' exposure to financial derivatives, the private sector debt and savings). Besides, the qualitative assessment could be geared towards complementing the model results.

Further empirical investigation in this field might include a cross-section analysis of the quantitative and qualitative drivers of the ratings assigned to sovereign issuers and of the relationship between the rating and government bond yields, in the euro area and beyond.

Annex 1

Our simulation on the model rating by DBRS

(October 2020. Worst scores are highlighted in red; best scores in green. The darker, the more intense)

Building block / Indicator	Very Strong	Very Weak	Indicator Value	Equivalent Score (0-20)[1]	MACRO SCORE[2]
1. FISCAL MANAGEMENT AND POLICY					**12.6**
Overall fiscal bal. (% GDP, 10y hist. +3y fwd, avg)	0	-8	-3.87	**10.3**	
Govt effectiveness (percentile rank, last 5 obs.)	85	25	69.71	**14.9**	
2. DEBT AND LIQUIDITY					**1.1**
General Govt gross debt (% GDP, last full year)	30	130	134.80	**0**	
Projected general Govt gross debt (% GDP, 5y forecast)	30	130	157.09	**0**	
Interest costs (% GDP, 3y hist. + 2y fwd, avg)	0.5	4	3.40	**3.4**	
3. ECONOMIC STRUCTURE AND PERFORMANCE					**16.7**
GDP per capita (USD thousands, 10y hist., avg)	45	5	34.09	**14.5**	
Output volatility (%, St. Dev., 20y hist. + 3y fwd)	1	6	2.12	**15.5**	
Economic size (USD billions, Sq. root, 5y hist.)	40	5	44.18	**20**	
4. MONETARY POLICY AND FINANCIAL STABILITY					**19.8**
A. Policy credibility					
Inflation Performance					
Rate of inflation (%, 10y hist. + 3y fwd, avg)	3	15	1.07	**20**	
Incidence of deflation (N. of years)	1	7	0.00	**20**	
Total domestic savings/GDP (%, latest)	200	20	264.71	**20**	
B. Financial risks					
Credit growth (%, 7y, avg)	0	20	-2.55	**20**	
Property price growth (%, 7y, avg)	0	20	-3.70	**20**	
Net NPL to capital (%, latest)	25	225	37.30	**18.8**	
5. BALANCE OF PAYMENTS					**14.7**
A. External imbalances					
Current account balance (% GDP, 5y hist.+ 3y fwd)	-1	-8	2.67	**20**	
Net international invest. position (% GDP, 5y hist.)	0	-50	-9.04	**16.4**	
B. Capacity for external adjustment					
Share of global foreign exchange turnover (ratio)	2	0.5	15.23	**20**	
Access to foreign exchange reserves (% of short-term external debt plus current account deficit)	1.5	0.5			
Exchange rate classification (qualitative)	1	5	5	**0**	
Integration in currency area:					
Economic weight within currency area (%, 5y hist.)	35	5	16.06	**7.4**	
Correlation of economic cycles (coeff., 20y)	0.9	0.4	0.97	**20**	
6. POLITICAL ENVIRONMENT					**15.7**
Rule of Law (Percentile rank, latest 5 obs.)	85	25	62.60	**12.5**	
Voice and accountab. (Percentile rank, latest 5 obs.)	85	25	81.48	**18.8**	
Total Score (Sum of the 6 macro-scores, from 0 to 120 points)					**80.6**
Final model Score (Total Score on a scale of 0 to 100)					**67.2**
Model rating					**A+ : A-**
Model rating (central point)					A
Actual rating					BBB+
Notch difference (Actual rating, Model rating-central point)					**-2**

Notes:
1) Equivalent Score goes from 0 ('very weak') to 20 ('very strong'). 2) Within each block, the score is derived as the simple average of sub-scores. The final Macro score is derived as the sum of blocks' scores.

Annex 2

Our simulation on the model rating by Fitch

(October 2020. Values under the 'Indicator Score' column are not highlighted in green/red colour since no risk scales are available in Fitch methodology at indicator level)

Pillars	Reference Year	Weight	Coefficient	Conversion	Indicator value (t)	Converted value (t)	Indicator Score (t)
Pillar 1: Structural features		**53.7%**					**9.54**
Governance indicators World Bank	Latest	20.4%	0.075	Percentile	68.41	68.41	5.15
GDP per capita (percentile rank)	Latest	12.3%	0.040	Percentile	77.12	77.12	3.05
Share in world GDP (%)	Latest	13.2%	0.607	Nat log	2.20	0.79	0.48
Years since last default/restructuring	Latest	6.4%	-2.481	Complex	0.00		0.00
Broad money (% of GDP)	Latest	1.4%	0.185	Nat log	107.07	4.67	0.86
Pillar 2: Macroeconomic performance, policies and prospects		**10.9%**					**-1.27**
Volatility in real GDP growth (2009-19)	Latest	4.9%	-0.767	Nat log	3.66	1.30	-0.99
Consumer price inflation (annual average %)[1]	3y centred	3.1%	-0.056	Average	2.00	2.00	-0.11
Real GDP growth (average in %)	3y centred	2.9%	0.093	Average	-1.70	-1.70	-0.16
Pillar 3: Public finances		**18%**					**-3.90**
Gross general Government debt/GDP (average in %)	3y centred	8.0%	-0.021	Average	151.65	151.65	-3.19
General Government interest/Revenues (average in %)	3y centred	4.7%	-0.046	Average	7.60	7.60	-0.35
General Government fiscal balance/GDP (average in %)	3y centred	3.0%	0.055	Average	-6.47	-6.47	-0.35
Foreign currency debt/gross Government debt (average in %)	3y centred	2.4%	-0.006	Average	0.12	0.12	0.00
Pillar 4: External finances		**17.5%**					**0.91**
Reserve currency flexibility (ln of euro share in global fx portfolio)	Latest	7.8%	0.551		3.01	3.01	1.66
Sovereign net foreign assets/GDP (average in %)	3y centred	6.7%	0.011	Average	-57.50	-57.50	-0.64
Commodity dependence (non-manufactured merchandise exports/CAR)[2]	Latest	0.8%	-0.003		14.43	14.43	-0.04
Official reserves /Current account payments (in months)[3]	Latest	1.3%	0.027		0,00[3]	n/a [RC>0]	0.00
External interest service/CAR[2] (average in %)	3y centred	0.7%	-0.012	Average	5.60	5.60	-0.07
(Current account balance + Net Fx direct inv.)/GDP (average in %)	3y centred	0.2%	0.002	Average	2.82	2.82	0.01
		100%					
Total Pillar score							5.30
Intercept							4.49
Total Model score							**9.79**
Model rating							**A-**
Actual score							6.79
Actual rating							BBB-
Notch difference (Actual rating, Model rating)							**-3**

per cent.
2) 'CAR' stands for Current Account Receipts.
3) This variable is set to zero for all sovereigns with a reserve currency flexibility score above zero.

Annex 3

Our simulation on the model rating by Moody's

(October 2020. Qualitative or not fully replicable indicators are highlighted in grey. Worst scores are highlighted in red; best scores in green. The darker, the more intense)

Factor / Indicator[1]	Indicator value	Equivalent category[2]	Equivalent score	Factor rating
Factor 1: Economic strength				**A**
Growth dynamics (weight: 35% = growth 25%, volatility 10%)				
Average real GDP growth (T-4 to T+5)	0.47	caa3	19	
Volatility in real GDP growth (T-9 to T)	1.4	aa1	2	
Scale of the economy (weight: 30%)				
Nominal GDP (US$, T)	2,011.5	aaa	0.75	
National income (weight: 35%)				
GDP per capita(PPP, US$, T)	44,160.8	aa1	2	
Adjustments to Factor score (0-9 scores)				
Other				
Factor 2: Institutions and governance strength				**A**
Quality of institutions (weight: 40%)				
Quality of legisl. and executive inst. (20%; WB index + 5 qualit. factors)		a	6	
Strength of civil society & judiciary (20%; WB index + 5 qualit. factors)		a	6	
Policy effectiveness (weight: 60%)				
Fiscal policy effectiveness (5 qualit. factors)				
Monetary and macroeconomic policy effectiveness (5 qualit. Factors)				
Adjustments to Factor score (0-6 scores)				
Government default history and track record of arrears (0-3 notch)				
Other (0-3 notch)				
Economic resiliency = Cross F1 and F2	**(A and A)**			**A**
Factor 3: Fiscal strength				**BB-**
Debt burden (weight: 50%)				
General Government debt/GDP (T)	134.8	caa2	18	
General Government debt/Revenues(T)	286.23	ba3	13	
Debt affordability (weight: 50%)				
General Government interest payments/Revenues (T)	7.23	a1	5	
General Government interest payments/GDP (T)	3.4	ba2	12	
Adjustments to Factor score (0-9 scores)				
Debt trend (Debt/GDP change, T-4 to T+1)	17.5	-1		
Gen. Govt foreign currency debt/Gen Govt debt (T) (+ qualit. factors)				
Other public sector debt/GDP (T) (+ qualit. factors)				
Public sector financial assets or sovereign wealth funds/General Govt debt (T) (+ qualit. factors)				
Other				
Government financial strength = Cross Economic resiliency and F3	**(A and BB-)**			**A-**
Factor 4: Susceptibility to event risk (Min function[3])				**BB**
Political risk		a		
Domestic political and geopolitical risk (WB index + 7 qualit. factors)				
Government liquidity risk		a		
Ease of access to funding (3 qualit. factors)				
Banking sector risk		ba		
a. Strength of the banking system (Average baseline rating, BCA)	Ba1			
b. Size of banking system (Total domestic bank assets/GDP, %)	208.23			
External vulnerability risk		aa		
Ext vulnerability risk (Curr. acc. bal. + Net ext. liab. + Access to fx mkt)				
Alpha-numeric range = Cross Govt financial strength and F4	**(A- and BB)**			**BBB+ : BBB-**
Model rating (central point)				**BBB**
Actual rating				BBB-
Notch difference (Actual rating, Model rating-central point)				**-1**

Notes:

1) In the table 'T' stands for last full year with available data. For grey-shadowed indicators (not fully replicable), we use the only quantitative indicators mentioned in the methodology.
2) Equivalent category ranges from AAA (the best) to C (the worst) on Moody's scale.
3) As per Moody's methodology, the score to Factor 4 is equal to the lowest among the scores assigned to the four sub-factors: Political risk, Government liquidity risk, Banking sector risk, and External vulnerability risk.

Annex 4

Our simulation on the model rating by S&P

(October 2020. Qualitative or not fully replicable indicators are highlighted in grey. Worst scores are highlighted in red; best scores in green. The darker, the more intense)

Key area / Indicator[1]		Indicator Value	Indicator Score (1 to 6)[2,3]	Key area Score
1. Institutional assessment[4]				**3**
Primary	**Effectiveness, stability and predictability of policymaking, political institutions, civil society**			
	Transparency and accountability of institutions, data and processes			
Adjustments	Debt payment culture			
	External security risks			
2. Economic assessment				**3**
Primary	**GDP per capita (US$, T used as current year estimate)**	**30,657**	**2**	
Adjustments	GDP growth vs. peers (real GDP 10y average above/below similar GDP per capita sovereigns)	0.40%	*1*	
	GDP growth fuelled by rapid increase in depository corporation claims on nongovernment sector			
	Economic concentration > 20% in one sector or volatility due to natural disasters or weather conditions			
	Material data inconsistencies, gaps or discontinuities			
(a) Institutional and economic profile *(1 and 2, average; 3 is assumed for the Institutional Assessment to be neutral)*				***3 = Moderat. strong***
3. External Assessment				**3**
Primary	**Currency status**	**Actively traded**	**4**	
	External indebtedness = Narrow Net External Debt/Current Account Receipts, CAR (T to T+2(F))[4]	**235.63%**		
Adjustments	(NIIP-Narrow Net External Debt)/CAR > 100% (T to T+2 or 3(F)) >100%	>100%	*-1*	
	Current Account surplus (or deficit)/CAR >0 (T-1 to T+2 or 3(F), average)	7.60%	*-1*	
	(Ext. short-term debt by remain. maturity / CAR) > 100%	192.90%	*1*	
	Volatility in terms of trade (St. Dev. past 10 years > 10%)		*0*	
	Risk of marked deterioration in the cost of or access to external financing			
	Low external debt due to exposure to debt constraints (e.g. arrears, restructuring, rescheduling)		*0*	
	Countries with material data inconsistencies			
4. Fiscal assessment *(A and B average, rounded down in line with S&P's)[5]*				**5**
(A) Fiscal Perf. and flexibility	**Change in General Government Debt / GDP (%, T to T+2 or 3F)**	**6.2%**	**5**	
Adjustments	Government liquid assets/GDP (%, T) (upgrade if >25%)	5.1%	*0*	
	Government ability (or limited ability) to increase revenues and/or cut expenses in the short end			
	Unsustainable or volatile revenues base (e.g. real estate taxes or royalties > 25% revenues)			

Key area / Indicator[1]		Indicator Value	Indicator Score (1 to 6)[2,3]	Key area Score
	Shortfall in basic services and infrastructures (UNDP human development index 'medium' or 'low')			
	Unaddressed medium-term pressure on age-related expenditures			
(B) Debt burden	**General Government Interest Payments/Revenues (%, T to T+2 or 3F)**	**7.60%**	**6**	
	Net General Government Debt / GDP (%, T)	**149%**		
Adjustments**	Government borrowing needs likely to be covered by official concessional funding during the next 2-3 years			
	*Share of Government debt denominated in foreign currency >40% or average maturity < 3y			
	*Non-residents share of Government debt > 60% of Government commercial debt			
	*Debt service profile is subject to significant variations			
	*Banking sector exposure to Government/Total assets > 20%			
	Contingent liabilities (from banks, non-banks, non-financial public enterpr., others)			
5. Monetary assessment *(Primary and Secondary average; +adjustments)*				**2**
Primary	**Exchange rate regime** (based on S&P's tables)	**Reserve**	**1**	
Secondary	**Credibility and effectiveness of monetary policy and inflationary trends** (based on S&P's tables)		**1**	
Adjustments	Transmission mechanisms are significantly weakening			
	Resident deposits in foreign currency > 50% total ('dollarization')			
	Restrictions on payments to non-residents on current transactions or discriminatory currency arrangements			
	Prolonged price and wage trends diverging from the monetary union (i.e. unsynchronized with the zone)			
	Membership in a monetary union		*+1*	
(b) Flexibility and performance profile *(3 to 5, average)*				***3.33 = Intermediate***
Institutional and economic profile (a)				**3**
Flexibility and performance profile (b)				**3.33**
Model rating				**BBB+**
Actual rating				BBB
Notch difference (Actual rating, Model rating)				**-1**

Notes:

1) In the table 'T' stands for year 2020; 'F' for Forecast; 'CAR' for Current Account Receipts; 'NIIP' for Net international investment position.
2) Indicator Score ranges from 1 (the strongest) to 6 (the weakest).
3) Adjustments are positive (-1); negative (+1); and no adjustments (0).
4) For these items, S&P's published values are used. For the institutional assessment, which is qualitative, S&P's value (3) does not change the average result of '(a) Institutional and economic profile'.
5) S&P's actually assigned score to Italy's 'Fiscal assessment' was 4 as of October 2020, hence a better assessment than the 5 stemming from our simulation.

* At least two negative adjustments are required to change the primary score by one category.

** These are negative adjustments, except for the first one (not applied for Italy since 'Debt Burden' is already at its weakest score ,6).

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The Bank of Italy's In-House Credit Assessment System for Non-financial Firms

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1 The Bank of Italy's ICAS

Since 2012, the Bank of Italy has extended the range of eligible collateral to improve banks' access to monetary policy operations, with the goal of supporting the provision of bank credit to firms and households. One of the tools deployed for this purpose is an internal model for assessing the creditworthiness of Italian non-financial companies (*In-House Credit Assessment System*, ICAS), to be used in the context of the Eurosystem's collateral framework.

Similar systems have been developed at other national central banks in the Eurosystem. These systems play an important role in the conduct of monetary policy in ordinary times. Their contribution becomes even more important following financial crises and economic shocks, such as the Covid-19 pandemic of 2020, as they preserve the transmission mechanism of monetary policy. Euro-area banks have taken advantage of the wide range of measures adopted since March 2020 by the Governing Council of the ECB in response to the crisis. The Bank of Italy's ICAS (henceforth BI-ICAS) has enabled Italian banks to fully exploit one of these new measures, namely, the easing of the collateral framework. By improving banks' collateral availability, this measure has countered one of the negative effects of the pandemic, namely, the drying up of other sources of bank funding. BI-ICAS is particularly important for smaller banks, which do not have an Internal Rating Based

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(IRB) Model for credit risk assessment and specialize in lending to small and medium-sized enterprises.

At the end of 2022, the net value of bank loans pledged by Italian counterparties amounted to 135 billion euros, 34 billion euros of which were assessed by BI-ICAS. This chapter provides a detailed description of BI-ICAS.

ICASs are one of three sources for the valuation of collateral in monetary policy operations of the Eurosystem, the other two being the rating agencies and banks' IRB models.[1]

ICAS systems are also currently in use at the central banks of Austria, France, Germany, Ireland, Portugal, Slovenia, and Spain. Since 2013, BI-ICAS has provided an important source of liquidity for Italian banks, whose loans to non-financial companies are a large portion of banks' assets but are difficult to use as collateral because they are typically non-marketable and unrated.

The model calculates the probability of default (PD) of non-financial firms over a 1-year horizon. In the first stage, the estimates are obtained by means of a statistical model, which draws on two data sources: balance sheet information and the detailed credit record from the National Credit Register (NCR). In the second stage, the output of the statistical model is combined with the expert assessment by two analysts that take into account a range of supplementary information, such as sector risk and the quality of corporate governance.

BI-ICAS generates full ratings (i.e. PDs based on both the statistical model and the expert assessment) for over 4000 firms on a yearly basis. In addition, the statistical model generates 'statistical PDs' for around 370,000 firms. The degree of utilization of ICAS is demand driven, i.e. it relies on the initiative of banks.

This chapter is organized as follows: Sect. 2 outlines the Eurosystem framework within which BI-ICAS operates. Section 3 describes the architecture of the system. Section 4 provides details on the statistical model and on the calibration approach. Section 5 describes the validation results for the models. Section 6 presents descriptive statistics on the amount of collateral pledged with BI-ICAS and on the Italian non-financial companies rated by the system. Section 7 concludes. Two Appendices describe the validation procedures adopted for the model.

2 The Eurosystem Credit Quality Standards

The eligibility requirements set by the Eurosystem for collateral are aimed at mitigating the financial, legal, and operational risks incurred when a national central bank provides liquidity to its bank counterparties. Minimum credit quality

[1] Until 2019, the Eurosystem Credit Assessment Framework included a fourth source of valuation, namely, 'rating tools', i.e. statistical tools for measuring credit risk. In 2019, the Eurosystem decided to phase out this source of valuation and the two rating tools currently authorized in Italy have lost their status in March 2021.

Table 1 The Eurosystem's harmonized rating scale for ECAI (Source: ECB)

ECAI credit assessment		Credit quality steps (CQS) 1	2	3	4	5
Short-term	DBRS Morningstar		R-1H, R-1M	R-1L, R-2H, R-2M, R2-L, R-3		
	FitchRatings		F1+	F1, F2, F3		
	Moody's		P-1	P-2, P-3		
	S&P's		A-1+, A-1	A-2, A-3		
Long-term	DBRS Morningstar	AAA/AAH/ AA/AAL	AH/A/ AL	BBBH/BBB/BBBL	BBH	BB
	FitchRatings	AAA/AA+/ AA/AA−	A+/A/ A−	BBB+/BBB/BBB-	BB+	BB
	Moody's	Aaa/Aa1/Aa2/ Aa3	A1/A2/ A3	Baa1/Baa2/Baa3	Ba1	Ba2
	S&P's	AAA/AA+/ AA/AA−	A+/A/ A−	BBB+/BBB/BBB−	BB+	BB

requirements are a key element of the eligibility criteria, for both marketable and non-marketable assets.[2]

The Eurosystem Credit Assessment Framework (ECAF) defines the minimum credit quality requirements as well as the procedures and rules meant to ensure that the Eurosystem only accepts assets with high credit standards as collateral.

The ECAF currently relies on three sources of credit assessment:[3]

- Credit rating agencies, formally defined as 'external credit assessment institutions' (ECAIs; 4 of them were authorized at the end of 2022);
- In-house credit assessment systems developed and run by NCBs (7 systems were operating at the end of 2022);
- Banks' IRB systems (around 40 systems were authorized at the end of 2022).

ECAIs are mainly used for assessing marketable collateral, whereas ICASs and IRB systems are mainly used for non-marketable collateral. To enhance its internal credit assessment capabilities, in recent years the Eurosystem has encouraged the development of ICASs and their number has increased significantly.

The ECAF makes the credit ratings from all eligible credit assessment systems comparable by mapping each of their rating grades into a credit quality step (CQS) within the Eurosystem's harmonized rating scale (Table 1).[4] For instance, CQS3 includes triple-Bs. This CQS is equivalent to a probability of default of between 0.1

[2] Eligible non-marketable assets mainly encompass credit claims, which include bank loans (including shares of syndicated loans), some leasing and factoring credit claims, and drawn credit lines.

[3] See above, footnote 2.

[4] ECB (2015).

and 0.4% over a 1-year horizon, and it currently stands as the minimum credit quality requirement for the eligibility of any asset in the general framework.[5]

Every year the Eurosystem carries out a performance monitoring procedure for each eligible credit assessment system, with a view to ensuring comparability of the information obtained from different sources. The ECAF monitoring procedure has two components: (1) a quantitative statistical component, to check whether the system has accurately predicted default rates and, as a result, whether the mapping of the ratings of each credit assessment system in the harmonized rating scale is still appropriate; (2) a qualitative component, which examines credit assessment processes and methodologies.

Within the ECAF credit assessment systems, ICASs play a special role: on the one hand, they reduce reliance on rating agencies, in line with a general recommendation by regulators, like the Financial Stability Board, after the great financial crisis. On the other hand, they allow banks that do not have IRB systems to fund their loans to the non-financial sector, thus supporting the transmission mechanism of monetary policy.

Besides the ordinary ECAF framework, a temporary Additional Credit Claims (ACC) framework has been in place since 2013 to improve the availability of collateral and overcome the liquidity shortages that followed the sovereign debt crisis of 2012. Within this framework, monetary policy counterparties are allowed to pledge a wider range of credit claims as collateral, with lower credit requirements, in particular when those claims are pledged in a pool. The ICAS ratings are widely used for the assessment of collateral within the ACC framework.

3 Bank of Italy's In-House Credit Assessment System's Architecture

3.1 Aims and Governance of the System

As an ECAF-recognized credit assessment source, BI-ICAS supports the conduct of monetary policy. The main aim of BI-ICAS is to allow counterparties in monetary policy operations, in particular those that do not manage an IRB system, to use a larger portion of their assets as collateral. The wealth of information on non-financial companies made available by BI-ICAS is also used by the Bank of Italy for the purpose of financial stability analysis and, occasionally, for banking supervision purposes.

The individual firm assessment produced by BI-ICAS is confidential information. To encourage banks to use the system, each counterparty receives the list of its eligible obligors.

[5] Specific requirements apply to asset-backed securities (ABS) and retail mortgage-backed debt instruments (RMBDs).

BI-ICAS is managed by the Financial Risk Management (FRM) Directorate, which is part of the Directorate General for Markets and Payment Systems. Within the Risk Management Directorate, the Credit Risk Assessment Division is in charge of the ICAS activity, which includes model development, rating production, and coordination and control tasks.

Since 2015, a number of Bank of Italy's local branches[6] have been actively involved in producing ratings, to exploit their knowledge of the regional economic context and increase the number of BI-ICAS assessments (see also Sect. 6). Based on a rotation mechanism, a list of firms to be assessed is periodically allocated to analysts, mostly in local branches; a selected number of firms is assessed by the FRM Directorate.

3.2 Definition of Default

To identify the default status of a firm, BI-ICAS merges the credit information from the whole banking system. For this purpose, Bank of Italy uses the information provided by banks via the NCR and, since 2018, via the database known as AnaCredit. Banks must report defaults according to Regulation (EU) No 575/2013 (CRR). The ICAS default definition relies on Article 178 of the CRR, which sets forth that a default occurs when a bank considers that the obligor is unlikely to pay (UTP) its credit obligations or the obligor is past due more than 90 days on any material exposure towards the bank. The default definition aggregates the whole default information for a given obligor into a single indicator.

For the purposes of its statistical model, Bank of Italy has adopted the binary default definition, whereby a borrower is considered in default if both of the following conditions are met:

- the total amount of exposure reported as bad debt, unlikely to pay and more than 90 days past due by each bank is greater than 5% of the total exposure of the borrower to the banking system and greater than 500 € (materiality rule);
- the previous condition is met for 3 consecutive months (persistency rule).

The binary definition of default is used also for the calibration and the internal validation of the model. For estimation purposes, the use of the binary default definition seems appropriate from a prudential point of view and for technical reasons, since the logit model involves the use of a binary independent variable.

As of January 2020, a new harmonized default definition (the 'fractional default definition') has been adopted for evaluating the ICAS performance within the yearly

[6]Until 2021, the local branches located in the following cities had participated: Turin, Genoa, Milan, Venice, Bolzano, Trieste, Bologna, Florence, Ancona, L'Aquila, Rome, Naples, Bari, Catanzaro, and Palermo. In 2022, the production of ratings was concentrated in seven branches (Turin, Milan, Venice, Bologna, Florence, Rome, and Naples).

ECAF monitoring process. The new default definition aggregates the whole default information into a single default indicator reflecting the materiality, computed by dividing the aggregate defaulted exposure towards banks by the total credit exposure. Over a given monitoring period, the fractional default variable is equal to the maximum level of the materiality recorded for a given company. This new definition is used for internal and external validation.

3.3 Input Data and Collection Process

Debtor static data—The system includes static (i.e. snapshot) data on non-financial firms, such as the name, identification number, tax number, legal form, location, sector of economic activity, etc.

Credit behaviour data—The National Credit Register is the national archive of bank loans, and AnaCredit is its pan-European equivalent. Banks and other financial intermediaries are required to send a wide set of information about the financial liabilities of individual entities (companies, public entities, and households) to the central register. In return, banks have access to information on the debt exposure of their borrowers vis-à-vis the whole banking system. The NCR is thus the main data source for credit behaviour information to be used in ICAS. In particular, the default status, according to the ECAF definition, is established for each firm on the basis of information from the NCR and the AnaCredit database; the latter has become available alongside the NCR since 2019, for credit information on the euro area.

Financial statement data—ICAS relies on the Bank of Italy's financial statements archive (Sistema informativo economico-finanziario, SIEF) which in turn relies on data collected from Cerved Group.

Such data are available in two databases (Centrale dei Bilanci, also known as CEBI, and Cerved). The CEBI database collects about 80,000 financial statements per year from Italian medium and large limited-liability companies. The data are collected partly through banks participating in the CEBI program and for the rest through the Official Business Register, managed by the Italian Chambers of Commerce. The Cerved database covers a very large portion of Italian small- and medium-sized companies and the data source is the National Official Business Register. Financial statements are reclassified according to the CEBI accounting scheme, which applies to both national GAAP and IFRS financial statements. ICAS uses SIEF-reclassified financial statement data as input, which allows comparability among the financial statements of different companies.

SIEF also has a group archive (*Gruppi*), which provides information on the structure and the composition of the main Italian industrial groups. It covers around 500 listed companies and groups with a consolidated income above 250 million euros. Groups under foreign control are included in the database whenever they have a significant Italian shareholder stake. The database is updated every month following a detailed analysis of annual and semi-annual reports, consolidated financial statements, balance sheet data of the subsidiaries, and other relevant information.

Cerved makes available data on industry forecasts through the SIRC platform, allowing to assess the perspective competitive positioning of individual firms within their industry sector.

Sustainability data—To account for the Environmental, Social and Governance (ESG) risk factors, the system relies on several external data sources. With reference to climate risk, Institutional Shareholder Services, Carbon4 finance, Cerved Group, and Moody's Analytics provide indicators on physical and transition risks.

Qualitative information—To assess the quality of management, analysts rely on data from the Official Business Register of the Italian Chambers of Commerce. It includes data on six million companies and individual firms, covering company information (standing data and legal events) and corporate governance information (top managers, officers, controllers, and auditors).

The ICAS analysts use additional information, including from: (1) the main financial news agencies, (2) Bank of Italy's publications; (3) rating agencies' research, for individual economic sectors and firms; and (4) the internal rating models of Italian banks.

4 The BI-ICAS Process for Calculating the PD

The models for predicting default probabilities can be grouped into three categories: traditional models based on expert assessment, capital market models, and credit scoring models. The latter category is the most heterogeneous one and it includes traditional models and machine learning models.[7]

Capital market models derive the issuer probability of default from the market prices of financial instruments such as shares, bonds, and credit default swaps. These models hinge on the pricing models for financial assets.[8] There are broadly two types of capital market models: the reduced-form models (Jarrow et al. 1997; Duffie and Singleton 1999) and the structural models (Merton 1974; Crosbie and Bohn 2002). Structural models, based on option pricing theory, estimate the default probability by modelling the value of the company's assets, and thus of its capital structure; reduced-form models treat the company default as an exogenous event, not depending on the capital structure, and guided by a statistical process whose parameters can be inferred from observable market prices.

Credit scoring models predict a default through some key economic and financial indicators for the firm.[9] These models, which are widely used in the banking

[7] The concept of rating is generally associated with an assessment including not only the result of a quantitative model but also the expert judgment of one or more analysts. The concept of score generally refers to the output of an automatic (quantitative) assessment.

[8] See Hillegeist et al. (2004).

[9] Scoring models can be defined as multivariate models that use the main economic-financial indices of a company as input, obtaining a numerical value, called a score, which represents the probability of default.

Fig. 1 BI-ICAS rating process

industry, can be divided into discriminant analysis models and regression models (linear, logit, and probit). More recently, machine learning models have been developed for credit scoring purposes. These rely on mathematical approaches such as neural networks, decisional tree techniques (including random forest and gradient boosting), and support vector machines.[10]

Discriminant analysis is based on the assumption that independent variables may provide an indication of firms belonging to predefined groups (i.e. defaulted and non-defaulted), while regression models provide reliable estimates of output variables based on a set of predictor (independent) variables that are usually easier to measure. Within the IRB model practice, the most common regression model is the logit, which estimates the conditional probability that a firm is insolvent by means of a logistic regression, employing economic and financial indicators as independent variables. In general, logistic regression is preferred over linear discriminant analysis, as the required working assumptions are more easily satisfied. The BI-ICAS rating process is based on a two-stage procedure, which combines a statistical module assessment with an expert assessment (Fig. 1).[11]

The first stage of assessment, based on a statistical module, consists of a system of logit models that exploit two sets of variables: indicators obtained from the NCR and indicators based on financial statements.

The first set of indicators describes the relationship of the firm with the banking system (credit behaviour). These indicators are derived from information relating to the ratio of drawn to granted credit and the number and average amount of overdrafts.

The second set of indicators is drawn from financial statements and includes variables such as profitability, financial structure, debt service capacity, asset quality, and operating risk.

[10] Moscatelli et al. (2019) show that the use of machine learning techniques can improve the performance of scoring models mainly when the latter only rely on publicly available information (such as non-financial companies' financial statements), whereas the value added of machine learning declines when the scoring models also rely on high quality, non-publicly available data, such as credit behaviour indicators based on the Credit Register.

[11] See Ohlson (1980).

Model parameters are estimated using the observed defaults in the NCR as a dependent variable. The model computes a 1-year default probability and a rating level according to the master scale mapping.[12]

The second stage of the assessment envisages the involvement of two financial analysts who use a wider range of information as well as up-to-date news. The analysts can either confirm the rating resulting from the first stage or modify it by notching the master score up or down.

The analysts rely on financial statement data (e.g. debt sustainability, cash generation, and financial structure) as well as on other types of information, such as the company's strategic position within the business sector, the quality of governance and management, and the geographical location. While all the ICASs developed within the Eurosystem are similar in their main features and they all comply with Eurosystem requirements, some differences can be observed in terms of information sources and methodology.

Banque de France, for example, also collects qualitative information through direct contacts with firms' managers during the assessment process and by means of a monthly monitoring of the economic situation.[13] Banco de España has developed distinct statistical models for non-financial companies and industrial groups, based on their stand-alone and consolidated financial statements.[14] Bundesbank and Oesterreichische Nationalbank have jointly developed a Common Credit Assessment System (CoCAS) based on the so-called consensus approach.[15]

4.1 *The Statistical Model*

The BI-ICAS statistical module predicts the probability of default over a 1-year horizon for Italian non-financial companies. The model estimates a point-in-time (PIT) PD.

The estimation process employs a cross-sectional approach. In particular, the estimation sample covers 6 years of defaults (from 2014 to 2019), the training sample covers 4 years (from 2015 to 2018), and the test sample covers 2 years (2014 and 2019).

The architecture of the BI-ICAS statistical model has two distinct components:

[12] In the context of rating systems, two approaches can be adopted, one letting the economic cycle to affect credit risk estimates and the other one insulating the latter from the cycle. The two approaches generate different rating types, commonly known as point-in-time (PIT) and through-the-cycle (TTC). PIT ratings aim at evaluating the current situation of an entity by taking into account both cyclical and permanent effects. In contrast, TTC ratings focus mainly on the permanent component of default risk and are essentially independent from cyclical changes in the entity's creditworthiness.

[13] Banque de France (2010, 2015).

[14] Banco d'España (2020).

[15] Deutsche Bundesbank (2015).

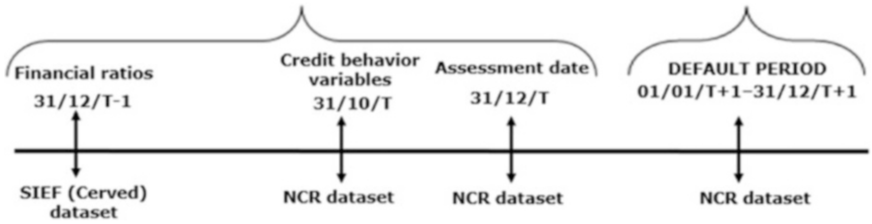

Fig. 2 Data timeline

1. a *credit behaviour component*, namely, a logit regression aimed at modelling data from the NCR;
2. a *financial component*, namely, a logit regression based on yearly financial statement data, such as financial structure and profitability indicators.

After their estimation, the two components are merged by means of a further logit regression. Some crucial financial variables might be overridden by credit variables, due to the higher significance of the latter in the short run. This could result in a weaker model performance. For this reason, developing a single model using financial and credit information jointly may be a sub-optimal choice.

Furthermore, the different data frequencies (monthly data for credit behaviour information and annual data for balance sheets) could generate additional biases in the PD estimation.[16] Financial ratios are typically available with a time lag of 1 year, while credit data are available with a 2-month lag. For example, if a company is assessed on 31st December of year T, the most recent financial statement available at that moment would be 31st December of the previous year (T-1), while the credit register information would be available for the reference date of October of year T (Fig. 2).

For the above reasons, the two components are estimated separately during model development.[17] Such a model structure is common among Italian IRB models.

The absence of correlation between credit behaviour and financial indicators is verified before the integration of the two scores.

The structure of the model is presented in Fig. 3.

The credit behaviour component consists of three different sub-models, based on firm size (micro, small, medium and large firms), according to the European Commission definition, based on total assets, turnover and number of employees. The three models capture the differences in the use of credit lines by firms of different size.

Similarly, the financial component is structured in sub-models to account for different classes of firms according to their sector and type of financial statement

[16] Giannozzi et al. (2013).

[17] EBA (2017).

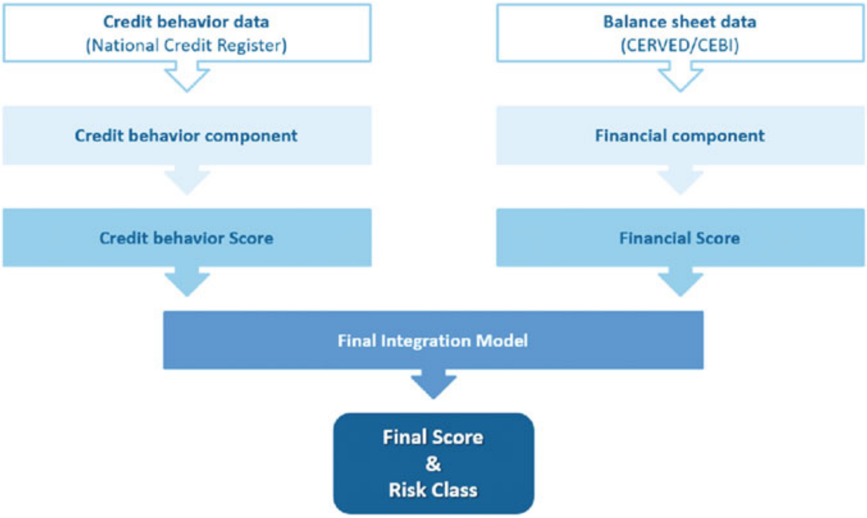

Fig. 3 Statistical model architecture

(ordinary financial statement or short annual financial statement).[18] Each sub-model exploits selected indicators that capture credit risk for firms belonging to broad sectors.[19] Overall, the financial component includes eleven sub-models.

The final step of the statistical model consists of the integration of the two components (Fig. 3). The partial scores resulting from each component are integrated through a logistic regression, providing the final score. To map the score into a rating class, the final score is converted into a PD via the inverse logit function:

$$\mathrm{PD} = \frac{1}{\left(1 + e^{-\mathrm{Score}}\right)}$$

This approach is used to aggregate different information sets in rating systems (Giannozzi et al. 2013). The integration approach relies on four different sub-models according to firm size (micro, small, medium, and large companies).

Finally, obligors are allocated to different risk classes according to their estimated PD. The risk classes have been set, in line with rating agencies' current practices, according to historical default rates and then mapped into the Eurosystem Credit Quality Steps.

[18] The short annual financial statement may only be drawn by joint stock companies that, for two consecutive financial years, have not exceeded two of the following limits (micro and small enterprises): (1) total assets ≥4.4 million euros, (2) total revenues ≥ 8.8 million euros, (3) average number of employees during the year ≥50 persons.

[19] Industrial, Trade, Construction, Services, Real estate, and Holdings.

4.2 The Expert Assessment

The expert assessment is performed by financial analysts and aims at reviewing the statistical assessment through a qualitative analysis, based on some credit risk drivers. The expert assessment is applied to a fraction of the non-financial firms for which a statistical assessment is available (around 4000 out of about 370,000 firms at the end of 2022). These firms are selected mainly for their relevance as debtors of the banks using ICAS as a credit assessment source.

The expert assessment starts from the PD generated by the statistical model and proceeds along several steps. The analyst assessment is based on a wider range of information sources as well as on recent data and news.

Analysts take specifically into account the firm profile resulting from balance sheets (e.g. profitability, cash generation, debt service coverage ratio, and financial equilibrium) as well as from credit behaviour data; they also consider other elements such as the strategic position in the company's sector of activity, the quality of governance and management, and the prospects of the reference market. The development of a methodology to integrate climate risk considerations into the analysts' assessment is ongoing. The expert assessment can either confirm the rating produced in the statistical stage or modify it by notching the score up or down. The analyst obtains a risk score for each profile. Such score indicates that according to the analyst, the data considered improve, confirm, or worsen the risk assessment produced by the statistical module.[20]

The assessment starts with a review of the firm's static data, in order to get an initial overview (size, sector of activity, age, financial group structure, geographical location, and so on). This information does not translate into a specific assessment but provides the necessary background for the subsequent assessment. The automatic rating is then assessed by looking at its components (the credit behaviour PD and the financial PD) as well as at the variables that have been used in the models, to get an initial indication of the position of the company compared with the general population or peer groups (by sector, geographical area, or risk class).[21]

In the next stage of assessment, analysts examine the last 4 years of available balance sheet data and compare them with the peers. Information on the firm is compared with the average and percentile value for the same sector or peer group. In this regard, the analysts consider trends and balance–sheet ratios along four different profiles: (1) profitability; (2) financial structure and debt sustainability;

[20]The score could assume three to four different levels for each profile (positive, neutral, negative, or very negative).

[21]For this purpose, the relative quintile for each indicator is calculated for the total population of companies assessed by the statistical module and for the subsample of all firms in the same sector, geographical area and size class.

(3) liquidity and cash generation; and (4) growth indicators.[22] At this stage, analysts are also required to read and assess the full financial statement of the company. To analyze financial flexibility, the analysts look at the firm's payment behaviour and access to external financing. The relevant data are taken from the NCR and consider the relationship between the firm and the banking system.[23] In the next stage, the analysts examine the management's quality and corporate governance, based on the principle that a transparent and fair governance structure has a positive impact on company performance and that firms with strong governance systems tend to outperform peers.[24] According to best practices, a more advanced corporate structure fosters internal control and consistency in the management strategy and execution. An analysis of the economic environment, the industrial sector and the geographic location where the company primarily operates is then performed to assess the contribution of these factors to the company's credit profile. Next, the analysts look into the group: if the company is part of a group, as either a parent or a controlled firm, the analyst examines the group's influence on the credit profile. If the group is deemed to be a risky one, this can lead to a notching down of the company. On the contrary, a positive contribution to the firm's credit profile is provided by explicit forms of financial guarantee from a stronger parent company or other firms in the group. As a general rule, the group's rating is considered as a ceiling for the individual firm rating.

In the last stage, the expert analysis takes into account third-party opinions and recent news from media, press, and internet, and it may include reports from other financial institutions or other external sources. In addition, the analysts collect every recent news item that may affect the firm's assessment. Even outside the regular assessment process, all the news that may have a significant impact on the overall assessment of the firm are taken into account, leading in some cases to a downward revision of the assessment or to its suspension.

To reach a high level of consistency and reliability, the expert assessment is based on a template that guides the analysts through a number of predefined steps associated with each profile, considering specific information and producing an evaluation

[22] The main balance sheet indicators are included in the statistical module and hence already reflected in the automatic rating. However, at this stage it is possible to consider a wider range of indicators and to look at balance sheet data in a more comprehensive manner.

[23] NCR information is already used in the statistical module. However, a more detailed inspection of the relationship between the firm and each single bank has been considered useful at this stage. This information is important because in the Italian system firms tend to turn to several banks for financing needs. The change in the number of banking relationships and in the use of granted credit lines is considered important information for spotting possible tensions in the financing lines and for assessing the availability of financing sources.

[24] The general quality and track record of the management are analyzed on the basis of information collected from the Italian Official Business Register database, which includes around six million companies and individual firms, covering both company information (standing data, legal events) and corporate governance and staff information (officers, controllers, auditors, and top managers). From the same database, it is possible to retrieve information on compliance with best practices in terms of corporate governance.

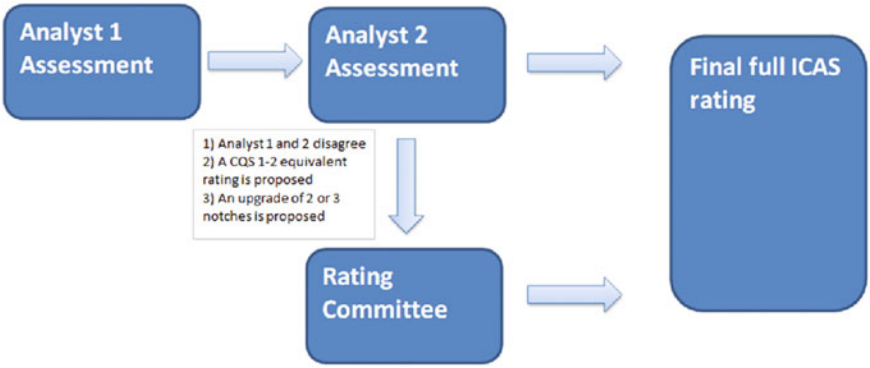

Fig. 4 Decision process

based on a set of predetermined rules. On top of such a template, analysts are allowed to consider whatever other information is deemed relevant and to evaluate it in qualitative terms. For each of the above-mentioned steps, an assessment is conducted. Partial scores resulting from each step are weighted and aggregated to produce a final grade. A decision matrix translating the final grade into the rating decision (upgrade, confirm, or downgrade the automatic rating) provides a non-binding guideline to analysts for taking the final decision. For each firm, an independent assessment by at least two analysts is required.

Analysts can lower the assessment as much as they want, while they can raise the final rating only by one notch. If they want to notch up the automatic assessment by more than one level, they have to submit a proposal to the ICAS Rating Committee.

The Rating Committee is composed of senior management representatives of the Financial Risk Management Directorate. The analysts involved in the assessment are required to attend the meetings.

The last step of the process is the production of a final report containing all the relevant details about the firm's assessment. In the final report, analysts are also required to describe the main motivations of the assessment. Each credit assessment decision has to be properly documented in all its different stages.

Once the analysts or the Rating Committee take the final rating decision, the latter is recorded in the ICAS database and normally remains valid for the next 12 months, unless new relevant information becomes available (see Fig. 4).

5 The Model Validation

5.1 The Role of the Validation

The best practices in the field of credit risk assessment recommend the separation of the validation activity from model development and from rating production. This separation guarantees the independence and impartiality of validators. In the Bank of Italy, the responsibility for validation has been assigned to a separate unit (Financial Risk Control Division) since 2014.

The validation activity usually includes both the internal validation and the monitoring process.

The purpose of internal validation is to check that the rating attribution process relies on methodologies and procedures that are aligned with best practices. Furthermore, internal validation verifies that the rating model is adequately robust and efficient. This latter activity is performed each time a new version of the model is adopted or whenever significant innovations are put in place and it consists in checking the whole structure of the model, both in the statistical component and in the expert system component.

The goal of performance monitoring is to assess the stability of the rating system over time and to verify the predictive ability of the model over the course of the year.

Since BI-ICAS is focused strictly on the PD calculation, the internal validation does not include the examination of the Loss Given Default (LGD) and of the Exposure At Default (EAD).

The validation and monitoring of the PDs can be assessed with, among other tools, benchmarking and backtesting.

Benchmarking techniques compare the PDs calculated by the model under consideration with the ones calculated by other models on the same portfolio of firms. These techniques consist of calculating a statistical distance between the models. The main drawback of this approach is the limited availability of ratings calculated by other models, since the ICAS typically assesses small and medium-sized enterprises (SMEs) that are not assessed by other systems. Furthermore, benchmarking requires strong confidence in the rating system used for the comparison, since it is taken for granted that its PDs are a good reference.

Backtesting procedures are based on a comparison between the ratings calculated ex-ante and the number of defaults observed ex-post. The scientific literature provides several statistical tests, which help the validator in understanding how accurate a model is in predicting the PDs correctly. Within the validation framework, two main aspects are typically taken into account: the discriminatory power and the predictive power. The first one measures the ability of the model to distinguish the rated entities according to their future status (defaulted or not defaulted) at a predefined time horizon. The second one compares the number of defaults that actually occurred in a certain rating class with the number of defaults that are predicted by the model. Discriminatory and predictive power analysis are described in more detail in Appendix 1.

5.2 Expert System Validation

After having calculated the statistical PD, the ICAS system produces the final rating, obtained by combining the results of the quantitative step with a qualitative analysis, performed by the Expert System, which relies on the work of a dedicated team of analysts.

The team has to consider eight different profiles in its assessment. Two profiles are just informative for the analyst and do not require a score. For the other six profiles, the analysts assign a score ('very bad', 'bad', 'neutral', and 'good'). The profiles are: (1) balance sheet ratios and peer group analysis, (2) financial flexibility, (3) quality of the management and corporate governance, (4) industrial sector, geographic location and economic environment, (5) group analysis, and (6) third party opinions and other recent information. The goals of the validation of the expert system are:

1. To understand how analysts use the different profiles of the expert system.
2. To assess how the final judgment is influenced by the different profiles of analysis.
3. To explore the influence of the second analyst on the assessment proposed by the first analyst.
4. To understand if the assessment of the analysts is able to anticipate the evolution of the risk class of the companies which can be observed 1 year later.
5. To understand the analysts' behaviour in assigning the final ratings and the scores to the profiles.
6. To backtest the ICAS ratings.

A detailed analysis of the six profiles assessed by the validation of the expert system is presented in Appendix 2.

5.3 Bank of Italy's Internal Backtesting Analysis: Results for 2021

As already mentioned in Sect. 4.1, the validation analysis which is carried out by a separate unit of Bank of Italy, the Financial Risk Control Division, includes a backtesting procedure based on a comparison between the probabilities of default estimated ex-ante by BI-ICAS and the actual default rates observed ex-post.

More in detail, the pool of obligors assessed by the system at a certain date is split among different risk classes based on their estimated PD level (the 'static pool'). For instance, one can rely on the risk classes (Credit Quality Steps or CQS) defined by the Eurosystem in its credit assessment framework. Then for each class, the firms that have defaulted in the 12 months following the date of creation of the static pool are counted. The default rate is obtained by calculating the ratio of defaulted firms to total firms and is compared with the expected default rate in each class. If the

Table 2 Backtesting for the ICAS Statistical Module (defaults in the 12-month period ending on 31 October 2021. Source: Bank of Italy's own calculations based on BI-ICAS data)

CQS	CQS firms numbers	Expected defaults (upper bound)	Observed defaults
1&2	17680	18	16
3	61278	245	148
4	69063	691	378
5	31768	477	292
6	46166	1385	790
7	23972	1199	796

expected and observed default rates are not significantly different from a statistical point of view, the outcome of the test is positive and the model has performed well. In the case of BI-ICAS, backtesting is carried out separately on the Statistical Module and then on the full BI-ICAS (Statistical module and Expert System) to check whether the Expert System is able to improve the Statistical Module's predictive power.

As an illustration, the following are the results of the exercise carried out in early 2022 as part of the monitoring process of the BI-ICAS predictive power with reference to their annual PDs, estimated on 31 October 2020 (for the Statistical Module) and on 1 January 2021 (for the full BI-ICAS). The expected defaults implied in these estimates were compared with the effective defaults observed during the subsequent year.

The results of the BI-ICAS backtesting for 2021 are positive.[25] First, the predictive power analysis for the statistical module (see Table 2) shows that actual (observed) defaults[26] are below the upper bound of those expected by the model for each CQS.[27]

Similarly, the results of the predictive power analysis for the full ICAS (considering the Statistical and the Expert modules together) are very good: Table 3 shows that also in this case the number of actual defaults is below the upper bound of the expected ones.

[25] There are in principle two ways of reading the results of backtesting (see also Appendix 1). One way is to adopt the risk aversion profile of a ''supervisor' and make sure there is no underestimation of the PDs in the various rating classes. Alternatively, one may adopt the approach of a 'production unit' with business objectives and check whether the whole ICAS system is too conservative or too loose. The BI-ICAS' internal validation combines both approaches.

[26] Default definition is based on the concept of fractional default, according to which an obligor's defaulted amount is set at the full exposure of the obligor towards the bank reporting the default. For this reason, total reported defaults are not integer values.

[27] In this study, reference is made only to the upper bound of each CQS, but in principle each CQS consists of both an upper and a lower bound of expected default rates against which the actual defaults should be compared: for instance, for CQS3, the range of default rates is 0.1 to 0.4% and, as a consequence, in Table 2 the lower bound is 61 defaults and the upper bound is 245.

Table 3 Backtesting for the Expert System of the ICAS (defaults in the 12-month period ending on 1 January 2022. Source: Bank of Italy's own calculations based on BI-ICAS data)

CQS	Number of firms per CQS	Expected defaults (upper bound)	Observed defaults
1and 2	88	0	0
3	654	3	0.1
4	840	8	0.4
5	507	8	0.4
6	423	13	0.5
7	213	11	2.5

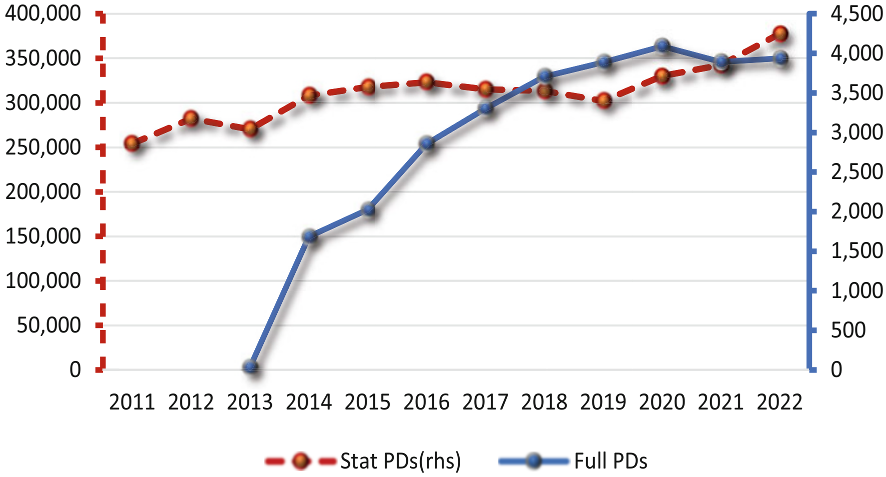

Fig. 5 Number of BI-ICAS full and statistical probabilities of default (Source: BI-ICAS database)

6 Usage, Coverage and Rating Distribution of BI-ICAS System

The BI-ICAS production has increased over time, reaching over 370,000 automatic ratings (i.e. purely statistical PDs) at the end of 2022. Full ratings (i.e. ratings including an expert assessment) increased from 1700 in 2014 to almost 4000 in 2022 (Fig. 5).[28]

As already mentioned, ICAS ratings enable banks that do not have an IRB system for credit risk assessment to access monetary policy refinancing. In addition, statistical model ratings provide a virtually complete coverage of the Italian non-financial limited liability corporations, and such ratings are also being used for financial stability analysis and economic research. While the number of BI-ICAS ratings has increased almost linearly over time until 2022, when considering the net value

[28] For automatic ratings, the data for 2022 refer to end of November, rather than to end of the year.

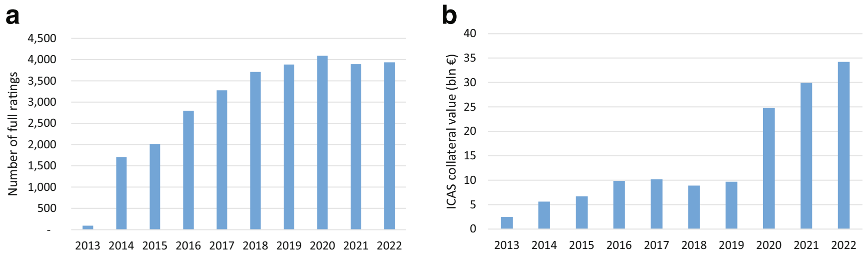

Fig. 6 (**a**, **b**) Number of full ratings (left-hand side) and face value (right-hand side, billions of euro) of collateral pledged thanks to BI-ICAS assessment, 2013 to 2022 (Source: BI-ICAS database)

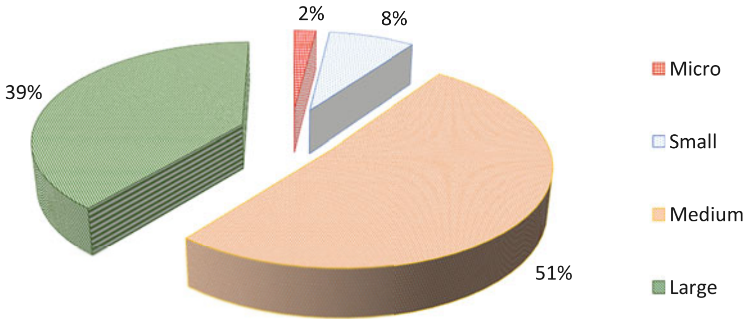

Fig. 7 Distribution of rated companies by firm size in 2022 (Source: BI-ICAS database)

of collateral pledged by banks relying on BI-ICAS a sharp increase took place in 2020 and in subsequent years (Fig. 6a, b),[29] mainly reflecting the temporary measures adopted since March 2020 by the ECB to relax the eligibility requirements for credit claims in response to the pandemic crisis.

6.1 Main Features of the Companies Assessed by BI-ICAS with a Full Rating

Around one-half of the universe of debtor firms assessed by BI-ICAS with a full rating are medium-sized companies, while a slightly smaller share (39%) is represented by large companies.[30] The remaining portion is composed of small- (8%) and micro-size (2%) firms (Fig. 7).

[29] Data shown in Fig. 6b are assigned by ICAS PDs' to all the non-financial corporate legal entities, excluding households.

[30] We stick to the definition of firm size of the European Commission, based on staff headcount and either turnover or balance sheet total (see footnote 19).

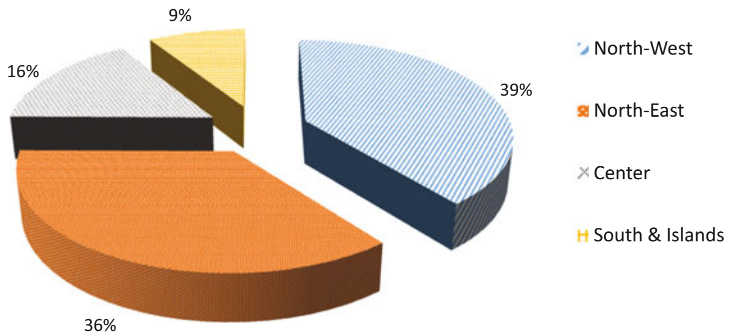

Fig. 8 Distribution of ratings by firms' geographic area in 2022 (Source: BI-ICAS database)

The distribution of firm size has remained almost stable over time; in the last few years, the share of large firms has slightly increased at the expense of small and micro firms.

As regards geographical distribution, less than one-half (39%) of rated companies are located in the North-West of Italy, while a slightly lower share of rated companies (36%) is based in the North-East. The remaining firms are located in Central Italy (16%) and in the South and Islands (9%) (Fig. 8).

As in the case of firm size, the geographical distribution of rated companies has been broadly stable over time, with a slight increase of firm ratings in the North-East compared with those in the North-West over the last year.

From an industry perspective, almost half of the rated companies are in the manufacturing sector (46%), followed by the wholesale and retail sector (23%) (Fig. 9).

Over the last 10 years, a decline in the share of manufacturing firms has been matched by an increase in the share of wholesale firms.

6.2 The Evolution of Credit Risk Across Firms Assessed with BI-ICAS

Since the number of non-financial firms assessed with a statistical PD is a very high share of the total non-financial sector firms, BI-ICAS allows to track over time the financial conditions of Italian non-financial companies at an aggregate level.

Based on ICAS data, Italian firms' financial conditions broadly improved from 2013 onwards: the negative effect of the fragile cyclical conditions on firms' ability to repay their bank debt in the early years was subsequently offset by the rebalancing of the capital structure and by the low interest rates observed until 2021.

Based on the ICAS of the Bank of Italy, the median 1-year-ahead default probability fell from 2.5% in 2013 to less than 1.0% in 2022 (see Fig. 10). The

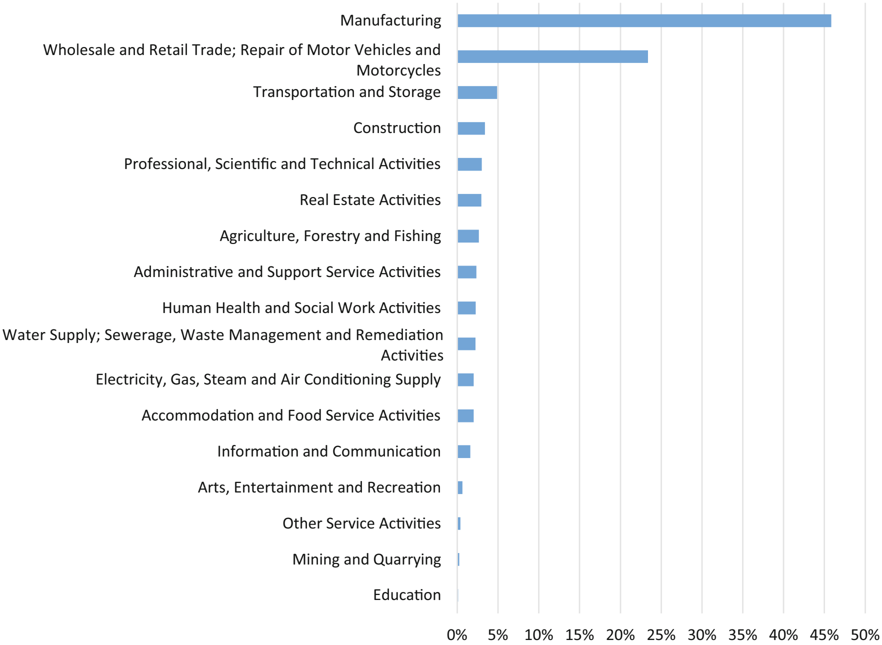

Fig. 9 Rating distribution by sector of economic activity in 2022 (Source: BI-ICAS database)

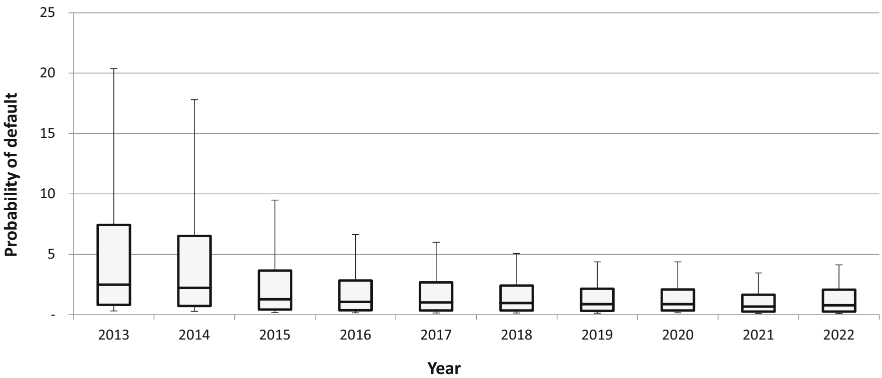

Fig. 10 Distribution of the probability of default (percent) of Italian non-financial firms assessed with a statistical PD. The graph shows the 90th (top whisker), 75th (top edge of the box), 50th (middle edge), 25th (bottom edge), and 10th (bottom whisker) percentiles of the distribution for each year (Source: BI-ICAS database)

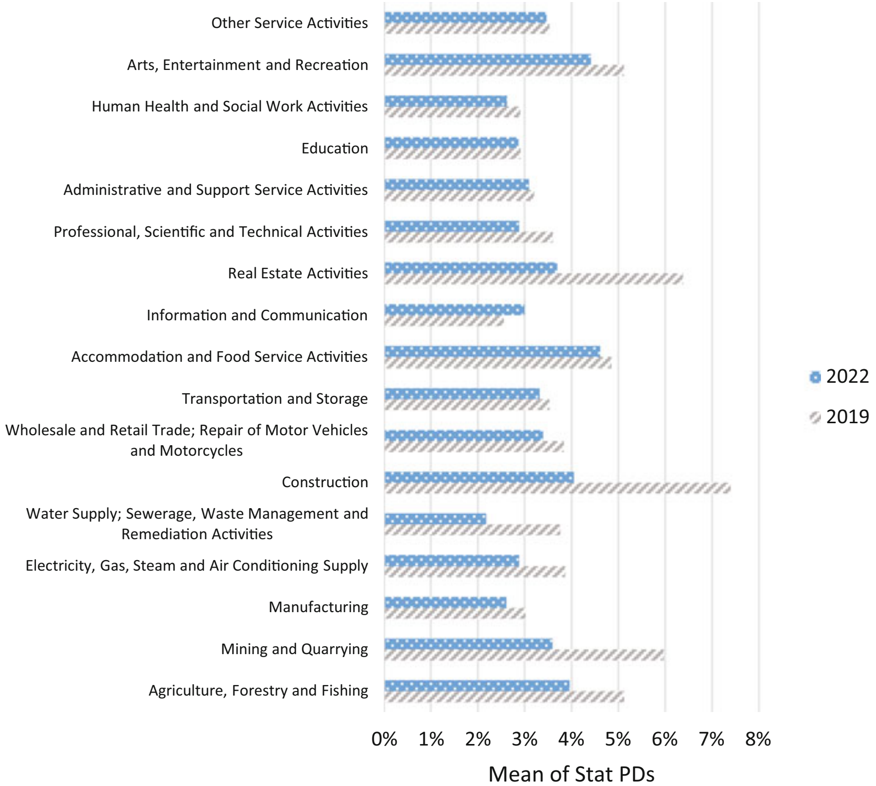

Fig. 11 Evolution of the probability of default by sector of economic activity (Source: BI-ICAS database)

decrease in the values corresponding to the 75th and 90th percentiles (respectively, the upper end and the top of the vertical lines of each box in Fig. 10) of the sample distribution indicates that the improvement affected also weaker firms.[31]

According to BI-ICAS data, between 2019 and 2022 non-financial firms' probability of default decreased in all the main economic sectors, except in the information and communication sector, which recorded an increase (Fig. 11).

[31] The PD data for the 2022 refer to end of November; for the rest of the sample the reference date is the end of December.

6.3 The Contribution of BI-ICAS to Monetary Policy Refinancing in the Covid-19 Crisis

In ordinary economic conditions, the BI-ICAS ratings enable banks that do not have an IRB system to increase their access to Eurosystem refinancing. This is particularly true for smaller banks, specialized in lending to small and medium-sized enterprises. The number of bank counterparties using BI-ICAS ratings for pledging their bank loans has increased over time: from fewer than 20 banks at inception in 2013, to more than 50 in 2022. The net value of bank loans pledged as collateral with a BI-ICAS assessment increased as well over the same period, rising from 2.5 to around 34 billion euros (see above, Fig. 6b). In terms of the sheer size of the banks that make use of BI-ICAS, at the end of 2022, the total value of refinancing granted to these banks (including the liquidity received against marketable assets, relying on other credit risk assessment sources such as rating agencies) amounted to more than 170 billion euros.

The role of BI-ICAS has become even more important since the financial crisis triggered by the Covid-19 pandemic, by helping to preserve the transmission mechanism of monetary policy. The significant increase in 2020 of the net value of bank loans pledged as collateral with a BI-ICAS rating reflects in part the temporary reduction of haircuts decided by the ECB and in part Bank of Italy's targeted measures aimed at enlarging collateral availability (Bank of Italy 2020). Despite this increase, the potential amount of eligible loans that may potentially be assessed by BI-ICAS is still much larger than the amount that is currently pledged. The targeted measures include an easing of the eligibility criteria for pledging pools of bank loans to non-financial firms and households: among other things, maximum PD thresholds have been raised and smaller non-financial firms have been added to the eligible universe. In addition, while the credit risk of pools of bank loans has always been assessed with BI-ICAS, the new measures included a widening and a more flexible use of this system.

7 Conclusions

Over the last decade, the Bank of Italy has made major efforts to broaden the range of eligible collateral and improve banks' access to monetary policy refinancing, with a view to supporting bank lending to firms and households.

An important tool for this purpose is the Bank of Italy's In-House Credit Assessment System, which has allowed Italian banks, in particular smaller ones, which do not have an internal model for assessing credit risk (IRB), to increase the available collateral by pledging loans granted to small and medium-sized enterprises.

This tool has proven particularly valuable since the Italian economy was hit by the severe economic shock caused by the Covid-19 pandemic. In this context, BI-ICAS has allowed Italian banks to take full advantage of the measures adopted in the spring 2020 by the Eurosystem and, by increasing the availability and value of collateral, has supported the provision of bank credit to firms, in particular small and medium-sized ones.

Appendix 1

Statistical Module Validation

The validation procedure consists in the analysis of two main aspects of a rating system: the discriminating power and the predictive power.

Discriminating Power Analysis

The main purpose of a rating system is to distinguish between 'healthy' and 'sick' units (firms), depending on whether or not the occurrence of the default event is considered probable for each of them.

In most cases, the model is expected to draw a line between the two types of units; the most common procedure is to define a cut-off probability and to consider 'healthy' those units that have an estimated default probability lower than the cut-off one and 'sick' the firms with a higher one.

The model therefore must have discriminating power, namely, precision in assigning to the 'healthy' companies a default probability lower than the cut-off one and to the 'sick' companies a higher value.

The discriminating power consists of two characteristics:

- specificity, i.e. the ability to correctly classify the units for which the event does not take place;
- sensitivity, which is the ability to correctly classify units for which, instead, the event occurs.

As the cut-off increases, the model will be more effective in correctly classifying healthy companies, and less will be its ability to identify sick ones. Thus, there is a trade-off between specificity and sensitivity.

A common way of representing the discriminating capacity of a model is the Receiver Operating Characteristic (ROC) curve, which displays the above trade-off. One way to verify the discriminating power of the model is to calculate the Area Under ROC Curve (AUROC). To better illustrate this tool, we can refer to a default definition in which the default status and the non-default status are indicated, respectively, by the number '1' and '0'.

By construction, the AUROC assumes values ranging from 0 ('the model is completely wrong') to 1 ('the model discriminates perfectly'), whereas 0.5 indicates a purely random model. Practically, a rating system with an AUROC ≥ 0.7 is considered as adequate.

It is important to underline that the evidence about the units gone into default and those that survived in the time period under consideration is only one of the possible realizations from the probability distributions of the defaulters and the non-defaulters. In other words, the ‘default’ phenomenon has fundamentally a stochastic nature, meaning that, in theory, if the same experiment is repeated, different realizations of these distributions would be obtained, with every realization being characterized by a different value of the AUROC (i.e. the AUROC is distributed according to a particular functional form with specific parameters).

The stochastic nature of the ‘default’ phenomenon can be investigated with the ‘U of Mann-Whitney’ statistics, linked to the AUROC through an equality relation; the statistical properties of the Mann–Whitney U are then applicable to the study of the stochastic behaviour of the AUROC.

Against this background, the Mann–Whitney statistics can help in quantifying the distance between the value achieved by the AUROC and its expected value, by calculating appropriate confidence intervals; furthermore, this instrument allows to carry out hypothesis tests, for example to verify whether the discriminating power of the rating system under validation is significantly different from the value of perfect randomness.

Predictive Power Analysis

Another important characteristic that is investigated in a rating system is its predictive capacity (namely, the ability to display a good quality of calibration).

In a broad sense, the calibration quality refers to the ability to identify the real probability of default for an individual debtor or for a class of homogeneous borrowers.

However, the real PD is unknown and therefore it is not possible to estimate it precisely. Therefore, to test the quality of the PD calibration the observed (ex-post) default frequencies are compared with the estimated (ex-ante) probabilities of default.

In order to carry out the aforementioned comparison, it is necessary to use a test whose null hypothesis basically states that the ex-ante estimates of the different PDs are correct. Typically, a rating system includes various classes of risk and the validator needs to evaluate PD forecasts for all risk classes.

One possible approach for testing multiple risk classes at the same time is that of multiple comparisons. As an alternative, a single statistical test is used to compare risk classes simultaneously (joint testing).

When multiple testing is applied, at the first stage of the analysis each risk class is assessed individually. Under the usual assumption of independence among the defaults, the number of defaults by risk class follows a binomial distribution. The second stage of the analysis looks at the intersection of the results of the individual tests, so as to check if the rating system adopts appropriate PDs estimates for all the classes.

For the validation of the ICAS model, we implemented multiple testing in order to: (1) verify the absence of an underestimation of the PDs for the various rating classes, estimated by the whole ICAS *system*; (2) understand if the PDs estimated via the ICAS system are in line with the actual defaults; and (3) ascertain if the PDs estimated via the ICAS statistical *model* were equal to the empirical frequencies of default. In other words: multiple tests were carried out, respectively: (1) on the whole ICAS, by adopting a risk aversion profile for default risk typical of a 'supervisor'; (2) on the whole ICAS, by adopting the risk profile of a 'production unit' with business objectives; and (3) only on the 'statistical model' part of the ICAS, to verify if there are problems underlying the purely quantitative part of the Bank of Italy's rating system.

Accepting as the null hypothesis the assertion '*the expected defaults are higher than those achieved, for each rating class*' (i.e. adopting the 'supervisor' view), a one-tailed binomial test is conducted for each rating class. In this case, the distribution of each test adopts as its average the PD value of the upper end of the probabilities range that identifies each rating class. Each test is evaluated at two different levels of confidence (95% and 99%).

When the number of actual defaults is significantly lower than that of the expected defaults for all rating classes, the ICAS *system* is considered 'prudential', i.e. it never leads to underestimating the risk of default.

Alternatively, accepting as null hypothesis the statement 'the expected defaults are equal to those achieved*, for each rating class'* (i.e. adopting a 'production unit' view)—the statement is equivalent to say 'the ICAS *system* is precise'—a two-tailed binomial test is conducted for each rating class. Also in this case, the distribution of each test has the average value equal to the upper end of the probabilities range that identifies each rating class. Each test is evaluated at two different levels of confidence (95% and 99%).

When the number of actual defaults is significantly higher or lower than that of the expected defaults for some rating classes, the hypothesis 'the ICAS system is precise' is rejected, i.e. the estimate of the risk of default is not always aligned with the observed reality.

Lastly, accepting as null hypothesis the statement '*the expected defaults coming from the statistical model at the basis of the ICAS rating system are equal to those achieved, for each rating class'* (i.e. investigating whether the statistical model has any problems)—the statement is equivalent to saying 'the ICAS *model* is precise'—a two-tailed binomial test is conducted for each rating class. In this case, the distribution of each test has the average value equal to the average of the probabilities of default assigned by the ICAS to the borrowers that are part of each rating class. Each test is evaluated at two different levels of confidence (95% and 99%).

When the number of actual defaults is significantly higher or lower than that of the expected defaults for some rating classes, the hypothesis '*the ICAS model is precise'* is rejected, i.e. the estimate of the risk of default by the statistical model is not always aligned with reality (and the adjustment of the model-estimated PDs to the upper PDs in every rating class can help to improve the precision in the PD forecasting via the BI-ICAS system). However, whenever a multiple-testing analysis is conducted, the possible impact on the final results of the 'alpha-inflation problem' must be considered. As mentioned above, in this analysis a rating system is considered good if and only if each single rating class is well calibrated; even if only one class shows some problems, then the analyst rejects the hypothesis that the whole system is adequate. It is known, however, that as the number of hypotheses to be tested simultaneously increases, the error of the type 1 relative to the global hypothesis does not remain constant (i.e. it rises, leading to an 'inflation of the alpha').

In order to keep this error under control, one may adopt different approaches: in the literature the most widespread strategy consists in adjusting the p-values obtained on the single-class tests, by increasing them. Many of these methods were applied also with reference to the BI-ICAS validation, either in the case of adopting the 'supervisor' risk profile or in the 'production unit' illustrated above.

By resorting alternatively to joint testing, one may verify whether the deviations between the realized defaults and those expected for the individual classes are in line with the assumed dependency structure between the rating classes. This outcome, however, is obtained at the cost of not being able to ascertain if, in the presence of a good calibration in some classes, there is nonetheless a wrong calibration in others.

Within the family of joint tests, the most commonly used procedures are those proposed by Spiegelhalter and Hosmer and Lemeshow.

The Spiegelhalter test, based on the Brier Score, proposes to overcome the multiple testing gaps by combining the information on the calibration quality available at the individual level. Under the null hypothesis of perfect calibration, for which the expected value of the default distribution is equal to the PD estimate for each unit, the test statistic is distributed according to a standardized normal. The test is based on the debated assumption of independence among the defaults.

It should however be noted that the results of the Spiegelhalter test should be read carefully. In particular, the Spiegelhalter test statistic is based on a weighted average PD that is estimated on the entire portfolio of examined debtors. Given that, only an average overestimation/underestimation of the probabilities of default causes the rejection of the null hypothesis of perfect calibration at the individual level. The test therefore fails to correctly identify as unacceptable those situations in which an overestimation of PDs for some units is compensated by the underestimation of PDs for other units of the sample.

To overcome this issue, the Hosmer–Lemeshow test is used, which compares expected defaults and realized defaults within each pre-defined rating class. Also the Hosmer–Lemeshow test, like the Spiegelhalter one, uses a normal approximation of the binomial distributions that lead to a chi-square distribution of the statistic; this approximation could be questionable because there might be an issue of bad approximation for rating grades with a small number of borrowers.

Appendix 2

Validation Analysis of the Expert Module

The validation procedure of the ICAS system also examines the Expert System part of the Bank of Italy's rating system, investigating its characteristics within different areas of analysis; below we provide a summary of the main ones.

Effects of the Expert System on the Risk Classes Attributed by the Statistical System

In order to understand how much the sample assessed by the full PD differs from the statistical PD, it is useful to build a transition matrix. In a transition matrix, where rows represent the risk classes attributed by the statistical system and columns are the risk classes attributed by the 'expert system', the main diagonal contains all the assessments in which the risk class assigned by the statistical system is confirmed, while downgrades are in the top right triangle and upgrades on the bottom left. The matrix is useful in order to synthetize at a glance how much the full PD diverges from the statistical PD. The bigger the dispersion in comparison to the main diagonal, the bigger the role of the analysts in the assignment of the full PD.

Influence of the Six Analysis Profiles on the Final Judgment for All Analysts

The aim of this analysis is to evaluate, with reference to all the analysts, if all the analysis profiles are taken into account by the analysts or some of them are systematically disregarded and, in addition, which profile has the strongest influence on the final assessment. In the current framework, all the profiles contribute with the same weight to the 'full PD', with the exception of the 'balance sheet ratio' and the 'financial flexibility' which have a double weight. In order to measure which profile is more important for the final judgement of the analysts, a multinomial logistic regression has been applied, where the dependent variable is the direction of the change in the rating set by the analyst (upgrade, downgrade, and confirmation), while the independent variables are the scores assigned by the analyst on the six profiles.

Role of the Second Analyst

Once the analyst has made his decision, the latter is verified by a senior analyst to guarantee the respect of the so-called 'four-eyes principle'. The first analyst makes a proposal about the rating that can be either a confirmation of the rating stemming from the statistical model or a proposal to change it. The second analyst checks that the rating assessment has been correctly performed and completed; afterwards, he examines the proposal.

In order to obtain a quantitative and synthetic measure of the agreement between the two analysts, Cohen's Kappa coefficient can be used, a statistical indicator that measures 'inter-rater' agreement for qualitative objects. If the analysts always agree, then $\kappa = 1$. If there is no agreement among the analysts, except what would be expected by chance, $\kappa \leq 0$.

The 'weighted Cohen's Kappa' is an evolution of the 'simple Cohen's Kappa', since it counts differently the level of disagreement emerging from the study. A disagreement that assigns a confirmation instead of an upgrade is weighted less than a disagreement that subverts the decision and turns a proposal of upgrade in a downgrade. In a decision matrix between analyst 1 and analyst 2, off-diagonal cells contain weights indicating the seriousness of that disagreement, double-weighting the disagreement when there is an inversion in the direction of the first assessment (from an upgrade to a downgrade and vice versa).

Relationship Between the Expert System and the Statistical Risk Class 12 Months Later

This analysis aims to assess the ability of the Expert System to foresee the statistical risk class that the firm will have after 1 year. The idea is that the Expert System improves the accuracy of the evaluation of a firm by exploiting information sources that, although available at the moment of the statistical assessment, are hardly usable in a quantitative model. This information is expected to have an impact on the statistical risk class after 1 year. If the estimated full PD, in which all the available information is taken into account, is a good proxy of the direction of the statistical risk class after 12 months, then there should be a relationship between the class attributed by the analyst today and the statistical risk class 12 months later.

After having selected the upgrades, the confirmations and the downgrades of the analysts, one needs to compute if there is a positive relation between the analyst's judgement and the change in the statistical PD after 12 months. One then calculates in how many cases the direction of the expert analysis is the same of the statistical PD after 12 months, and, on the contrary, in how many cases a 'total discordance event' is recorded, in which the analyst assigns an upgrade, followed 12 months later by a statistical downgrade and vice versa. The relationship is synthetized by Cohen's Kappa; also in this case the computation of the 'weighted Kappa', which penalizes the cases of total discordance, is useful.

Differences in the Behaviour of the Analysts in Judging the Profiles and in Assigning the Final Ratings

It may be of interest to understand if there are ‘biases’ among experts in examining firms, for example, if there are groups of analysts who favor one or more profiles in the production of the final rating relatively to the others and if there are profiles that are not significant for some analysts in the attribution of the final rating, but that are important for others.

In order to answer these questions, the reference dataset is divided by selecting records relating to each analyst; subsequently, a multinomial logistic regression is used to investigate how much each analyst weighs the profiles. This approach provides a regression ‘beta’ matrix available for each profile and for each analyst.

First of all, the significance of the various profiles among the analysts is investigated, by subjecting the hypothesis of equality to 0 of the betas to a statistical test; a generally desirable characteristic is for analysts to consider all profiles as significant. The betas obtained in this way are aggregated using a cluster analysis, based on the ‘Ward method’, to identify groups of analysts who adopt the same type of investigation.

In order to ensure a high significance to the results, the analysis is limited to those analysts that performed at least 100 evaluations.

It can be interesting to analyze the cases in which there is a high convergence among the behaviour of some analysts, by checking for instance if two analysts that display a similar behaviour work in the Bank of Italy’s central administration or in the regional branches, or if they live in the same geographical area or have something else in common that can explain the similarity in their behaviour.

Cluster analyses can also be made to understand if there are groups of analysts who evaluate in a conservative way some specific profiles when other analysts systematically provide high scores for the same inputs.

As a general rule, it is desirable to observe differences among the analysts in scoring the profiles and even that some analysts, on average, are stricter than others in expressing their own judgments on the profiles.

Analysis of Defaults

This analysis is restricted to cases in which a default occurred, for which it is possible to investigate how the analysts performed in anticipating the worsening of the credit condition of the assessed firms. Limiting the analysis to cases of defaults, the number of occurrences in which the expert system correctly decided for a downgrade, for a confirmation, and for an erroneous upgrade is counted. A statistical test of causality is performed.

A deeper investigation, focused on the six different profiles of analysis, shows which profile contributed to correctly signal a future default and if there are misleading profiles that assigned a positive score in a case that ended up with a default.

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The Role of Rating Agencies: Implications for the Financial System and Central Banks' Efforts to Reduce their Reliance

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1 Credit Ratings, the Financial System and Monetary Policy: An Overview

The financial crisis of 2008 and the sovereign debt crisis of 2010–11 have led regulators to seek ways to reduce reliance on rating agencies. In 2010, the Financial Stability Board (FSB) made a clear recommendation in this respect (FSB 2010). Since then, and with reference to monetary policy in the euro area, the Eurosystem has made some progress in the path towards reducing this reliance, thus finding itself better equipped to face the Covid-19 pandemic of 2020, the energy crisis of 2022 and the related possibility of rating downgrades.

The main reason behind the FSB's recommendation was the awareness that rating actions, and in particular sovereign downgrades, heavily affect the financial system—especially banks—and the real economy, also due to the existence of a 'sovereign ceiling' for domestic issuers, i.e. a practice whereby rating agencies seldom rate private sector issuers above their sovereign (see also chapter "Sovereign Ratings"). The impact may be quite significant if the sovereign rating falls below the investment grade threshold.[1]

In such a scenario, sovereigns face the risk of a bond sell-off and an increase in the cost of funding. For banks, a drop in the market value of their portfolio of government bonds typically leads to a reduction of available collateral and a mark-to-market loss on their bond portfolio, ultimately resulting in a higher cost and a lower availability of wholesale funding, with unavoidable repercussions on bank lending. Also, insurance companies are exposed to sovereign and corporate downgrades via their impact on market prices, entailing capital losses; corporate downgrades imply higher capital requirements as well.

Asset managers are affected by sovereign downgrades via the impact on market prices; in the case of institutional investors, a downgrade below investment grade may create significant selling pressure. Sovereign and corporate downgrades can lead central counterparties and clearing members to adopt measures to mitigate their exposure towards counterparties and collateral issuers, with possible 'cliff effects' in the call and collection of margins.[2]

Non-financial firms' ratings too typically co-move with sovereign ratings, again as the result of the sovereign ceiling effect, and so do credit risk premia, although the link is weaker than in the case of banks. As a consequence, sovereign downgrades often imply a higher cost and a lower access to bank and bond funding for firms, with negative effects on their investment decisions.

Why does the Eurosystem need credit ratings for monetary policy implementation? In line with its statute, the Eurosystem provides credit to its eligible banking counterparties only against adequate collateral. For this purpose, the 'Eurosystem Credit Assessment Framework' (ECAF) defines the procedures and rules for the

[1] The investment grade label is assigned to issuers with a rating at least equal to BBB−. The sub-investment grade label refers to issuers with a rating below BBB−.

[2] This outcome is more likely for bilateral transactions than for centrally cleared transactions.

fulfilment of the Eurosystem requirement of high credit standards for all eligible assets. To assess the credit quality of assets for the application of haircuts in refinancing operations and for eligibility in the context of purchase programmes, the Eurosystem takes into account information (ratings or probabilities of default) from several credit assessment sources, including credit rating agencies.

Rating agencies are just one of three ECAF sources of valuation of collateral,[3] but they play a special role because the Eurosystem relies on agencies for roughly two-thirds of monetary policy collateral (virtually all marketable assets) and for all the assets acquired under the purchase programmes. As a consequence, most of the financial risks borne by the Eurosystem's balance sheet arise from assets assessed by rating agencies.

In recent years, academics and practitioners have discussed the ways in which central banks may reduce their reliance on agency ratings, especially for sovereign assets. Recent studies[4] recommend that the Eurosystem ends making use of agencies' sovereign ratings and rely instead on the assessment of sovereign risk either developed internally or provided by another EU public institution, such as the European Stability Mechanism (ESM).

The Eurosystem is making an effort to reduce its reliance on credit rating agencies. On the one hand, the Eurosystem is looking more closely into the methodologies adopted by the rating agencies accepted in the ECAF; on the other hand, it is strengthening its internal credit assessment capabilities, by increasing the number of national central banks' In-House Credit Assessment Systems (ICASs; see chapter "The Bank of Italy's In-House Credit Assessment System for Non-Financial Firms") for non-financial corporations and by adopting a due diligence process for the private sector asset purchase programmes (asset-backed securities, covered bonds, and corporate bonds).

In response to the coronavirus pandemic, in April 2020 the Governing Council of the European Central Bank (ECB) adopted a broad set of policy measures aimed at mitigating the economic impact of the crisis and, indirectly, at reducing its reliance on rating agencies. The first package consisted of collateral easing measures to increase the acceptance of credit claims as collateral and, as a consequence, foster the recourse to internal credit assessment systems, such as the Internal Rating Based models (IRBs) and ICASs, in alternative to agencies. In the second package, the ECB introduced a comprehensive set of measures to mitigate the impact of potential rating downgrades and avoid cliff effects on collateral availability.

The Eurosystem is still committed to reducing its reliance on rating agencies and is assessing possible ways to further strengthen the role of ICASs. Such a commitment is witnessed, although indirectly, also by the Eurosystem's Action Plan of July 2021, which includes climate change considerations in the monetary policy strategy. The Action Plan foresees, among other things, the development of minimum

[3] The other two sources (see Sect. 3.1) are national central banks' In-House Credit Assessment Systems (ICASs) and counterparties' Internal Ratings-Based (IRB) systems.

[4] See Orphanides (2017) and Clayes and Goncalves Raposo (2018).

standards for the incorporation of climate change risks into the Eurosystem's internal ratings, namely, the ICASs. The first group of measures to incorporate climate change into monetary policy operations were announced in July 2022 and implemented soon afterwards.

The remainder of the chapter is organised as follows. Section 2 provides an overview and some empirical evidence about the effects of sovereign downgrades on the main economic and financial players. Section 3 describes the role of credit ratings within the Eurosystem's collateral framework and, for a comparison, in the monetary policy set-up of other major central banks. After an overview of the policy and academic debate, we examine the extent to which the Eurosystem has so far reduced its reliance on rating agencies.

2 The Impact of Rating Actions on the Financial System and the Real Economy

Sovereign downgrades have a significant impact on the financial sector and the economy at large. They often trigger a wave of domestic corporate downgrades that involves both financial and non-financial firms, implying that sovereign and corporate rating shocks tend to materialise jointly or with a short lag. Sovereign downgrades have important second-round effects also on other financial players such as insurance companies and asset managers; they also affect the functioning of central counterparties and collateralised markets.

2.1 *Sovereign Issuers*

In general terms, sovereign downgrades can have a negative effect on public finances through an increase in government funding costs. Although the information conveyed by sovereign downgrades is often anticipated by 'outlooks', 'reviews', and 'watches', market reactions confirm the importance of the ratings' certification role.[5]

When ratings remain within the investment grade category after the downgrade, the impact on yields and the cost of debt is usually modest. Research based on European data prior to the sovereign debt crisis of 2011–2013 suggests that a one-notch downgrade causes on average an increase by 8 basis points in the 10-year sovereign yield on the secondary market.[6]

In contrast, a sovereign downgrade from investment grade to sub-investment grade by one or more rating agencies has significant cliff effects, as it triggers forced

[5] See e.g. IMF (2010).

[6] Afonso et al. (2012) analyse credit events involving 24 EU countries between 1995 and 2010.

sales by some categories of investors and mechanically determines a structural reduction in the demand for government bonds.

First, investors such as pension funds are often restricted to holding investment-grade bonds or have caps on the amount of sub-investment-grade debt they can hold.

Second, investors frequently allocate a significant portion of their money to tracking indices in which only investment-grade bonds are included (e.g. the FTSE World Government Bond, Bloomberg Barclays Global Aggregate, and JP Morgan Global Government Bond indices). When a sovereign loses its investment grade status, it is automatically excluded from these indices. Consequently, investors tracking such indices quickly reduce their exposure to the downgraded sovereign. Notably, passive investors that have these indices as their benchmarks, such as ETFs and passive mutual funds, are likely to fully liquidate their positions within a short time frame.

These are not the only effects of a downgrade on the demand for bonds, but they are the most important and immediate ones. Other important effects, although more gradual, stem from the fact that sovereign ratings tend to be a ceiling for those of domestic financial and non-financial companies (see for instance Borensztein et al. 2013), so that a sovereign downgrade to sub-investment status tends to be followed by the loss of investment grade status of several financial and non-financial companies (see below, Sects. 2.2 and 2.5).

The downgrade to sub-investment grade by a single agency (if other agencies keep assigning an investment grade rating to the sovereign) may not be enough to trigger forced sales, as each investor or producer of bond indices relies on different agencies or different rules for combining their ratings. Typically, an issuer needs an investment grade rating from at least two of the three main agencies (FitchRatings, Moody's, Standard & Poor's) in order to be included in an index or portfolio.

However, several episodes suggest that a single downgrade is enough to cause a first significant wave of sales. In fact, rating-constrained investors are likely not to wait to become forced sellers and they often start selling when the first downgrade to sub-investment grade occurs. Evidence from a sample of 20 countries (Hanusch et al. 2016) indicates that the largest increase in short-term bond yields is observed after the first downgrade to sub-investment grade (on average around 140 basis points *vs* 60 after the second downgrade). Investors may as well start to reduce their positioning on expectations of a downgrade before the latter is officially announced.

The downgrade to sub-investment grade of the South African sovereign by Moody's on 27 March 2019 and the consequent exit from the FTSE World Government Bond index[7] are a case in point: these events were followed by an *increase* (rather than a decrease) in bond prices, as the downgrade had been largely anticipated and investors were pre-positioned for it (Goko 2020).

The number of forced sales triggered by a downgrade is hard to predict, although it is often deemed closely related to the distribution of government bond holdings

[7] The previous downgrades to junk by Standard & Poor's and FitchRatings (on 24 November 2017 and 18 December 2019) had not been sufficient to exclude the country from this important index.

across economic sectors. Foreign investors are usually likely to hold bonds through index-tracking investment entities and are more rating-sensitive than domestic investors, who often hold domestic securities partly owing to a 'home bias' (possibly as a rational response to frictions[8]) and not simply as the result of risk-return considerations. In fact, several investors tend to exempt the securities of their domestic sovereign from restrictions based on ratings or risk, or they hold sovereign bonds indirectly through funds that track a domestic benchmark (so that no rules on ratings are involved). Furthermore, empirical evidence about advanced economies (Arslanalp and Tsuda 2012; Bank of Italy 2020) shows that domestic banks often step in to fill the financing gaps created by foreign sales and capital outflows. Incidentally, in recent years, domestic banks may have become less prone to do so, in order to avoid substantial mark-to-market losses and comply with more stringent banking regulations.[9]

Other factors beyond the relevance of foreign holdings[10] and the shock-absorbing role of banks may contribute to the intensity of selling after a sovereign downgrade.

For example, front running by speculative investors such as hedge funds can be an amplifying factor, especially if the forced selling by rating-constrained investors is highly predictable and quantitatively important.

2.2 Banks

The downgrade of a sovereign issuer typically has a large impact on the domestic banking system, reflecting several transmission mechanisms (see e.g. Panetta et al. 2011, Angelini et al. 2014, and, more recently, Schnabel 2021).

The first channel is represented by losses on banks' portfolios of government bonds. An unexpected sovereign downgrade causes a drop in the market value of government bonds, thus implying a loss on the banks' bond portfolio, which weakens the balance sheet, increases riskiness, and ultimately raises the cost of funding.

The second channel is represented by the reduction of the value of collateral. In money markets, lower collateral availability may result in banks having to top up the collateral in mark-to-market transactions and/or facing higher haircuts on repo and secured loans (see also Sect. 2.4). Moreover, a lower value of collateral affects

[8] See, e.g. Levy and Sarnat (1970) and Coeurdacier and Rey (2012).

[9] On the one hand, domestic sovereign exposures keep enjoying a favorable prudential treatment, having zero risk-weights. On the other hand, the rules on leverage ratios and—in Europe—the supervisory exercises have tightened the prudential treatment of sovereign exposures (see Lanotte et al. 2016). Furthermore, banks might want to avoid the substantial mark-to-market losses that would emerge in case of a pronounced increase in bond yields (see, Fig. 1.17.3 in International Monetary Fund 2019).

[10] Foreign investors tend to be more reactive to news and change their holdings more rapidly than domestic investors.

banks' ability to tap central bank refinancing operations. In the adverse scenario in which government bonds lose eligibility as central bank collateral, additional tensions may materialise as these bonds would suddenly lose the 'eligibility premium' related to central bank operations (Corradin 2017).

The third channel is related to the existence of a sovereign ceiling for private borrowers: to the extent that sovereign downgrades raise the yields on domestic government bonds and/or lead to domestic bank downgrades, the cost of wholesale funding for banks increases.[11]

Fourth, by reducing sovereign creditworthiness, sovereign downgrades may impair the effectiveness of the public guarantee schemes deployed in many jurisdictions (including Italy) to support bank lending to non-financial companies (NFCs), both in good and in bad times (such is the case of the public guarantee schemes put in place in 2020 to face the Covid-19 crisis).

The impact of a sovereign downgrade on the economy can be amplified by second-round effects. Banks may have to address liquidity and capital shortages by reducing credit supply and increasing capital. To the extent that raising capital is costly in an environment with higher risk premia, banks might opt for a contraction in lending, larger than it would have otherwise been. This deleveraging may further weaken the economy, hindering the government's fiscal outlook, and feeding back on sovereign stress.[12] In turn, a weakening of the banking system may be seen as a contingent liability for the Government and thus raise sovereign risk, giving rise to a vicious circle.

What is the empirical evidence about the sovereign-bank link in the euro area? One way of assessing it is to monitor the risk premia requested by investors to hold assets issued by sovereign entities and by banks, and in particular their links. A reliable proxy is the premium paid on credit default swaps (CDSs). Using the premia on the CDSs written on banks and sovereign issuers, we can assess how the joint riskiness of the two sectors has evolved in different countries and over time.

Figure 1 plots the correlation between sovereign and bank credit risk measured by CDSs for some major European countries since 2008. The co-movement shows a significant increase during the sovereign debt crisis in the years 2010–2012; since then, it has edged down in some countries but remains high in Italy, Spain and, to a lesser extent, France. In 2016, the correlation rose in Germany, Ireland, the Netherlands, and the United Kingdom, during the financial market turbulences that occurred around the UK referendum on European Union membership (Brexit). The correlation spikes again in Italy and Spain in 2018, when the appointment of new governments in both countries fuelled political uncertainty. In the first half of 2020, with the outbreak of the Covid-19 pandemic, the correlation has increased

[11] Sovereign ratings normally act as a ceiling for the ratings to corporate borrowers. Arezki et al. (2011) and Correa et al. (2014) find out a positive correlation between changes in sovereign ratings (especially downgrades) and bank stock prices. Adelino and Ferreira (2016) show that rating agencies downgrade intermediaries operating in countries where the sovereign has been downgraded and do so irrespectively of banks' health.

[12] See van Rixtel and Gasperini (2013) and Correa and Sapriza (2014).

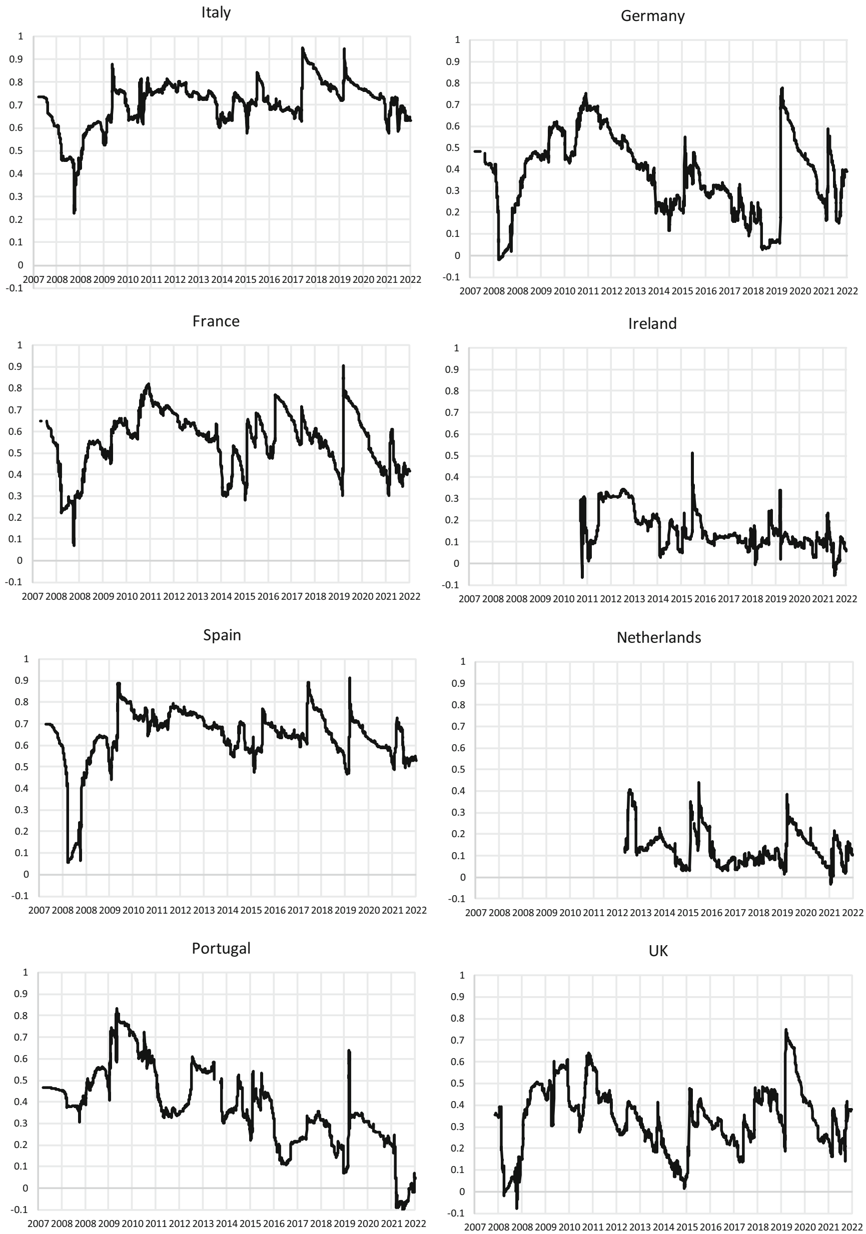

Fig. 1 Correlation between sovereign and banks CDSs premia (The correlation between daily changes in 5-year CDSs of sovereign bonds and bank bonds is computed as an exponentially weighted moving average). 1 January 2008 (2012 for Ireland, 2013 for the Netherlands) to 31 December 2022. (Source: own calculations based on daily data provided by ICE Data Derivatives UK Limited)

Table 1 Sovereign rating and Debt/GDP ratio. (Source: Bloomberg Finance L.P. and IMF Fiscal Monitor)

Country	Italy	France	Spain	Portugal	Germany	Ireland	The Netherlands	UK
Current S&P rating (as of end 2022)	BBB	AA	A	BBB+	AAA	AA−	AAA	AA
Debt/GDP ratio (%, as of end 2021)	151	113	119	127	70	55	52	95

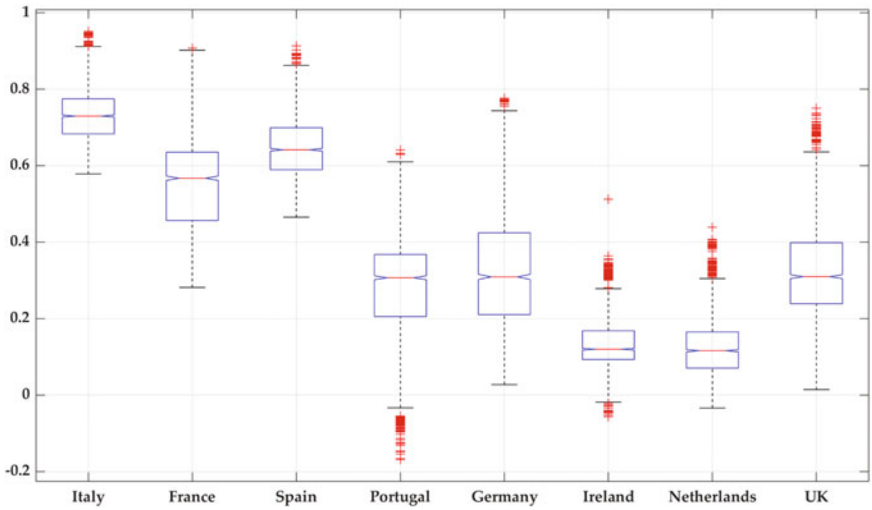

Fig. 2 Box plot of correlation between sovereign and banks CDS premia (The box plot shows descriptive statistics of the correlations displayed in Fig. 1, referred to a sample of daily data going from May 2013 to the end of December 2022. On each box, the central mark indicates the median, and the bottom and top edges of the box indicate the 25th and 75th percentiles, respectively. The whiskers extend to the most extreme data points not considered outliers, and the outliers are plotted individually (using the '+' symbol). (Source: own calculations based on daily data provided by ICE Data Derivatives UK Limited)

remarkably in all countries, alongside a general surge of risk premia across financial markets, even though it has gradually declined from the second half of the year onwards. In summary, this evidence confirms that changes in sovereign risk premia tend to transmit to the banking sector; the correlation rises sharply in times of tension and for some countries is higher than for others.

One may wonder whether there is a relationship between public debt, sovereign ratings, and sovereign-bank correlations. Table 1 shows the Standard & Poor's sovereign rating and debt/GDP ratio of the European countries considered.

Figure 2 compares the main descriptive statistics about the sovereign-bank credit risk premia correlation. On all these accounts, the countries look very heterogeneous. The relationship between sovereign ratings and sovereign-bank risk premia correlation is weakly negative (high correlations are associated with low ratings). The risk premia correlation is the highest for Italy, Spain, and France, which, according to all rating agencies, currently have different levels of creditworthiness. In the case of Portugal, the sovereign-bank risk premia correlation is similar to that of Germany and much lower than that of Italy, despite the fact that Portugal and Italy have similar ratings and debt/GDP ratios. Among countries with a lower debt/GDP ratio and higher ratings, Ireland and the Netherlands show the lowest correlation over time. In 2020, the correlation in the UK, typically volatile, fell to very low levels, comparable to those observed in Germany and Portugal. To sum up, while no general pattern seems to link risk premia correlations, debt ratios, and credit ratings, one possible reading of these data is that in times of crisis correlations increase, especially for some countries with larger amounts of public debt or worse credit ratings.

2.3 Insurance Companies and Asset Managers

A sovereign downgrade usually entails significant capital losses for insurance companies. It often leads to portfolio adjustments by asset managers, especially when the sovereign loses investment grade status, with potentially important implications for market prices.

Insurers are exposed to sovereign and corporate downgrades via their impact on market prices and, in the latter case, also via higher capital requirements. Rating downgrades affect insurers' solvency ratios through three transmission channels: (1) they reduce the market value of corporate bond holdings, which decreases their excess of assets over liabilities and, proportionally, own funds (at the numerator of their capital ratio); (2) they increase the Solvency Capital Requirement (at the denominator of their capital ratio) charged for the bonds held by insurers because of their increased riskiness; and (3) they lower the market value of bonds considered in the capital requirement calculations (at the denominator of their capital ratio). When investment-grade bonds are downgraded to sub-investment grade, these effects may be highly significant.

Asset managers are exposed to a sovereign downgrade via its impact on market prices. Such effect may be large, partly because of the growing role played by passive funds (see also Sect. 2.1). Passive investors have more than quadrupled in the last decade, and their assets under management climbed from around USD 2 trillion in 2010 to USD 10 trillion at the end of 2020[13]; at that time they represented

[13] See Anadu et al. (2020) and ICI (2021).

about 20% of total managed funds worldwide.[14] Managers are usually required to track financial market benchmarks, and the main bond index providers (Bloomberg, Barclays, ICE BofA, JP Morgan, Markit iBoxx, and FTSE) combine ratings in various ways, to obtain credit profiles for every issuer. Therefore, should a downgrade below investment grade occur, a significant selling pressure could arise, the latter's intensity depending *inter alia* on: (1) the amount of the downgraded sovereign bonds managed against a specific benchmark; (2) the selection criteria of assets for the benchmark; and (3) the asset management style and strategy.

As already mentioned in Sect. 2.1, if a sovereign issuer loses investment grade status and, as a consequence, it is excluded from the major global indices, then a negative impact on prices stems from both passive investors [15] and active funds.[16] Second-round effects may also play an important role: potential outflows related to investors' redemptions could contribute to exacerbate the reaction; furthermore, in recent years, hedge funds and proprietary trading firms have exploited automatic selling flows coming from passive investors,[17] increasing their own selling activity. Conversely, such speculative players could have a stabilising effect, by covering their short positions and buying at prices viewed as very distant from fair values.

2.4 Central Counterparties and Collateralised Markets

Sovereign and corporate downgrades can affect the measures taken by central counterparties (CCPs) and clearing members to mitigate their exposure towards counterparties and collateral issuers. In recent years, the role of collateralised markets for short-term funding and collateral transformation (i.e. repo and securities lending) has grown, together with the increased reliance on CCPs in many market segments, fostered by post-crisis regulatory reforms to incentivise central clearing in derivative contracts. These phenomena have significantly increased the role of collateralised market segments in propagating tensions within the whole financial system, amplifying pro-cyclical developments in time of stress. The payment of

[14] See Sushko and Turner (2018): they estimated the share at 20% in 2018 but, given the significant increase of passive investment in recent years, at the end of 2020 the level was probably higher. Financial Times (2022) quoted a report by JP Morgan according to which in the United States, between end 2019 and end 2022, the share of passive funds has increased from 23 to 29% of total managed funds.

[15] See ESRB (2020a).

[16] According to Aramonte and Eren (2019), in the case of corporate bonds, active managers could sell up to one third of their holdings in case of downgrade below investment grade.

[17] Due to the technological developments that affected markets microstructure in recent years, this impact could be exacerbated by algorithmic and high frequency players (widely known as "momentum players"); their speculative, directional activity could amplify the degree of the movement, leading to so called "flash crash" events. See BIS (2016, 2018).

variation margins, the posting of initial margins, and the application of collateral haircuts to collateralised exposures may have helped prevent the build-up of excessive leverage in the financial system, thus mitigating counterparty credit risk. Conversely, the greater use of collateral and margin practices may have transformed part of the credit risk into liquidity risk, as market participants should be able to provide cash or high-quality collateral at short notice in response to sudden movements in market prices or to credit downgrades of counterparties/collateral issuers (European Systemic Risk Board 2020a).

Another side effect of sovereign and corporate downgrades is that they may lead to cliff effects in the demand for collateral. This occurs if, in case of downgrades, risk management procedures result in sudden and material margin calls or changes in collateral practices in derivatives and securities financing transactions (SFTs).[18] This outcome is more likely for bilateral transactions than for centrally cleared transactions.[19] After a downgrade, these linkages may: (1) force clearing members/counterparties to post or replace large amounts of collateral at short notice, especially if the credit event involves government bonds, which are frequently used as collateral; or even (2) cause their exclusion from clearing facilities as well as the bilateral segment of the market. The liquidity drain could spread into the broader financial system in an unpredictable way. The criteria for setting margins between CCPs and clearing members are explicitly dealt with in the EMIR regulation, whereas little is known about collateral practices in the relationship between clearing members and their own clients.

The episode of high market volatility experienced in March 2020, following the outbreak of the coronavirus pandemic, is a reminder that financial stability risks may result from large margin calls and that these risks should be mitigated in both centrally and non-centrally cleared markets. Although it was noted that even in the most stressful days the margin framework functioned without significant disruptions in Europe, that episode underscores the need to reduce reliance on credit ratings and adopt alternative approaches in risk management, such as the adoption of gradual steps in reaction to rating downgrades (ESRB 2020b).

[18]The European regulatory framework (EMIR) sets out minimum requirements for what concerns collateral eligibility criteria and, more generally, for margins, which primarily depend on the historical volatility observed on the market for each financial instruments. These requirements must be fulfilled by CCPs' internal models, which normally take into account a large number of indicators in addition to external credit ratings.

[19]The *ISDA Master Agreement* include references to 'credit events' and 'credit downgrade' by a rating agency. Furthermore, the parties can indicate 'additional termination events', which often include the downgrade of an entity's credit rating. The eligibility criteria of the securities posted as collateral in repo transactions are listed in the *Global Master Repurchase Agreement*, and subject to additional constraints related to counterparties risk management practices. In bilateral markets, these agreements typically contain a Credit Support Annex that clearly specifies type, credit quality, and applicable haircuts for all eligible collateral.

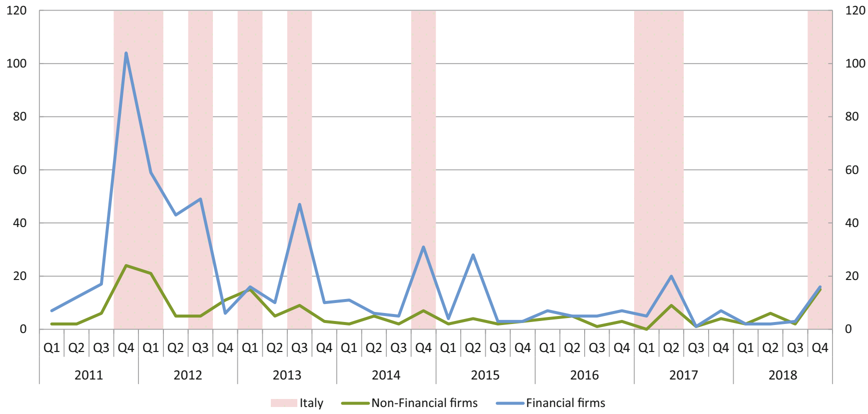

Fig. 3 Corporate downgrades following a sovereign downgrade in Italy (quarterly data from January 2011 to December 2018). Number of rating downgrades, net of upgrades, assigned to financial and non-financial firms by DBRS Morningstar, FitchRatings, Moody's, and Standard & Poor's. The shaded areas indicate the quarters in which the rating of the Italian Republic has been downgraded (Source: Bank of Italy (2018))

2.5 Non-financial Companies

Sovereign and corporate downgrades negatively affect firms' funding costs and can consequently reduce fixed investments, with negative effects on the real economy. Several transmission channels may be at work.

Non-financial company ratings co-move with sovereign ratings, though the link is weaker than for banks. The international evidence suggests that sovereign downgrades are often followed by a wave of credit downgrades of domestic firms. These linkages were at work in Italy during the sovereign debt crisis of 2011–12 (Fig. 3). The immediate risks for non-financial companies thus relate to their funding cost and access to the bond market.

Almeida et al. (2017) show that corporate downgrades following a sovereign downgrade also have adverse implications for investments. When corporate downgrades are caused by the downgrade of the domestic sovereign entity, (1) the most creditworthy firms are more likely to be downgraded, due to the ceiling role implicitly attached to the sovereign rating; and (2) the ensuing increase in funding costs has a significant impact on corporate investment decisions.[20] This may generate a sharp contraction in business investment, with adverse effects for the real economy both in the short- and long-term, through its impact on the capital stock. Investment falls relatively more for formerly highly rated companies that have strong cash flows and better investment opportunities.

[20]The study uses a large sample of 80 countries between 1990 and 2013, thus capturing *inter alia* the rating dynamics observed during the European sovereign debt crisis.

Finally, volatility in credit ratings could affect the firm capital structure in the longer run. The US experience suggests that the risk of a forthcoming change in rating (either positive or negative) has by itself a small but significant impact on firm behaviour: firms that face a high likelihood of a rating revision issue less debt compared to their peers (up to 1% of their internal equity), presumably because of the uncertainty on their future funding costs (Kisgen, 2006).

3 Reducing the Eurosystem's Reliance on Credit Rating Agencies: Progress Made So Far

3.1 The Role of Credit Ratings in the Eurosystem's Collateral Framework

In line with the Statute of the European System of Central Banks and of the ECB, the Eurosystem provides credit to its eligible banking counterparties only against adequate collateral. Typically, eligible collateral includes marketable assets (such as bonds) and non-marketable assets (such as credit claims). The adequate collateralisation criterion aims at mitigating financial risks in monetary policy operations. To achieve this goal, the collateral accepted must not only be sufficient (i.e. it should cover the amount of refinancing granted to counterparties), but it shall also be of high credit quality such that, in the event of a counterparty default and a subsequent liquidation of the collateral in the market, it is highly probable that the Eurosystem would be able to recover the full amount of its claim (see chapter "The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency").

For this purpose, the ECAF defines the procedures, rules, and techniques which ensure that the Eurosystem requirement of high credit standards for all eligible assets is met (ECB 2015). The assessment of the credit quality is the first step for establishing the eligibility of marketable assets and credit claims and for assigning a suitable haircut. The Eurosystem takes into account information (ratings or probabilities of default) from credit assessment systems belonging to one of the following three sources: (1) external credit assessment institutions (ECAIs); (2) national central banks' In-House Credit Assessment Systems (ICASs); and (3) counterparties' Internal Rating-Based (IRB) systems.

To bring together in a harmonised fashion the information provided by all of these credit assessment systems, the ECAF makes the credit ratings from all accepted sources comparable by mapping each of their rating grades into an appropriate 'credit quality step' (CQS) within the Eurosystem's harmonised rating scale. First, the minimum credit quality requirement for the eligibility of all assets in the general framework (where a first best rating rule applies) is CQS 3 (corresponding to a BBB rating level) of this scale. Additional requirements are set for asset-backed securities

(ABSs).[21] Second, the Eurosystem applies larger valuation haircuts to assets of lower credit quality, to achieve risk equivalence across all eligible assets.

The ratings assigned by the four recognised ECAIs within ECAF (DBRS Morningstar, FitchRatings, Moody's, Standard & Poor's) are mainly used for assessing the credit quality of marketable collateral, whereas ICASs and IRB systems are mainly used for credit claims. ECAIs are employed to assess close to 100% of the 1642 billion euros marketable assets mobilised as collateral (net of haircuts) for Eurosystem credit operations at the end of 2022. As regards non-marketable instruments and the so-called Additional Credit Claims[22] (ACCs, accepted since December 2011), which amount to a net value of 881 billion euros, IRB systems are the most important source of valuation, being used to assess around 355 billion euros worth of credit claims. NCBs' ICASs are employed to assess 224 billion euros of non-marketable assets and ACCs, while ECAIs are employed for about 104 billion euros. The remainder of non-marketable instruments is valued with other minor sources.

Ratings from ECAIs are also used for the eligibility of assets in the context of the Eurosystem's asset purchase programmes.

To sum up, most of the financial risks borne by the Eurosystem's balance sheet arise from assets evaluated by rating agencies, which therefore play a prominent role in the Eurosystem's risk assessment framework.

3.2 The Use of Credit Ratings for Monetary Policy by Other Major Central Banks and Recent Changes in Response to the Covid-19 Crisis

Similarly to the Eurosystem, other central banks rely on ratings issued by eligible rating agencies for the implementation of monetary policy. This section briefly illustrates current practices in the use of credit ratings by other central banks across the globe.

The Bank of Japan (BoJ) collateral eligibility guidelines[23] state that, with a view to maintaining the soundness of the central bank assets, the BoJ shall only accept collateral with sufficient creditworthiness. General eligibility standards for collateral require, among other things, that creditworthiness (i.e. repayment of principal and interest) should be considered high enough by the BoJ in light of various factors concerning the obligor, including its financial conditions and ratings by eligible rating agencies. In particular, bonds issued by the Fiscal Investment and Loan

[21] The Eurosystem accepts only most senior tranches of ABSs that have at least two 'single A' ratings and are backed by a homogeneous and publicly reported pool of assets.

[22] Additional Credit Claims are those bank loans that do not fulfil the ordinary framework's eligibility requirements but satisfy the wider criteria set by each national central bank, which bears the related financial risks.

[23] See "Guidelines on Eligible Collateral" of Bank of Japan.

Program (FILP) agencies (which belong to the General Government) should be rated A or higher by at least two eligible rating agencies; foreign government bonds should be rated AA or higher by at least two eligible rating agencies; ABSs should be rated AAA by at least one eligible rating agency; and corporate bonds should be rated A or higher by at least one eligible rating agency. The Terms and Conditions for Outright Purchases of Commercial Paper and Corporate Bonds[24] state that the following eligibility criteria, among others, should be satisfied: for commercial paper, an a-2[25] rating or higher by an eligible rating agency; for asset-backed commercial paper, an a-1 rating by an eligible rating agency; for corporate bonds a BBB rating or higher by an eligible rating agency; for bonds issued by Real Estate Investment Corporations an AA rating or higher by an eligible rating agency.

The Bank of England (BoE) publishes broad collateral eligibility criteria for its operations,[26] which set a baseline for collateral quality. Ratings assigned by rating agencies are only indicative of the broad standards of credit quality expected for eligible securities. The BoE develops its own independent view of the risks in the collateral it takes, by accepting only those securities that it can value and manage effectively from a risk perspective. In the context of the Asset Purchase Facility, in August 2016, the BoE launched the Corporate Bond Purchase Scheme (CBPS), which consisted in purchasing sterling-denominated non-financial investment-grade corporate bonds. The CBPS eligibility criteria provided, among others, that the BoE would offer to purchase sterling corporate bonds of eligible issuers as long as the bonds were rated investment grade by at least one major rating agency, subject to the BoE's assessment process. In February 2022, the BoE began to reduce the stock of corporate bond purchases, by ceasing to reinvest maturing assets and by carrying out corporate bond sales to be completed by the end of 2023, fully unwinding the Bank's corporate bond portfolio.

The Federal Reserve Collateral Guidelines[27] provide that securities must meet the regulatory definition of investment grade at a minimum, and in some cases must be of AAA-rating quality. If a security has more than one credit rating assigned, the most conservative (lowest) rating will be utilised. In the context of the measures adopted during the Covid-19 crisis, the Federal Reserve established on 23 March 2020 the Secondary Market Corporate Credit Facility. Under this programme, the US central bank lent, on a recourse basis, to a special purpose vehicle (SPV) that purchased, in the secondary market, corporate debt issued by eligible issuers.[28] To qualify as an eligible issuer, the issuer must satisfy, among others, the following conditions: (a) the issuer was rated at least BBB-/Baa3 as of 22 March 2020, by a major 'nationally recognized statistical rating organization' (NRSRO). If rated by

[24] https://www.boj.or.jp/en/mopo/measures/term_cond/yoryo83.htm/

[25] Such classification refers to short-term ratings.

[26] See "Collateral management in central bank balance policy operations" of Bank of England.

[27] See "Federal Reserve Collateral Guidelines".

[28] The Facility ceased purchasing eligible assets on 31 December 2020.

multiple major NRSROs, the issuer must be rated at least BBB-/Baa3 by two or more NRSROs as of 22 March 2020; (b) an issuer that was rated at least BBB-/Baa3 as of that date but was subsequently downgraded, must be rated at least BB-/Ba3 as of the date on which the Facility makes a purchase. If rated by multiple major NRSROs, such an issuer must be rated at least BB−/Ba3 by two or more NRSROs at the time the Facility makes a purchase; (c) in every case, issuer ratings are subject to review by the Federal Reserve.

In its Terms and Conditions for its payment system and monetary policy instruments,[29] Sweden's Riksbank provides that a security must have at least the 'lowest acceptable' credit rating (corresponding to AA−) to be eligible as collateral; the credit rating must be confirmed by one or more of the rating agencies recognised by the Riksbank. In any case, the Swedish central bank reserves the right to rely on its own assessment to determine whether a security is accepted as collateral. As regards the purchase programme of corporate bonds, which was in place from September 2020 to December 2022, it involved corporate bonds issued in Swedish krona by Swedish NFCs and bonds had to meet, among others, the following criteria: (1) credit ratings no lower than Baa3/BBB−, from any of the credit rating agencies Standard & Poor's, Moody's, FitchRatings, Nordic Credit Rating or Scope Ratings or, if they had no such rating, be issued by companies with credit ratings no less than Baa3/BBB− from the same agencies; (2) if the company and/or the bonds had more than one credit rating, none of these could be below the lowest accepted credit rating; and (3) on the purchase date, there should be no indications that any of these credit ratings might have fallen below the lowest acceptable credit rating level.

In a slightly different context related to the management of foreign reserves, the Bank of Canada (BoC) has reduced its reliance on rating agencies. In 2017, the BoC published a detailed technical description of the methodology to assign internal credit ratings to sovereigns, using publicly available data only.[30] The methodology relies on fundamental credit analysis that produces a forward-looking and 'through-the-cycle' assessment of the investment entity's capacity and willingness to pay its financial obligations, resulting in an opinion on the relative credit standing or likelihood of default. This methodology is currently employed to assess eligibility and inform investment decisions in the management of Canada's foreign exchange reserves.

To sum up, the available evidence about other major central banks shows that they tend to rely on rating agencies for both collateral assessment purposes and for purchase programmes but they do so to a varying degree.

[29] See "Terms and Condition for RIX and monetary policy instruments" of Sveriges Riksbank.

[30] See Muller and Bourque (2017).

3.3 The Recent Policy Debate

In recent years, a number of academics and practitioners have discussed ways in which central banks may reduce their reliance on credit ratings, especially for sovereign assets. Orphanides (2017) and Clayes and Goncalves Raposo (2018) recommend that the Eurosystem discontinue making use of agency sovereign ratings and rely instead on the assessment of sovereign risk either developed internally by the Eurosystem or provided by another European public institution such as the ESM.[31]

The arguments put forward by Orphanides (2017) can be summarised as follows. The ECB has an obligation to ensure that the government debt it accepts constitutes ‘adequate’ collateral and protects the financial position of the ECB.[32] While the ECB should not penalise governments by unnecessarily restricting the use of good collateral, the ECB cannot accept government bonds of a member state as collateral if it knows that the fiscal fundamentals of that member state are not sustainable. This suggests that the criterion for assessing collateral eligibility should be fundamentals-based sustainability analysis rather than agency ratings. In the author’s view, such analysis should be performed independently by the ECB. As long as debt is deemed sustainable on the basis of a fundamentals-based evaluation, it should be considered as eligible collateral regardless of credit ratings. Orphanides concludes that the ECB could protect its financial position in its collateral framework via the appropriate use of a graduated schedule of haircuts based on indicators of fiscal fundamentals.

Similar views have been expressed by the Bruegel think-tank (Clayes and Goncalves Raposo, 2018). An alternative to rating agencies in the collateral framework would be for the ECB to use its own assessment of a sovereign’s credit risk to set haircuts, as the Bank of England and other central banks do. The ECB is admittedly in a much more complex situation than a central bank that deals with a single fiscal authority, as it has to deal with the multi-country nature of the euro area and with the potential distributional consequences that significant ECB losses could induce across countries (through a reduction of future profits distributed to member states or even higher inflation). In this context, to avoid the risk of the ECB appearing politicised (as in February 2015, when it decided to withdraw the waiver that was making Greek bonds eligible as collateral despite their low rating), according to these authors, it might be preferable for the ECB to rely on the risk assessment provided by external entities, e.g. the ESM. Clayes and Goncalvo Raposo conclude that this situation would not be perfect either, as it could lead to

[31] In a similar vein, Vernazza and Nielsen (2015) suggest that credit rating agencies should be stripped of their regulatory powers for sovereign ratings.

[32] This view has been expressed by the same author also in a more recent paper (Orphanides 2020); according to the author, the ECB should draw on the success of the temporary measures adopted in April 2020 in response to the pandemic and eliminate cliff effects in its collateral framework on a permanent basis, by ceasing the delegation of the determination of collateral eligibility of government debt to private credit rating agencies. In the same vein, see also Lengwiler and Orphanides (2021).

heated political debates among countries at the ESM. Nonetheless, they argue that it would still be better than delegating these decisions to rating agencies, which cannot be held accountable for their potential mistakes and for the pro-cyclicality of their ratings.

3.4 Reducing Reliance on Credit Rating Agencies: Progress Made So Far by the Eurosystem

Making the reliance on agency ratings less mechanistic was one of the recommendations issued by the FSB in 2010.[33] This recommendation was addressed to a broad range of private and public market players and investors, including central banks. The FSB Principles do not imply that market participants should avoid altogether the use of credit ratings but suggest that the use of such ratings be combined with their own judgement on creditworthiness. Furthermore, the FSB principles do not imply that market participants should mechanistically rely on another source, other than agencies, to provide credit ratings, as this could lead to pro-cyclicality in exactly the same way as the use of agency ratings.[34] In this respect, the Eurosystem is engaged in reducing its reliance on credit rating agencies along two paths.[35] The first one aims at better understanding the rating processes and methodologies adopted by the rating agencies accepted in the ECAF (ECB 2016). The second path is meant to enhance the Eurosystem's internal credit assessment capabilities, in particular by increasing the number of NCBs' ICASs for NFCs and by establishing a due diligence process in the context of the asset-backed securities, covered bond and corporate bond purchase programmes (Bindseil et al. 2017).

In principle, the ECAF provides the Eurosystem with a set of tools that prevent a mechanistic reliance on any rating system.[36] The first tool is an intensive monitoring process, in cooperation with the provider of the credit assessment system, including an investigation to determine whether and how a specific performance problem (e.g. realised defaults being higher than the relevant CQS threshold) is being addressed.

In addition, the ECB's Governing Council can: (1) remap a system's rating grades onto the Eurosystem's harmonised rating scale; (2) define specific eligibility requirements related to credit assessment systems; (3) apply discretionary measures; and (4) exclude or temporarily suspend a credit assessment system. Furthermore, regular

[33] See FSB (2010).

[34] See FSB (2014).

[35] See the Eurosystem reply to the European Commission's public consultation on credit rating agencies of February 2011.

[36] See the ECB's Public Guideline on ECAF rules.

surveillance reports published by the ECAIs are required for ABSs to be eligible as collateral; for covered bonds, new issue reports and quarterly surveillance reports are required to understand the credit ratings and to ensure their reliability both at the set-up of the covered bond programme and on an on-going basis. The Governing Council may also decide to suspend, subject to specific conditions, the credit quality threshold for debt instruments issued by certain euro area governments. Additional work has been done to improve the due diligence conducted on the ECAIs' ratings, rating processes, and methodologies, particularly in the areas of sovereign ratings and structured finance.[37]

For asset purchase programmes, the Eurosystem conducts credit risk assessment and due diligence prior to the purchase of eligible assets in the context of the Covered Bond Purchase Programme 3 (CBPP3), the Asset-Backed Securities Purchase Programme (ABSPP), and the Corporate Sector Purchase Programme (CSPP). The due diligence aims at identifying those issuers which, although fulfilling the minimum rating criterion, are considered as risky and therefore are excluded or limited from purchases.

Finally, the increased number of ICASs developed by NCBs in recent years has enhanced the Eurosystem's internal capabilities in the field of credit risk assessment, providing an alternative to agencies' ratings.

All these enhancements of internal due diligence and risk assessment capabilities are steps towards further reducing the Eurosystem's reliance on credit rating agencies, in line with similar initiatives by international public authorities to reduce reliance on credit rating agencies in legal, regulatory and other public frameworks.

In response to the coronavirus pandemic, in April 2020, the ECB's Governing Council adopted a broad set of policy measures, temporary in nature, to mitigate the economic impact of the crisis, similarly to what was being done by other central banks (see Sect. 3.2). The first package consisted of collateral easing measures to facilitate banks' access to Eurosystem liquidity operations. A second set of measures aimed at alleviating the effects of potential rating downgrades on collateral availability (see chapter "The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency").

In March 2022, the Governing Council of the ECB decided to gradually phase out the pandemic-related collateral easing measures in place since April 2020 (see chapter "The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency"). On that occasion it was confirmed that '*the ECB's Governing Council reserves the right to deviate also in the future from credit rating agencies' ratings if warranted, in line with its discretion under the monetary policy framework, thereby avoiding mechanistic reliance on these ratings*'.

Such a commitment is witnessed, although indirectly, also by the Eurosystem's Action Plan announced in July 2021,[38] for the inclusion of climate change considerations in its monetary policy strategy, and by the additional steps to incorporate

[37] See ECB (2015).

[38] See Visco (2021) and NGFS (2021).

climate change into its monetary policy operations, announced in July 2022. These measures take into account climate-related financial risk in the Eurosystem balance sheet and support the green transition of the economy in line with the EU's climate neutrality objectives.

In particular, to improve the external assessment of climate-related risks, the Eurosystem will urge rating agencies to be more transparent about how they incorporate climate risks into their ratings and to be more ambitious in their disclosure requirements on climate risks, also closely liaising with the relevant European authorities. To enhance its internal ratings, the Eurosystem agreed on a set of common minimum standards for how ICASs should include climate-related risks in their ratings.[39] These standards will enter into force by the end of 2024.

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[39] See ECB (2022).

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The Incorporation of Climate Change Risk in the Eurosystem Monetary Policy Framework and the Decarbonisation of the Corporate Bond Portfolio

Fabio Capasso, Roberto Imperato, and Luigi Russo

1 Introduction

Global warming and the increased frequency of extreme weather events show that climate change is one of the greatest challenges of the century for humankind. Governments and institutions worldwide are making joint efforts to mitigate the risks stemming from climate change. The 2015 Paris Agreement represents a significant milestone in the international response to the challenge of climate change.[1]

Climate change is a clear and present danger for the global economy, and it differs from other financial risks, as it is irreversible and non-linear. Climate change affects financial markets, institutions and enterprises primarily through two channels, namely, physical risk and transition risk (see Chap. "The Commitment to Sustainability in Financial Investments"). Physical risk concerns direct and indirect effects of weather and extreme climate events on businesses' infrastructure, operations and markets. Transition risk concerns the risks (and rewards) associated with the policies implemented by the public authorities for the transition to a lower carbon economy. Climate change risks have a significant impact on

[1] As of September 2022, 194 members of the United Nations Framework Convention on Climate Change (UNFCCC) are parties to the agreement. The Paris Agreement's long-term temperature goal is to keep the rise in mean global temperature to well below 2 °C above pre-industrial levels, and preferably limit the increase to 1.5 °C.

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financial markets and banking activity. Because of the correlation of the impacts and the interconnectedness of institutions and economies, climate risk is also important for financial stability.[2]

The empirical evidence suggests that following the Paris Agreement stock investors have increased their demand for low-carbon assets as an appealing investment opportunity; at the same time, investors do not seem to penalize carbon-intensive assets.[3] Other evidence shows that since 2015, the cost of borrowing through a syndicated loan for a fossil fuel firm has significantly increased (see Delis et al. 2023). The green transition is becoming a key issue in the financial field. Even though governments and legislators are primarily responsible for tackling climate change and they have the most appropriate tools to address this issue (see Chap. "Financial Risk Management and Climate Change Risk"), also central banks, including the Eurosystem, may contribute to act against climate change risks.[4]

Macroeconomic and financial market disruptions linked to climate change and transition policies could affect the conduct of monetary policy and the ability of the Eurosystem to deliver on its price stability mandate through various channels (interest rate, credit, asset price, exchange rate and expectations), especially due to the stranding of assets and, in turn, the weakening of the banking sector.[5] In these circumstances, the transmission of monetary policy may be impaired. Besides, climate change and the carbon transition affect the value and risk profile of the assets held on the Eurosystem's balance sheet, potentially leading to an undesirable accumulation of climate-related financial risks.

All actions that the Eurosystem may undertake to counter climate change risks must fall within the limits of its competences, which, in the area of monetary policy, are defined by the objectives and tasks set out in Article 127 of the Treaty on the Functioning of the European Union (TFEU), as well as by the instruments used. According to this Article, the primary objective of the European System of Central Banks (ESCB) is to maintain price stability. The ESCB can pursue secondary objectives to support, without prejudice to price stability, the general economic policies in the European Union (EU) with a view to contributing to the achievement of the objectives of the EU (as laid down in Article 3 of the Treaty on the European Union). These include the objective of working for the sustainable development of Europe based on a high level of protection and improvement of the quality of the environment. In addition, other provisions (i.e. Articles 7 and 11 of the TFEU) directly or indirectly assign the Eurosystem the task of including climate risk considerations into its policies and activities (see Elderson 2021).

[2] See, among others, Battiston et al. (2021) and ECB (2021b).

[3] See Monasterolo and de Angelis (2020).

[4] See among others, Lagarde (2021), NGFS (2021a) and Campiglio et al. (2018).

[5] See ECB (2021a).

This chapter covers the actions undertaken by the European Central Bank (ECB) to include climate change considerations in the Eurosystem's monetary policy strategy. Section 2 starts from the action plan published in July 2021. Section 3 describes the measures adopted by the ECB for the collateral framework, namely, the introduction of concentration limits for issuers with higher carbon emissions and the disclosure requirements for eligible assets, as well as the inclusion of climate risk considerations in the credit risk assessment systems. Section 4 is devoted to the actions aimed at decarbonising the ECB's corporate bond holdings. Section 5 concludes.

2 Climate Change Considerations in the ECB's Monetary Policy Strategy (July 2021)

On 8 July 2021, the Governing Council (GC) of the ECB announced its new monetary policy strategy, which for the first time explicitly incorporates climate change considerations. In that circumstance, the ECB has acknowledged the severe effects of climate change on economic and financial variables and ultimately on price stability, recognising, in addition, that addressing climate change is a global challenge and a policy priority for the EU.

Therefore, the GC is committed to ensuring that the Eurosystem fully takes into account the implications of climate change and the carbon transition for monetary policy, in line with the climate objectives of the EU, but without undermining its primary mandate. Against this background, the GC has decided to incorporate climate factors in its monetary policy assessment and to adapt its monetary policy operational framework in relation to disclosure, risk assessment, corporate sector asset purchases and the collateral framework, according to an ambitious climate-related action plan.

This plan was published by the ECB together with the announcement on the new monetary policy strategy, including a detailed roadmap. The action plan comprises measures that aim at broadening the Eurosystem policies to better account for climate change considerations and pave the ground for changes to the monetary policy implementation framework. The ECB also clarified that the design of these measures should be consistent with the price stability objective and should take into account the implications of climate change for an efficient allocation of resources. The ECB Climate Change Centre, in close cooperation with the Eurosystem Committees, coordinates the relevant activities within the ECB. The activities set out in the action plan include the following:

Macroeconomic modelling and assessment of implications for monetary policy transmission. The ECB will accelerate the development of new models and conduct theoretical and empirical analyses to monitor the implications of climate change and related policies for the economy, the financial system and the transmission of monetary policy through financial markets and the banking system to households and firms.

Statistical data for climate change risk analyses. The ECB will develop new climate change indicators to better evaluate climate-related risks and enhance transparency. The first set of indicators was published in January 2023.[6]

Disclosures as a requirement for eligibility as collateral and asset purchases. The ECB will introduce disclosure requirements for private sector assets as a new eligibility criterion or as a basis for a differentiated treatment for collateral and asset purchases.

Enhancement of risk assessment capabilities. The ECB will conduct climate stress tests of the Eurosystem balance sheet starting in 2022 to assess the Eurosystem's risk exposure to climate change, adopting the methodology of the ECB's economy-wide climate stress test.[7] Furthermore, the ECB will assess whether the credit rating agencies accepted by the Eurosystem Credit Assessment Framework (ECAF) disclose the necessary information to understand how they incorporate climate change risks into their credit ratings. In addition, the ECB considered to develop minimum standards for the incorporation of climate change risks into its internal ratings.

Collateral framework. This activity will ensure that climate change risks are reflected in the valuation and risk control frameworks for assets mobilised as collateral by counterparties for Eurosystem credit operations.

Corporate sector asset purchases.[8] The ECB already started in 2020 to consider climate change risks in its due diligence procedures for corporate sector securities purchases in its monetary policy portfolios. As of October 2022, the ECB also included climate change criteria in the allocation framework guiding corporate bond purchases. Furthermore, as of March 2023, the ECB started publishing its annual climate report related to the monetary policy corporate sector assets, complementing the similar disclosure on the non-monetary policy portfolios.

3 The Measures to Incorporate Climate Change into the Eurosystem's Monetary Policy Operations (July 2022)

On 4 July 2022, the GC of the ECB decided to take further steps to include climate change considerations in the Eurosystem's monetary policy framework, by: (i) introducing collateral pool limits for issuers with a higher carbon footprint (described below in Sect. 3.2); (ii) introducing climate-related disclosure requirements for collateral (Sect. 3.3); (iii) enhancing its risk management practices (Sect.

[6] See https://www.ecb.europa.eu/stats/ecb_statistics/sustainability-indicators/html/index.en.html

[7] See Alogoskoufis et al. (2021).

[8] Corporate assets purchased under the Corporate Sector Purchase Programme (CSPP) and the Pandemic Emergency Purchase Programme (PEPP).

3.4); and (iv) tilting corporate bond holdings in the monetary policy portfolios (Sect. 4).

These measures take into account climate-related financial risks in the Eurosystem balance sheet, support the green transition of the economy in line with the EU's climate neutrality objectives and provide incentives to companies and financial institutions to be more transparent about their carbon emissions and to reduce them.

We will also briefly describe a measure taken by the ECB before 2022, concerning sustainability-linked bonds (Sect. 3.1).

3.1 The Acceptance of Sustainability-Linked Bonds as Collateral

On 22 September 2020, the GC of the ECB decided that, starting from the beginning of 2021, bonds with coupons linked to sustainability performance targets (the so-called sustainability-linked bonds, SLBs) would have become eligible as collateral for Eurosystem credit operations and for Eurosystem outright purchases for monetary policy purposes, provided they comply with all other eligibility criteria.

This decision is an exception to the general rule of not accepting financial instruments with a step-up or a step-down coupon structure. The measure further broadens the range of Eurosystem-eligible marketable assets, signalling the support for innovation in the area of sustainable finance.

The coupon payment is linked to a performance target on one or more of the environmental objectives set out in the EU Taxonomy Regulation and/or on one or more of the United Nations Sustainable Development Goals related to climate change or environmental degradation.[9]

The ECB's decision to accept SLBs as collateral for its credit operations and outright purchases, combined with the publication of the ICMA Principles for the standardisation of these financial instruments,[10] contributed to the remarkable growth of the SLB market (see Maino 2022). Since the ECB's decision, the total outstanding amount of Eurosystem-eligible SLBs has increased more than tenfold, reaching almost 45 billion euros in February 2023. The share of eligible SLBs in the overall sustainable space (which also includes green bonds) has risen from 4 per cent to 20 per cent, owing also to the less buoyant growth of the green bond market (see Chap. "The Global Green Bond Market").

In the same period, the Eurosystem increased the amount of SLBs in its corporate bond portfolio, reflecting the expansion of that market.

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[9] See https://sdgs.un.org/goals

[10] See ICMA (2023).

3.2 The Introduction of Collateral Pool Limits for Issuers with a Large Carbon Footprint

The Eurosystem has decided to limit the share of assets issued by entities with a high carbon footprint that can be pledged as collateral by individual counterparties when borrowing from the Eurosystem. The new pool limits aim at reducing climate-related financial risks in Eurosystem credit operations. The measure should become effective before the end of 2024, once the necessary technical adjustments to the procedures have been implemented. As a first step, the Eurosystem will apply such limits to marketable debt instruments issued by non-financial corporations and further asset classes may be added as the quality of climate-related data improves.

Moreover, the Eurosystem will run tests of the limit regime ahead of its implementation, in order to support banks and other counterparties to be prepared in advance.

Finally, the Eurosystem will consider climate change risks when reviewing haircuts[11] applied to corporate bonds used as collateral.

3.3 Disclosure Requirements for Collateral

The Eurosystem decided to accept marketable assets and credit claims as collateral in Eurosystem credit operations only from companies and debtors that comply with the Corporate Sustainability Reporting Directive [12] (CSRD). These new eligibility criteria are expected to apply as of 2026 at the earliest, once the CSRD will be fully implemented.

This requirement, which will apply to all companies within the scope of the CSRD, will improve disclosure and generate better data for financial institutions, investors and the society.

Since a significant proportion of the assets that can be pledged as collateral in Eurosystem credit operations do not fall under the CSRD (such as asset-backed securities and covered bonds), the Eurosystem will support better and harmonised disclosure of climate-related data for them, engaging closely with the relevant authorities (EBA, EIOPA, and ESMA) to ensure a proper assessment of climate-related financial risks for these assets as well.

[11] Haircuts are reductions applied to the value of collateral based on its riskiness (for more details see Chap. "The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency").

[12] The CSRD requires all large companies and all companies listed on regulated markets (except listed micro-enterprises) to report the impact of corporate activities on the environment and society, and the audit (assurance) of reported information.

3.4 Risk Assessment and Management

The ECB's analysis has shown that the current disclosure standards by the rating agencies are not yet satisfactory.

To improve the external assessment of climate-related risks, the Eurosystem urges rating agencies to be more transparent about how they incorporate climate risks into their ratings and to be more ambitious in their disclosure requirements on climate risks (see Breitenstein et al. 2022). A close dialogue between the Eurosystem and the relevant authorities on this matter is crucial to reach this goal.

Additionally, the Eurosystem has agreed on a set of common minimum standards for how national central banks' in-house credit assessment systems (ICASs; see Chap. "The Bank of Italy's In-House Credit Assessment System for Non-Financial Firms") should include climate-related risks in their ratings. These standards will enter into force by the end of 2024.[13]

4 The Actions Aimed at Decarbonising Corporate Bond Holdings

In 2016, the ECB introduced the CSPP to strengthen the pass-through of the asset purchases to the financing conditions of the real economy.[14] The evidence is that the CSPP has been effective in this respect, reducing yield spreads both directly, on purchased and targeted bonds issued by European non-bank corporations, and indirectly, on all other non-eligible corporate bonds through the work of the portfolio rebalancing channel.[15]

Carbon-intensive companies have also benefited from the positive effects of the CSPP, because until September 2022, the ECB conducted corporate bond purchases guided by a market neutrality principle, without any discrimination based on environmental or social criteria. The operationalisation of this principle entailed the ECB purchasing securities in proportion to their relative bond market capitalisation, that is purchasing more from companies that had issued higher volumes of bonds.[16]

The implementation of the market neutrality principle has implied that the Eurosystem corporate portfolio exhibits a bias towards carbon-intensive industries, because large firms in these sectors are likely to issue more bonds and tend to receive a more favourable assessment by credit rating agencies compared to non-carbon-intensive companies (see Dafermos et al. 2020). This has led to a relatively high

[13] See ECB (2022).

[14] See ECB (2017).

[15] See Mäkinen et al. (2020) and Zaghini (2019).

[16] In practice, the ECB used to deviate from a strict interpretation of market neutrality in several instances (for example for risk management measures), implying that its bond holdings are not strictly proportional to the market capitalisation.

emission intensity of the corporate portfolio and an accumulation of climate risks in the Eurosystem balance sheet.[17] This carbon bias may also not incentivise the decarbonisation of the euro area economies.

The concept of market neutrality is not a legal rule nor a principle described in the European Treaties, but its operationalisation has been considered compliant with the Treaty prescription of ‘acting in accordance with the principle of an open market economy with free competition, favouring an efficient allocation of resources’.

However, in the presence of market failures, such as climate externalities, adhering to the market neutrality principle may reinforce pre-existing inefficiencies, thus giving rise to a suboptimal allocation of resources. If the market misprices the risks associated with climate change, adhering to the market neutrality principle may hamper, rather than favour, an efficient allocation of resources (see Schoenmaker 2019 and Papoutsi et al. 2022).

Against this backdrop, the ECB decided to reconsider the market neutrality principle, adjusting the benchmark that guides the corporate bond purchases in order to incorporate climate considerations.[18]

Following the above-mentioned considerations, the ECB decided to gradually decarbonise the corporate bond holdings in its monetary policy portfolios,[19] on a path aligned with the goals of the Paris Agreement, while the overall size of the purchases continues to be solely guided by the price stability objective. To that end, the main action performed by the Eurosystem so far is the tilting of corporate bond reinvestment purchases towards issuers with a better climate performance. This means that the Eurosystem is increasing the weight in its portfolio of companies that do better compared with those with a poorer climate-related performance. As a result, the corporate bond portfolio is gradually becoming less carbon intensive.

In addition, the Eurosystem introduced a differentiated bidding approach in the primary market issuance of bonds to favour issuers with better climate performance and green bonds.[20]

Finally, the Eurosystem imposes maturity limits on corporate-sector securities issued by companies with lower climate performance, in order to mitigate the longer-term exposure of its portfolio to transition risks. The new framework has been implemented since 1st October 2022.

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[17] See Schnabel (2021).

[18] See Elderson and Schnabel (2022).

[19] Similar measures have been introduced also by the Bank of England and the Sveriges Riksbank in 2021. For more details, see Bank of England (2021) and Sveriges Riksbank (2023).

[20] Currently, there is no uniform green bond standard within the EU. Consequently, the Eurosystem adopted a stringent identification process for the green bonds that benefit from a preferential treatment. The criteria include, as a starting point: (1) alignment of the green bond framework with a leading market standard, such as the International Capital Markets Association Green Bond Principles or Climate Bonds Initiative; (2) a second-party opinion indicating that adherence to that standard has been reviewed and is confirmed; and (3) a pledge in the bond prospectus to the effect that regular third-party assurance on the use of proceeds is foreseen (e.g. annual verification by an external auditor) until the funds concerned have been fully deployed.

To assess the climate performance of the issuers, the Eurosystem calculates a climate score for each issuer, based on three dimensions: backward-looking emissions, forward-looking targets and climate disclosures. More specifically, the overall climate score combines three sub-scores[21]:

The backward-looking emissions sub-score reflects the (disclosed) past greenhouse gas (GHG) emissions and emission intensities (normalised by revenue) of an issuer. It encompasses Scope 1 and 2 data[22] for any given issuer and Scope 3 data at the sectoral level.[23] The sub-score combines a best-in-class with a best-in-universe approach. The best-in-class approach compares companies against their peers within specific industry sectors, while the best-in-universe approach compares companies across the entire corporate universe. If issuers do not report emissions data, they receive a lower backward-looking emissions sub-score value.

The forward-looking target sub-score reflects an issuer's expected future changes in GHG emissions. Issuers that are on an ambitious decarbonisation path towards the Paris Agreement targets receive a higher score, particularly if the target is science-based and has been validated by a third party. If issuers have no self-reported emission data, such that emission reduction targets cannot be verified, they receive the lowest sub-score in this dimension. Similarly, if issuers do not have short-term decarbonisation targets, they receive the lowest value for this sub-score. In short, companies with more credible and ambitious decarbonisation targets receive a better score.

The climate disclosure sub-score reflects the quality of the GHG emissions data provided by issuers. It rewards issuers with high-quality disclosure, thus creating incentives to improve data quality. For example, the Eurosystem looks at whether issuers disclose their GHG emissions and whether a reliable third party verifies them. The Eurosystem does not rely on estimated or modelled data on issuers' emissions. If issuers have no self-reported emission data, they receive the lowest

[21] The metrics on which the three sub-scores are based are retrieved from publicly available data as well as other relevant information and methodologies, such as science-based targets. The design of the climate scoring methodology is guided by the requirements for the EU Climate Transition Benchmarks and EU Paris-Aligned Benchmarks under Regulation (EU) 2016/1011 as amended by (EU) 2019/2089.

[22] Scope 1 emissions encompass an entity's direct emissions, and thus its exposure to rising costs from higher carbon taxes. Scope 2 measures indirect emissions from electricity, heat and steam consumption, and therefore reflects an entity's exposure to rising input prices. Scope 3 is defined in the GHG Protocol as all the indirect emissions of an entity and its products, excluding those falling into Scope 2, i.e. it includes emissions across the entire value chain.

[23] Issuer-specific Scope 3 data quality is currently not deemed sufficient for the data-dependent decision-making process that will be used for tilting. However, sectoral Scope 3 data were assessed as being sufficiently reliable and were therefore included in the methodology. Using these data ensures that the tilting methodology more accurately reflects the issuer's overall carbon footprint. The inclusion of sectoral data also makes it possible to incorporate Scope 3 data progressively, thereby minimising any cliff effects that might occur if issuer-specific Scope 3 data were to be introduced at a later stage.

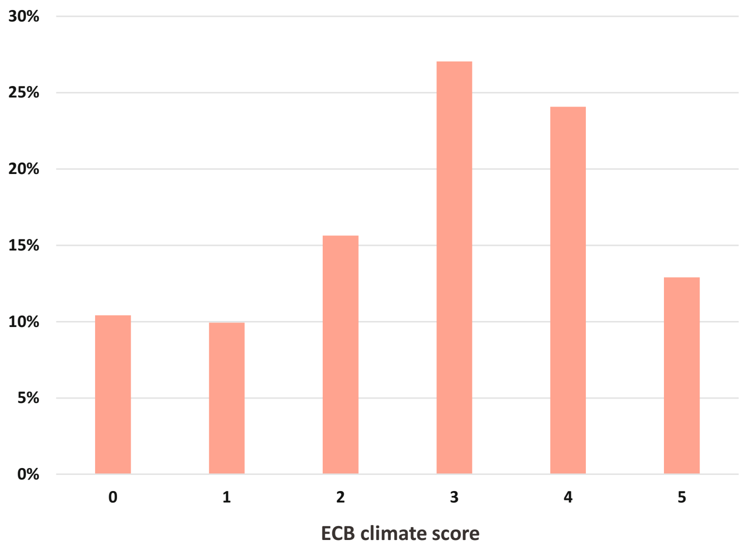

Fig. 1 Share of corporate bond issuers by score (as of 30 January 2023; source: ECB)

sub-score value, reflecting the fact that it is not possible to assess the transition risk to which these issuers are subject.

As of January 2023, the largest share of issuers in the corporate portfolio gets a climate score of 3 (around 27 per cent) or 4 (24 per cent). The issuers with the best score (5) are around 13 per cent, while fewer issuers (10 per cent) get 0, the worst score (Fig. 1).

On 2 February 2023, the GC of the ECB gave details of the modalities for reducing Eurosystem's holdings of securities under the Asset Purchase Programme through partial reinvestment. From March to June 2023, the reinvestment of the principal payments from maturing securities declined on average by € 15 billion per month. Besides, for the three private sector programmes,[24] primary market purchases were phased-out at the start of the partial reinvestments, with the exception of corporate issuers with a better climate performance and green corporate bonds, which are still being purchased in the primary market.

As the reduction of CSPP reinvestments impacted the effectiveness of the tilting parameters, which were estimated during the CSPP net purchases phase,[25] the GC also decided on a stronger tilting of its corporate bond purchases towards issuers with a better climate performance during the period of partial reinvestment.

The average effect of CSPP tilting on corporate bond yields is estimated to be broadly contained, as the market-based financing costs' increase for companies

[24] Namely, ABSPP, CBPP3 and CSPP.

[25] See Schnabel (2023).

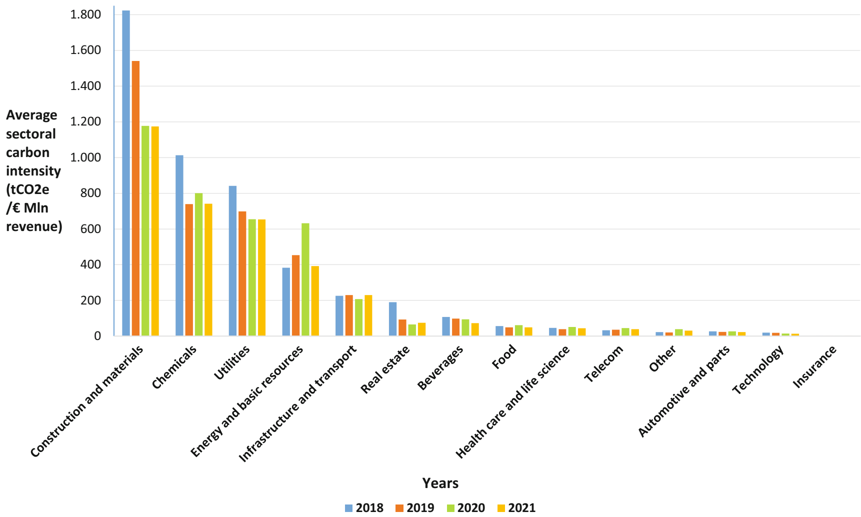

Fig. 2 Weighted average carbon intensity across sectors

which are underweight in purchases and decrease for those overweight on aggregate cancel out (see Aubrechtová et al. 2023).

4.1 Communication

The ECB started publishing climate-related information on corporate bond holdings regularly as of March 2023 (see ECB 2023). It will regularly publish such reports every year.

The disclosure contained in the climate report follows the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) of the Financial Stability Board for the initial framework and reporting. In addition, the Eurosystem has incorporated the TCFD's additional recommendations for asset owners[26] and has adopted the recommendations of the Network for Greening the Financial System (NGFS) in its reporting.[27] The report contains information on the Eurosystem's governance, its climate-related strategy, the climate scoring tool to assess the corporate bond portfolio issuers, a set of climate-related metrics of the corporate bond portfolio, and qualitative decarbonisation targets.

In the last few years, a significant improvement has taken place in the carbon intensity of issuers aggregated by sector, as measured by tonnes of CO_2 emitted over € millions of revenues (Fig. 2). This is particularly the case for the most

[26] See TCFD (2021).

[27] See NGFS (2021b).

carbon-intensive sectors, such as Construction and materials, Chemicals, and Utilities. Due to the presence of these emission-intensive sectors, there is a relatively high concentration of the corporate bond portfolio carbon emissions in a relatively small share of its holdings (76 per cent of the portfolio GHG emissions are concentrated in the worst 5 per cent of the emission distribution).

The Weighted Average Carbon Intensity[28] of the corporate bond purchases carried out after the implementation of climate change considerations is significantly lower (−65 per cent) with respect to purchases conducted during the first nine months of 2022.[29] However, the tilting will take time to produce a substantial effect on the overall corporate portfolio carbon metrics, as the stock of existing holdings is very large compared to the ongoing reinvestments.

5 Conclusions

Climate change is a clear and present danger for the global economy that affects financial markets, institutions and enterprises. Macroeconomic and financial market disruptions linked to climate change and transition policies could affect the conduct of monetary policy and the ability of the Eurosystem to deliver on its price stability mandate. Besides, climate risks have an impact on the overall risk of the Eurosystem's balance sheet.

The action plan adopted by the ECB in July 2021 and the measures to further include climate change considerations in the monetary policy framework announced in July 2022 reflect the commitment of the Eurosystem to decarbonise its bond holdings and integrate climate risks within its risk management framework.

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[28] The Weighted Average Carbon Intensity is computed as the total GHG emissions of each issuer standardised by a measure of company production value, weighted by the investment in the issuers' bonds as a share of the total portfolio value.

[29] See Elderson and Schnabel (2023).

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Part II
The Integration of Climate Change in Financial Risk Management

The Commitment to Sustainability in Financial Investments

Enrico Bernardini, Marco Fanari, and Franco Panfili

1 The Concept of Sustainability

In its broader view, the concept of sustainability is based on the definition formulated in 1987 by the Brundtland Commission[1] of the United Nations. Sustainability is based on a commitment between generations that ensures that the freedom of choice of future generations is not compromised by today's decisions and actions.[2] Over time, the vision of intergenerational equity has expanded towards a concept even wider than sustainable development, including the pursuit of environmental, economic, social, and institutional equilibria such as the protection of natural

[1] In the final Report of the World Commission on Environment and Development: Our Common Future in 1987 it was specified that: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission 1987).

[2] For many years, reflections on sustainability have focused on the relationship between economic growth and natural resources scarcity. The works of the Club of Rome in the 70s, inspired among others by Aurelio Peccei, identified the risks associated with demographic growth, the pressure that this would have exerted on consumption and therefore on available resources. These analyses were criticised arguing that resources scarcity, through the price mechanism, would have promoted the emergence of new technologies and would have induced a more efficient use.

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ecosystems, the responsible use of resources, the capacity to generate income and work, the equal access to education and health, and the exercise of the fundamental political rights for all people. This vision offers an intra-generational dimension of the concept of sustainability.

In addition, the various aspects of sustainability can interact with each other in a dynamic way with synergistic effects.

In 2015, with the approval of the 2030 Agenda,[3] the United Nations have identified 17 Sustainable Development Goals, including, among others, the fight against climate change, the protection of ecosystems and biodiversity, good management of natural resources, social and gender equality, and the fight against poverty. In economics and finance, the main dimensions of sustainability have been empirically framed around the environment, society, and corporate governance. These dimensions are the well-known ESG (Environmental, Social and Governance) factors.

2 The Threat of Climate Change

In recent years, the urgency of climate change effects has become prominent in the sustainability debate. The effects of climate change, induced by global warming, are broadly but unequally hitting the areas of the planet, with greater effects on some regions and on the most vulnerable segments of the population, both in developed countries and the less developed ones, which do not have the necessary resources to adapt. With the 2015 Paris Climate Agreement, signatory governments have formalised the commitment to containing the average increase in temperature, 'well below' 2 degrees Celsius compared to pre-industrial levels. Most of the involved nations have announced strategies and targets to reduce emissions. After signing the 2030 Agenda and the Paris Agreement, the European Union launched the Action Plan on Sustainable Finance in 2018.

This strategic plan places environmental sustainability at the centre of the European policies, to redirect capital flows towards sustainable investment, manage financial risks stemming from sustainability issues, and foster financial and economic transparency.

[3] The 2030 Agenda for Sustainable Development is a plan of action for people, planet and prosperity. Signed on 25 September 2015 by the governments of the 193 Member Countries of the United Nations and approved by the UN General Assembly, the Agenda sets out 17 Sustainable Development Goals, SDGs, which are part of a broader programme of action consisting of 169 associated targets to be achieved in the environmental, economic, social, and institutional domains by 2030.

The policy programme was reinforced in early 2019 with the launch of the European Green Deal,[4] a programme of legislative initiatives and investment plans for the following ten years, with the aim of achieving net zero greenhouse emissions by 2050. This long-term green strategy has been further enhanced by the measures taken in response to the coronavirus pandemic: more than one-third of the investments from the Next Generation EU fund will be devoted to the environmental objectives.

Finally, the Green Deal was strengthened in 2021 with the plan 'Fit for 55', reflecting a new level of ambition that enhances the target of reducing net greenhouse gas emissions by at least 55 per cent by 2030 compared with 1990 levels, and becoming carbon neutral by 2050.

The European Commission has estimated that in the period 2021–2030 the achievement of the climate and energy targets for 2030 will require investments in the energy sector (excluding transport) by EUR 336 billion per year, equal to 2.3 per cent of GDP.[5]

As of September 2022, about 170 countries have announced that they will pursue climate neutrality by mid-century and about 90 parties, covering approximately 80 per cent of global greenhouse gas (GHG) emissions, have adopted net-zero pledges either in law, in a policy document such as National Determined Contribution, in a long-term strategy, or in an announcement by a high-level government official. Governments outline the next steps at the United Nations Conference of Parties on an annual basis.

Climate change is also at the top of the G20 agenda. Under the Italian Presidency in 2021, the G20 has resumed the work of the Sustainable Finance Study Group, which was elevated to a permanent working group. The Group has developed a roadmap in some key priority areas, such as market development to align investments to sustainability goals; information on sustainability risks, opportunities and impacts; assessment and management of climate and sustainability risks; and role of public finance, international financial institutions, and policy incentives.

The urgency of climate change reflects the growing sensitivity of the public opinion on this subject. Especially among the younger generations,[6] awareness of

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[4] The Paris Agreement is an international treaty on climate change signed on 12 December 2015 during the XXI Conference of the Parties (COP) from 196 countries. Among its objectives, the most important goal is to limit the increase in the global average temperature below 2 °C compared to pre-industrial levels and preferably at 1.5 °C. According to the Report of the Intergovernmental Panel on Climate Change (2021), the planet has already experienced an average increase of the temperature of 1.09 °C compared to the temperature before the industrial revolution (1850–1900). In the absence of drastic reductions in the production of greenhouse gases, there would be an increase of temperatures between 1.4 and 4.4 °C by 2100, depending on the emissions path of greenhouse gases. It is necessary to halve emissions every 10 years to achieve carbon neutrality (equivalence of emissions produced and absorbed) in 2050.

[5] IPCC (2021) and European Commission (2019).

[6] Responses to the climate crisis have been spurred by increasingly alarming scientific data and by the protests of many movements, especially of young people, such as 'Fridays for future' (Figueres and Rivett-Carnac 2020).

the environmental risks is growing more and more, with a specific attention to the irreversible damages for ecosystems and human health.[7]

This awareness is fundamental to fuel better behaviours by tomorrow's adults and to guide future consumption choices and investment, making them more responsible.

As a consequence, more and more consumers and investors want to make climate-responsible choices.[8]

3 The Relevance of Sustainability for Financial Investments

In recent years, the importance of ESG factors has increased thanks to the growing interest of investors and authorities for socially responsible investments. Some empirical studies have explored the relationship between ESG profiles and the operational and financial performance of firms (Eccles et al. 2014; Antoncic et al. 2020; Conen and Hartmann 2019; Tsai and Wu 2021; Kim and Kim 2020).

Given the extent of research, literature reviews and meta-analyses have been performed on a number of issues, from the motivations underpinning the sustainability choices to the implications of ESG profiles for corporate performance.

Below we summarise the key results of recent research.

Friede et al. (2015) review more than 2000 studies and present the largest meta-analysis. Their review, largely relating to equity investments, reveals that about 90 percent of the studies identify a non-negative relationship between the ESG profiles and the financial performance of the companies. For a large majority of them, this relationship is positive and stable over time.

Clark et al. (2015) conduct a meta-study over the results of about 200 empirical works. They underscore that the market pressure towards short-term results is a major obstacle to the adoption of sustainable practices by corporate executives. Sound sustainability practices enable companies to benefit from the competitive advantages stemming from process and product innovation, consumer and employee satisfaction, and positive investor assessment. Favourable effects are also found in the mitigation of operational, legal, and reputational risks. These benefits translate into a more efficient allocation of resources, lower cost of capital and improvements in operational and market performance.

Whelan et al. (2021) review over 1000 studies on the relationship between ESG practices and corporate performance, by distinguishing financial performance (in terms of ROE, ROA, and stock return) and investment performance (in terms of alpha and Sharpe ratio). For the former, they find a direct relationship in 58 per cent of the studies; as concerns the investment performance, they find a direct relationship in 59 per cent of the studies. These percentages are similar or larger for the studies that focus on low-carbon policies by firms,

[7] IPCC (2021) and European Commission (2019).

[8] Italian Sustainable Investment Forum, BVA Doxa (2019), ISS ESG, Adelphi (2020).

According to Mervelskemper and Streit (2017), companies always benefit from communicating their ESG policies and disclosing the related indicators. This approach is a source of motivation for employees, which in turn raises their productivity (Burbano 2019; Hedblom et al. 2019). From a different perspective, investors can achieve extra returns by selecting companies with the highest ESG scores (Khan 2019; Madhavan et al. 2020).[9]

To overcome some limitations of the extant studies (like the unclear results in terms of correlation and causality, and the lack of economic interpretation of the results), Giese et al. (2019) consider three channels through which ESG factors can positively affect performance:

– cash flows (ESG companies generate higher dividends);
– risk (ESG companies have a lower corporate risk);
– valuation (ESG companies, thanks to a lower cost of capital, achieve a higher value).

Within the framework of a financial model based on the discounting of cash flows, a causal relationship is identified between changes in ESG ratings, the specific and systematic riskiness of the company and its financial indicators. The authors examine the effect of the changes in ESG ratings over a three-year period on idiosyncratic and systematic risk channels. The study shows that ESG factors, although less intense, are among the most persistent risk drivers, producing effects even after three years.

Naffa and Fain (2020) focus on equity investments based on particular aspects of sustainability, like gender equality, low carbon emissions, energy efficiency, and food safety. These features are related with important social, environmental, economic, political, and technological changes, with possible disruptive effects to daily life, as defined by Naisbitt (1982) and Boesl and Bode (2016). The analysis considers nine themes by defining appropriate portfolios and documents an excess return for most thematic portfolios compared to market indices.

According to the above studies, sustainable investing generates extra returns. In addition to sustainability, this general result may also be due to other factors. ESG risk may have been underestimated in the past, while investors have not correctly predicted the higher returns resulting from the sustained growth of the green sector.

The empirical application of the traditional risk-return model employs past data series, which inevitably makes the model retrospective, while sustainability assessment requires a forward-looking and long-term approach.

[9]Even before the meta-study by Friede et al. (2015), a positive effect of environmentally sound business management on yields was found (Klassen and McLaughlin 1996). Gompers et al. (2003) show that corporate governance provides a key (positive) contribution to returns; a weak governance negatively affect financial performance (Core et al. 1999). Auer (2016) finds that investment selection based on corporate governance profiles improves financial results and that companies with higher ESG scores are able to attain higher returns. In another influential series of articles, Edmans (2011, 2012) shows that portfolios invested in companies with highly satisfied employees generate significant excess returns.

In theory, constraining portfolio choices—by narrowing the set of stocks or imposing non-financial constraints—might hamper the portfolio return. The counterargument is that stock selection based on an ESG filter can help exclude securities with overestimated return expectations and/or high idiosyncratic risk (Hoepner 2010). The net balance of these two effects, of uncertain entity, must then be combined with the resulting positive externalities from the adoption of virtuous practices by companies. These externalities can foster sustainable growth, when firms adopt production methods that respect the environment, guarantee an inclusive workplace that is mindful of human rights, and align themselves to the best corporate governance standards.

4 The Main Initiatives of International and European Authorities Toward Sustainable Finance

In view of the political agenda, and against the background of the empirical results, the financial system will play a crucial role towards mobilising resources in support of the transition to a more sustainable economy. Twenty years after the Brundtland Commission report, several international initiatives have been adopted to step up the role of finance.

Launched in 2006 by the UNEP Finance Initiative[10] and the UN Global Compact,[11] the United Nations Principles of Responsible Investments[12] (UNPRI)

[10] The commitments undertaken by the institutional investors to the UNPRI reflect the duty to act in the best long-term interests of the beneficiaries of the managed financial resources. In this fiduciary role, environmental, social, and corporate governance (ESG) issues can affect the performance of investment portfolios. The signatories also recognise that applying these Principles may better align investors with broader objectives of society. Therefore, the commitments undertaken by UNPRI signatories are:

1. integrate ESG issues into investment analysis and decision-making processes;
2. be active shareholders and incorporate ESG issues into ownership policies and practices;
3. seek appropriate disclosure on ESG issues by the companies and organisations in which they invest;
4. promote acceptance and implementation of the Principles within the investment industry;
5. work together to enhance our effectiveness in implementing the Principles; and
6. report on their activities and progress towards implementing the Principles.

[11] The financial initiative of the United Nations Environment Program (*United Nations Environment Program Finance Initiative*, UNEP FI) is a collaboration between the Environment Program of the UN and the global financial sector. UNEP FI works closely with over 200 financial institutions signatories of the UNEP FI Statement on Sustainable Development, as well as with a number of organisations partners, to develop and promote links between sustainability and financial services.

[12] The *United Nations Global Compact* (UNGC) is a global and multilateral initiative to help aligning business activities and strategies to ten universally accepted principles in the fields of human rights, labour, the environment and fight against corruption, as well as catalysing private sector actions in support of the wider objectives of United Nations.

provide a voluntary framework whereby all investors can incorporate ESG criteria in their decisions.

In 2015, the Financial Stability Board created the Task Force on Climate-related Financial Disclosures (TCFD) to develop a set of voluntary disclosure recommendations to be used by companies in their provision of decision-useful information to investors, lenders, and insurance underwriters about the climate-related financial risks and opportunities of the companies.

In 2017, a group of central banks and supervisory authorities established the Network for Greening the Financial System (NGFS) to promote the exchange of experiences and the development of best practices for managing environmental and climate risks.

In 2018, the European Commission launched the European Action Plan for sustainable finance to mobilise the huge volume of resources needed to finance its decarbonisation strategy and to catalyse the support of the private sector. The Action Plan helps implement the Paris Agreement on Climate and the United Nations 2030 Agenda, defining the strategy and initiatives towards a sustainable financial system. Within this framework, the Commission has defined important measures, such as the reporting on sustainability, the taxonomy of environmentally sustainable economic activities, the European standards for green bonds, and the criteria for climate benchmarks.

The European Regulation on sustainability reporting in the financial services sector (Sustainability Financial Disclosure Regulation, SFDR)[13] strengthens the integration of ESG factors and sustainability risks in the asset managers' decision-making.

The SFDR aims at improving transparency in the market for sustainable investment, thus favouring investors and more generally the real economy and the long-term stability of the financial system. Transparency is also crucial to steer investors towards greater awareness of the impacts on the environment and society of the allocation choices of savings.

The goal of the Action Plan is the definition of a taxonomy of sustainable investments,[14] i.e. a set of detailed technical criteria to evaluate whether an economic activity can be considered as environmentally sustainable, that is whether it contributes to the achievement of the European environmental objectives.

The taxonomy was defined in June 2020. To become fully effective, this Regulation requires the definition of the technical screening criteria for the evaluation of the activities, to be adopted through delegated acts.[15]

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[13] EU Regulation n. 2019/2088.

[14] The EU taxonomy is one of the three pillars of the Action Plan, which also includes the European standards for green bonds and the EU Climate benchmark standard. These two initiatives set the reference criteria for classifying bond issues and indices in relation to specific sustainability criteria.

[15] In 2022, the Commission adopted a Complementary Climate Delegated Act including, under strict conditions, specific nuclear and gas energy activities in the list of economic activities covered by the EU taxonomy.

According to the Regulation, an eco-sustainable activity must:

– make a substantial contribution to the achievement of at least one of six environmental objectives of the European Union[16];
– not cause significant harm to any of the other environmental objectives ('do no significant harm' principle, DNSH);
– ensure compliance with minimum ethical and social principles (so-called minimum safeguard guarantees), and ensured by compliance with international standards and conventions.

The taxonomy will be used by financial market participants (investment firms, fund managers, pension funds, insurance, etc.) and by issuers offering instruments, financial products, and services within the European Union.

By creating an International Platform for Sustainable Finance,[17] the EU acts as a forerunner to similar initiatives that may be undertaken by other countries in the future.

The European Regulation on a standard for green bonds, under negotiations, is intended to favour the inflow of funding to projects that make activities more sustainable and, at the same time, ensure transparency in the use of funds. For a proper functioning of this segment of the bond market, it is necessary to certify a green bond, namely, to define standardised criteria for evaluating the environmental impact of the projects.

The International Capital Market Association (ICMA) has defined voluntary guidelines, the Green Bond Principles (GBP), as a reference for green bond issues. Taking stock of the ICMA guidelines, the European Commission has worked on a proposal to define more advanced standards to increase transparency and reliability for green bonds issued within the EU, giving further impetus for the development of this market segment. In 2019, the Commission proposed a standard for green bonds (European Union Green Bond Standard, EU GBS). In July 2021, this was translated into a proposed regulation to which issuers will adhere on a voluntary basis to gain the European Green Bond status for their securities.

In recent years, various categories of low carbon emission indices have been proposed and used by investors to measure the climate profiles of their portfolios. In view of the heterogeneity of the existing methodologies, objectives, and strategies,

[16] The six goals are: climate change mitigation; climate change adaptation; the sustainable use and protection of water and marine resources; the transition to a circular economy; pollution prevention and control; the protection and restoration of biodiversity and ecosystems.

[17] In 2019, the EU launched at the annual meetings of the Monetary Fund and the World Bank in Washington, the International Platform on Sustainable Finance (International Platform on Sustainable Finance, IPSF). The ultimate objective of the IPSF is to scale up the mobilisation of private capital towards environmentally sustainable investments. The IPSF therefore offers a multilateral forum of dialogue between policymakers that are in charge of developing sustainable finance regulatory measures to help investors identify and seize sustainable investment opportunities that contribute to climate and environmental objectives. Through the IPSF, members can exchange and disseminate information to promote best practices, compare their different initiatives and identify barriers and opportunities of sustainable finance, while respecting national and regional contexts.

the European Commission has introduced two new climate benchmarks: the climate transition benchmarks and the benchmarks aligned with the Paris Agreement.

This rapidly growing market deserves an improvement in the quality of information. The methodology for building climate benchmarks[18] has been developed to provide an official and clear reference in the offer of market indices that pursue the objective of fighting climate change; this also prevents the risk of illegitimate or ambiguous use of green labels.

The Shareholder Rights Directive[19] (SRD II), which strengthens the accountability mechanisms of corporate governance, requires an adequate commitment of institutional investors (insurance and pension funds) and asset managers. They are asked to be transparent on their engagement policy, describing the methodologies whereby they assess investee companies on the most important issues, such as strategy, corporate governance, social and environmental risks, and impact. The engagement policy should also clarify whether and how investors engage in a dialogue with the companies, exercise their voting rights, collaborate with other stakeholders, and manage possible conflicts of interest.[20]

The European legislation on non-financial information is at an advanced stage, thanks to a specific directive concerning corporate communication on sustainability (Corporate Sustainability Reporting Directive, CSRD[21,22]) that entered into force in January 2023. Companies will have to apply the new rules for the first time in the financial year 2024, for reports to be published in 2025.[23] From that date, a broader set of large companies, as well as listed small and medium enterprises (SMEs)—approximately 50,000 companies in total—will be required to report on

[18] The minimum standards associated to these indices were introduced by the Commission Delegated Regulation (EU) 2020/1818, which supplements the regulation (EU) 2016/1011/EU of the European Parliament and of the Council as regards the standards for the indices of EU Climate Transition Benchmark (CTB) and for EU Paris Aligned Benchmarks (PAB).

[19] Directive (EU) 2017/828 of the European Parliament and of the Council of 17 May 2017 amending Directive 2007/36/EC as regards the encouragement of long-term shareholder engagement.

[20] Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups.

[21] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting.

[22] The Corporate Sustainability Reporting Directive amends the existing reporting requirements of the Non-Financial Reporting Directive (NFRD). The Directive: (a) extends the perimeter to all large companies and all companies listed on regulated markets; (b) requests verification of the reported information; (c) introduce more detailed reporting requirements and the obligation to report according to mandatory standards; and (d) requires companies to digitally mark the information communicated so that it can be interpreted by a computer.

[23] The rules introduced by the NFDR (Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014) remain in force until companies have to apply the new rules of the CSRD.

sustainability adopting a double materiality perspective.[24] The non-financial statement will be based on the European Sustainability Reporting Standards (ESRS), a draft of which was published by the European Financial Reporting Advisory Group (EFRAG) in November 2022.

The new rules will ensure that investors and other stakeholders have access to the information they need to assess investment risks arising from climate change and other sustainability issues. The CSRD also makes the audit of the sustainability information mandatory for companies.

The most recent regulatory proposal regards the Corporate Sustainability Due Diligence Directive (CSDDD).[25] It should foster sustainable and responsible corporate behaviour and anchor human rights and environmental considerations in companies' operations and corporate governance. The new rules should ensure that businesses address adverse impacts of their actions, including in their value chains inside and outside Europe. Finally, the CSDDD should introduce the obligation for large companies to prepare transition plans for a decarbonisation pathway consistent with the Paris Agreement.

These laws provide guidance on corporate reporting and communication on the main risks stemming from their business and on the policies and results with reference to ESG factors. The disclosure of such information may enable to manage these risks, reduce the information asymmetry between investors and companies, and facilitate the companies' access to capital markets.

5 Trends in Sustainable Finance

In recent years, the share of sustainable investment in the financial market has rapidly grown, in parallel with the investor awareness on the effects of ESG factors on asset prices. The ESG-labelled instruments and the number of portfolio managers applying sustainability criteria have sharply increased.

According to the report of the Global Sustainable Investment Alliance (2021), in 2020 at least USD 35,300 billion (of which 12,000 in Europe and 17,000 in the United States) were allocated to sustainable investments, up by 15 percent compared to 2018. This amount is approximately equal to one-third of global equity assets under management; in some countries, it has exceeded half of the total. The assets

[24] Whereas n. (29) '. . .reporting not only on information to the extent necessary for an understanding of the undertaking's development, performance and position, but also on information necessary for an understanding of the impact of the undertaking's activities on environmental, social and employee matters, respect for human rights, anti-corruption and bribery matters. Those Articles therefore require undertakings to report both on the impacts of the activities of the undertaking on people and the environment, and on how sustainability matters affect the undertaking. That is referred to as the double materiality perspective, in which the risks to the undertaking and the impacts of the undertaking each represent one materiality perspective'.

[25] Corporate Sustainability Due Diligence Directive, published on 23 February 2022.

managed by the 4902 signatories of the UN PRIs have exceeded USD 121 trillion.[26] At the end of September 2022, the number of ESG-type ETFs in circulation on a global scale was 1449, with a market value of USD 368 billion, and a range of objectives covering, albeit not uniformly, all of the United Nations Sustainable Development Goals (Trackinsight 2022).[27]

Green and sustainable bond issues exceed USD 2000 billion on a global scale[28]; private sector issues with these labels are around 3 percent of total corporate bonds; and public issues are under 1 percent of total public sector securities.

Since the start of 2021, the new security issues have exceeded USD 400 billion, with a significant growth of those of social nature, also favoured by the adoption of the ICMA standards; among them are the EU issues to finance the temporary Support to mitigate Unemployment Risks in an Emergency (SURE) instrument.

The strong growth of sustainable finance has spurred a variety of investment strategies. They can be grouped according to the following criteria[29]:

(a) exclusion of certain securities or sectors, based on national rules or international treaties (for example, relating to weapons and tobacco);
(b) ‘best in class’, focused on positive selection of companies with the best ESG profile compared to their sector peers or in general;
(c) ESG integration, consisting in the explicit and systematic inclusion of important ESG factors in financial analysis;
(d) thematic (or positive impact) investments that try to generate a positive impact, voluntary and quantifiable, in some areas including the environment (e.g. energy, water, and waste), in addition to financial returns;
(e) voting and engagement with issuers, as tools to improve business conduct, contribute to sustainable development and maximise risk-adjusted returns.

These strategies may sometimes be combined. According to the latest survey conducted by Eurosif (2018) on European professional managers, at the end of 2017, the most popular strategies were those under exclusion, followed by voting and engagement, with a strong growth of ESG integration in recent years.

Sustainable investments require the availability of reliable data to guide investors and prevent the risk of an improper use of sustainability labels (the so-called green-washing and ESG-washing). ESG scores, the basis of many investment strategies,

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[26] UN PRI data for the fourth quarter of 2022. The value considers the assets managed by fund managers and fund owners, the latter weighing slightly more than 20 billion.

[27] According to Trackinsight data, 15 of the 17 Sustainable Development Goals (Sustainable Development Goals, SDG) set by the United Nations, are covered by ESG ETFs. More than 400 ETFs are lined up with an SDG and most of the resources are aligned with three goals: a) climate action (SDG 13); b) industry, innovation and infrastructure (SDG 9); and c) affordable and clean energy (SDG 7) (Trackinsight 2023).

[28] Data on green and sustainable bonds, referred to mid-August 2021, are computed from Bloomberg Finance L.P. data.

[29] The classification has been developed by Eurosif and is included in the Principles of Responsible Investment of the United Nations (UNPRI).

currently show limitations in terms of completeness and quality of information, also due to the heterogeneity of the assessment methodologies.

The entities that provide ESG scores often express very different views on the same issuer. The scores are based on proprietary methodologies and there is no reference model, unlike financial evaluations and credit ratings. The discrepancies of ESG scores and ratings may also arise from the selection of different sustainability profiles and indicators, and from the relative importance assigned to them by the analysts. [30]

The heterogeneity among ESG indicators may also depend on the objective of the evaluation, i.e. whether it is aimed at investors interested only in the financial impact on the company, or whether it is addressed at stakeholders with relevant interests in all factors that can have a significant impact on the environment and society.[31] The solutions adopted by the providers of ESG scores are affected by the quality of corporate information, which is rather heterogeneous across geographical areas and business sectors. The initiatives aimed at fostering non-financial reporting and data validation will increase the consistency of ESG assessments in the future.[32]

Finally, most available indicators are backward looking.[33] This is at odds with the concept of sustainability, which is inherently forward looking. It would thus be advisable for companies to adopt sustainability commitments with quantitative targets and a clear timing.[34]

6 Climate Risks and the Role of Central Banks

The fight against climate change is primarily within the responsibility of national governments. They can design and implement incentives (e.g. a carbon tax), regulations, and sanctions. Yet, given the complexity of this challenge, the contribution at global level of authorities, firms, and individuals is crucial.[35] Central banks pay

[30] Berg et al. (2019).

[31] In the first case, factors affecting the company financial value will be identified (revenues, costs, profitability, etc.), in the second case all the factors that have an impact on the environment will be identified, regardless their financial relevance.

[32] A significant initiative is the agreement signed by the five main sustainability standard-setters: Sustainability Accounting Standards Board (SASB), Global Reporting Initiative (GRI), Carbon Disclosure Project (CDP), Climate Disclosure Standards Board (CDSB), International Integrated Reporting Council (IIRC), in order to coordinate their standards and create a global reporting system, able to integrate with financial reporting (see Statement of Intent to Work Together Towards Comprehensive Corporate Reporting) or the proposal to set up a global body for the definition of reporting rules that integrate sustainability data with accounting data (Sustainability Standards Board) under the aegis of the IFRS.

[33] Shoenmaker and Shramade (2019).

[34] 2° Investing Initiative (2017).

[35] Visco (2020).

attention to the sustainability profiles, and in particular to climate risks, for their potential effects on the ability to pursue the institutional goals, such as price stability and financial stability.[36] Sustainability factors can interfere in a number of ways with the transmission of monetary policy and banking supervision.

Physical and transition risk factors[37] affect the macroeconomic variables that matter for monetary policy, including production, investment, labour productivity, and inflation expectations.[38]

To evaluate these effects, it is necessary to adapt the macroeconomic models in order to have more accurate projections for monetary policy decision-making.[39]

Sustainability risks require a broadening of the analysis and a wider time horizon to factor in the effects of climate change which now seem unavoidable, although uncertain in intensity and frequency. This paradigm shift has been dubbed the 'tragedy of the horizon' by the former Governor of the Bank of England Carney.[40]

The climate-related macroeconomic risks are also a source of instability at the microeconomic level through the potential effects on profitability and solvency of bank debtors, on the value of the collateralised assets and on the overall stability of the financial system.

For these reasons, central banks and supervisory authorities are at the forefront of the assessment of these risks and are reviewing their policy instruments accordingly. Several initiatives have been taken to prepare the financial system to face climate-related risks, encouraging financial institutions to widen their operational and risk management practices. Leading by example, central banks favour the channelling of funds towards the transition to a low-carbon economy.

7 Central Bank Initiatives

Central banks have taken significant joint efforts to tackle climate risks and seize the opportunities of an orderly transition towards a more sustainable economic and financial system. Among these initiatives, the NGFS was established in 2017. The Bank of Italy has joined the NGFS since 2019 and actively contributes to all of its work streams, such as micro and macro-prudential supervision, macroeconomic analysis, monetary policy, sustainable investments, and sustainability data and research on climate and environmental issues.

[36] Bernardini et al. (2021).

[37] Physical risk arises from progressive climate change and, in particular, from growth of temperatures, by the greater irregularity of the precipitations and by the increase of the probability of extreme natural events. Transition risk arises from the possibility of a disorderly transition towards a low-carbon economy.

[38] NGFS (2020a).

[39] Signorini (2020).

[40] Carney (2015).

The NGFS plays a central role in sharing the experiences of central banks and supervisors and facilitating multilateral research and initiatives. The uncertainty, endogeneity, and non-linearity of climate phenomena[41] make the analysis of climate risks very complex.

For this reason, cooperative action can help build intellectual capacity and develop appropriate methodologies in a shorter time frame. Some recent NGFS studies offer a methodological contribution and stimulate intermediaries in the analysis and consideration of climate risks:

- the macroeconomic scenarios, published in June 2020 and updated yearly since then, provide the basis for conducting analyses and stress tests of climate risks[42];
- the overview of environmental risk analysis by financial institutions, published in September 2020, highlights that such practices are still not widespread, due to data challenges and limited internal capabilities of the intermediaries. The overview encourages the dissemination of supervisors' expectations to stimulate banks to measure and disclose their own environmental risk assessments[43]; and
- the review, published in March 2021, of the central banks' options for adjusting the monetary policy implementation framework for climate-related risks. Credit operations, collateral eligibility criteria, and securities purchase programmes are three important policy areas with climate-related operational options.[44]

In July 2021, the Eurosystem decided to include the analysis of climate risks in the overall review of its monetary policy strategy. Without prejudice for the primary objective of price stability, the mandate of the ECB foresees the support for the general economic policies of the European Union, including environmental protection and sustainable growth.

Central banks are also exposed to climate risks as investors (NGFS 2020c). In this role, it is important that these risks are duly taken into account in the management of their balance sheets, with a view to preserving financial soundness and independence. To the extent that the current market prices do not adequately reflect climate risks, there is a possibility that a disorderly adjustment of prices occurs, with negative effects on investor portfolios.[45]

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[41] Monasterolo (2020).

[42] NGFS (2021b).

[43] NGFS (2020b).

[44] As far as credit operations are concerned, the interventions may consider adjustments on valuation (to reflect the exposure to climate risks of loan counterparty or composition of the collateral), the eligibility criteria of the counterparties on the basis of their sustainability reporting and green investments. As far as collateral is concerned, the interventions may regard margins, negative (or positive) screening in the eligibility criteria, or the alignment of the collateral with climate indicators. As far as purchases are concerned, different weighting strategies can be envisaged based on the climate change indicators (tilting) or negative screening (NGFS 2020a, 2021a).

[45] Schnabel (2020).

The general principle of central banks as investors is market neutrality, aimed at avoiding price distortions and preserving the efficient functioning of financial markets. Yet, it is becoming clear that this principle should be adapted, in a context in which market forces are leading the concentration of greenhouse emissions to levels not in line with another type of neutrality, i.e. climate neutrality.[46] Within the Eurosystem, central banks agreed in February 2021 on a common stance for climate-related sustainable investments in non-monetary policy portfolios.[47] The common stance promotes the assessment and disclosure of climate-related risks for these portfolios. In March 2023, the Eurosystem has started the publication of climate-related data for the non-monetary policy portfolios, based on the recommendations of the TCFD. Several Eurosystem central banks had already published climate-related data on their non-monetary policy portfolios, including the Bank of Italy since 2022.[48]

8 The Bank of Italy as a Sustainable Investor

The Bank's investment policy pursues the twofold strategic objective of preserving the capital invested under adverse scenarios and prudently seeking a return, to help cover the operational costs. For foreign exchange currency reserves, the Bank also aims at a high degree of liquidity.

Since 2019, the Bank of Italy has integrated sustainability criteria in its financial investment strategy, based on a review of the available evidence and an in-depth analysis of sustainable strategies and ESG indicators. This decision also aims at promoting corporate social responsibility and improving financial and reputational risk management. As a result, more resources are available for firms that respect the environment, ensure inclusive workplaces which are mindful of human rights, and adopt the best corporate governance practices.[49]

ESG criteria were initially adopted for the internally managed equity portfolios for the Italian market and the rest of the euro area, owing partly to the wide availability of ESG data for equities. In 2020, the sustainable investment policy was gradually extended to other asset classes. In particular, the ESG criteria were applied to equity investments in the United States and Japan, by replacing the collective investment instruments used for these markets with similar instruments linked to ESG benchmarks.

[46] Visco (2019).

[47] The agreement has been reached following extensive preparatory work carried out by the Eurosystem and it benefited from the analysis developed at the NGFS, whose recommendations it incorporated.

[48] Hoepner et al. (2020).

[49] Bank of Italy (2019) and Cipollone (2021).

The replication of ESG indices in place of standard indices has been applied also to the management of the corporate bond portfolios, which is carried out internally for euro-denominated securities and through external managers for those denominated in US dollars.

In 2020, a portfolio of green bonds issued by supranational institutions and agencies was also set up. These euro- and dollar-denominated bonds came on top of the subscription made in 2019 of a share of the USD green bond fund managed by the Bank for International Settlements, mainly composed of sovereign and supranational bonds.

The commitment to sustainability was reaffirmed in 2021 with the Responsible Investment Charter, which presents the Bank's sustainable investment strategy.[50] The Charter defines the Bank's broad vision of sustainability, including all ESG aspects, and the principles and criteria that inspire its investment activity. It identifies the perimeter of the application and draws up the operational guidelines for the Bank's commitment. The Charter applies to the financial portfolio and foreign exchange currency reserves over which the Bank has full decision-making autonomy. It does not apply to portfolios relating to monetary policy, whose management is under the responsibility of the Eurosystem (Angelini 2021).

In its Charter, the Bank identifies three strategic lines of action: (a) promoting the disclosure of information on sustainability by issuers and other financial system operators; (b) integrating the ESG criteria into the management of its own investments, thus helping to disseminate good practices in this field; and (c) publishing data and analyses on sustainable finance, regularly communicating the achievements, thereby contributing to the spreading of an ESG culture in the financial system and among citizens.

In 2022, the Bank started the publication of its annual Report on sustainable investments and climate-related risks. The Report addresses the commitment, undertaken with the publication of the Charter, to disclose the methodologies adopted for ESG risks in the investment policy for the Bank's non-monetary policy portfolios, and the results obtained. The Report is inspired by the recommendations prepared by the TCFD and the NGFS 'Guide on climate-related disclosure for central banks'.

In 2022, the Bank outlined a pathway to further decarbonise equity and bond portfolios. The new measures involve the assessment of the companies' commitments, their long-term transition plans, and the results achieved in this field. In addition, new initiatives will be launched to raise the awareness of and hold dialogues with companies on the disclosure of sustainability data. To contribute to the emission reduction, a thematic equity portfolio has been created, including companies operating in renewable energy sources, energy efficiency, electric mobility, and green construction. These investments can contribute to the ecological

[50] The exclusion criteria are based on the fundamental conventions of the International Organization of labour, on international treaties on controversial weapons, on the non-proliferation treaty of nuclear weapons, and on the protocols to the Convention on the prohibitions or restrictions on the use of some conventional weapons.

transition by fostering the necessary technological innovations. The portfolio of green bonds will be enlarged.

9 Conclusions

Sustainability considerations have gained importance for investment decisions. The pandemic has increased the awareness of sustainability-related risks, such as climate risks, which typically materialise in the long run. The opportunities offered by the transition to a low-carbon economy may be important drivers of portfolio choices. To evaluate these prospects, reliable and comparable information is key. The initiatives underway require a coordination effort to avoid the proliferation of different standards by geographic area and instrument type and to build trust in users. The integration of sustainability factors into financial risk management[51] and portfolio allocation[52] are challenging new areas.

Central banks are playing an important role towards the climate transition, leading by example the financial system. The Bank of Italy has undertaken initiatives to promote sustainable finance and to integrate its principles into the management of its investments. This path, which extends over a number of asset classes, has recently been reaffirmed in the Sustainable Investment Charter, which defines the principles and actions that the Bank intends to implement in the coming years.

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The Strategic Allocation and Sustainability of Central Bank Investments

Davide Di Zio, Marco Fanari, Simone Letta, Tommaso Perez, and Giovanni Secondin

1 The Strategic Asset Allocation

In the last 15 years, the unconventional monetary policy measures adopted by major central banks in response to the crises have caused structural changes in their balance sheets (Logan and Bindseil 2019; Schwabb and Caballero 2019). The purchase programmes of the Eurosystem have significantly changed the national central banks' exposure to financial risks (see Chap. "The Cost of Unconventional Monetary Policy Measures: A Risk Manager's Perspective"; Bank of Italy 2017, 2022a). The sizeable growth of refinancing to the banking system, together with the expansion of eligible collateral (see Chap. "The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency"), has further affected the NCBs' balance sheet composition.

In parallel, the fight against climate change and the transition towards a more sustainable economic model have gained a growing importance for central banks. As discussed in Chap. "The Commitment to Sustainability in Financial Investments", these developments have implications for monetary policy, banking and financial supervision, and the investment of non-monetary policy portfolios (NMPPs; Lagarde 2021). In managing their investments, central banks can set an example for investors by allocating more resources to companies with the best environmental, social, and corporate governance practices (Visco 2019).

These developments have challenged the traditional objectives of the investment policy for central bank NMPPs and they have introduced new goals. In particular, a central bank must:

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- Keep a strong capital position to face the growing risks associated with its institutional functions.
- Ensure the profitability of the public resources it manages.
- Promote sustainable economic growth by adopting appropriate investment policies.

Central banks should thus adopt an effective strategic asset allocation (SAA) process that integrates financial and sustainability factors.

The SAA implemented by the Bank of Italy since 2010 entails two stages. The first stage is based on an integrated asset and liability management (ALM) approach, which takes into account its balance sheet structure, suitably integrated with some implicit items like monetary income, operating expenses, etc. (henceforth the 'integrated balance sheet'). Although the latter are not recorded in the standard financial statement, they affect the central bank's financial strength over the medium- to long term. The second stage relates to the selection of listed bonds and equities to be included in the portfolio. Since 2019, for such asset classes, the Bank of Italy has introduced sustainability principles, with the adoption of environmental, social, and governance indicators.

The SAA has driven the Bank of Italy's investment process towards greater portfolio diversification and the improvement in the sustainability of investments. The investment process is integrated with institutional considerations that have led the Bank of Italy to invest a significant share of its assets in Italian government bonds in compliance with external constraints.[1] The size and diversification of foreign exchange reserves have increased (see Appendix). Investments in the shares of companies with the best ESG practices have grown as well. These choices have led to a significant improvement in the environmental footprint of the portfolio: it shows a lower degree of greenhouse gas emissions and lower energy and water consumption with respect to the market portfolio (see Chap. "The Exposure of Investments to Climate and Environmental Risks"; Signorini 2020).

This chapter illustrates the SAA methodology adopted by the Bank of Italy and the inclusion of the sustainability considerations in this framework. Section 2 presents the central bank's main assets and liabilities. Sections 3 and 4 describe the generation of stochastic scenarios and the portfolio optimization process, respectively. Section 5 shows the results of the SAA process. Section 6 discusses the inclusion of sustainability issues in the Bank of Italy's investment decisions. Section 7 concludes.

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[1] In particular, art. 123 of the Treaty on the Functioning of the European Union (TFEU) prohibits the monetary financing of governments by the Eurosystem central banks. The ECB is responsible for verifying compliance of the NCBs with the provision of the TFEU. In practice, it is not permitted to subscribe public securities on the primary market. Purchases are permitted on the secondary market within maximum thresholds linked to the GDP of each country.

2 Capital, Investments, and the Integrated Balance Sheet

Financial soundness safeguards the independence and credibility of a central bank. The adequacy of its capitalization must be measured above all with reference to the most adverse 'states of the world', or future scenarios (Fanari and Palazzo 2018).

Unlike private investors, who optimize the unconditional risk-return profile of their portfolios, typically within a short-term investment horizon, central banks have to build portfolios that tend to appreciate (or depreciate as little as possible) in scenarios in which they may be expected to take more risks as a result of their institutional functions. Therefore, the typical central banks' modus operandi involves holding those assets, such as gold and foreign currencies, which tend to appreciate in periods of stress for the domestic economic and financial system that might occur in the medium- to long term.

Current and prospective financial soundness requires an analysis of all economic and financial items on which it rests. Some of these items, whose relative importance varies according to the institutional context, are of a non-accounting and contingent nature. A non-exhaustive list of such items includes:

- Liabilities related to the function of lender of last resort and, more generally, to the financial stability objective.
- Operating costs.
- Monetary income.[2]

These elements can be framed as implicit assets and liabilities, whose value corresponds to the present value of the cash flows they are expected to generate. The estimation of these implicit assets and liabilities is key for the assessment of the financial soundness of central banks (Stella 1997, 2005; Bindseil et al. 2004). The integrated balance sheet is thus the analytical tool to include into the SAA all the main sources of costs, revenues, and risks, taking also into account implicit assets and liabilities (Table 1). Among the implicit assets, monetary income is a permanent source of revenues that contributes to support the central bank's capital strength (Buiter 2007, 2021).

Over the last decade, the function of safeguarding financial stability has largely been performed through unconventional monetary policies. They have involved the move of a large number of financial instruments, public and private sector securities, into the Eurosystem's balance sheet, with the corresponding risks (Le Maux and Scialom 2013; Schwabb and Caballero 2019).

For all monetary policy items, the integrated balance sheet takes into account the risk-sharing rules within the Eurosystem.[3] In particular, the risk-shared monetary policy operations (as well as the portion of banknotes in circulation) are recorded in

[2] The 'monetary income' is defined as the annual income obtained from the assets held against the banknotes in circulation and deposit liabilities to credit institutions (Bank of Italy 2022b).

[3] See the box 'Rules on risk sharing on monetary policy operations' in Bank of Italy (2022b).

Table 1 Integrated balance sheet

Assets	Liabilities and net economic capital
Monetary policy: – Refinancing operations – Asset purchase programmes Investment portfolio: – Euro area government bonds – Euro-denominated corporate bonds – Equities	Bank reserves TARGET2 balances Present value of implicit liabilities
Foreign currency reserves Gold reserves Present value of implicit assets	Net economic capital

the integrated balance sheet on the basis of the Bank of Italy's share in the capital of the ECB.

The integrated balance sheet reports all items at market value, regardless of their accounting classification. Net economic capital, i.e. the difference between assets and liabilities, quantifies the available financial resources and is the object of the optimization. The process includes some (short-term) constraints aimed at avoiding accounting losses, which might affect the credibility of the central bank (see Sect. 4.2).

3 The Scenario Generation Model

3.1 Methodology

Net economic capital, as defined in Sect. 2, is the variable that summarizes a central bank's financial strength. Estimating its evolution over time requires the simulation of several economic and financial variables. The model selection is influenced by several factors; the main choice is between: (a) models that involve the simulation of each variable, or a narrow set of variables, separately; and (b) integrated models, such as vector autoregressive (VAR) models, that allow the simultaneous generation of a large set of economic and financial variables.

Models in the first category have the advantage that they can better capture the economic underpinnings of specific variables and asset classes. For instance, the evolution of interest rates could be simulated with term structure models (see, for example, Diebold and Li 2006), while stock returns could be estimated with factor models (e.g. Fama and French 1992). The disadvantage is that further assumptions are needed for the build-up of scenarios across asset classes,[4] possibly leading to inconsistencies.

Within the second category, VAR models lend themselves to the generation of a large set of variables recursively, taking into account their mutual relationships.[5] However, the number of variables included should be limited to preserve the consistency of the estimates, as well as the possibility of interpreting clearly the estimated parameters.

VAR models can be further classified into two types: frequentist VARs and Bayesian VARs (BVARs).[6]

Frequentist VARs are generally based on classical statistical and econometric methods. Parameters are treated as fixed (and unknowable) entities to be investigated by means of estimators; the latter are random variables that can be represented as functions of sample observations. Practical applications of these models in portfolio management have highlighted some critical issues. First, their complexity hinders the interpretation of the results, in particular when the number of simulated asset classes is large. Second, the results often generate corner solutions, due to small differences in expected returns, with allocations concentrated on a few assets only (He and Litterman 2002).

Black and Litterman (1992) attempt to make asset allocation algorithms easier to use and interpret with a model that enables the analyst to incorporate its own views on expected returns. The integration of these views is possible thanks to the application of Bayes' theorem. It leads to a different paradigm with respect to the frequentist approach. The Bayesian paradigm relies on a subjective definition of probability: model parameters are considered as random variables resulting from the merger between empirical data and other information that is not included in the time series. To perform the estimation, the analyst has to provide some prior information (either informative or not), which is absent in the frequentist approach. The analyst's expectations are incorporated into the model as subjective views on the set of parameters to be estimated through an appropriate multivariate distribution, known as the prior distribution. The analyst's confidence in her own views is reflected in the dispersion of this distribution: the higher the investor confidence, the more concentrated the prior distribution (Meucci 2015).[7]

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[4] Usually through the estimate of covariance matrix among variables, possibly resorting to its factorization. In most cases, factorization of the covariance matrix make use of Cholesky decomposition (e.g., Strang 2016).

[5] In recent years, global VAR models (GVAR) have also been developed to describe the trend of the global economy and financial markets (Pesaran et al. 2004).

[6] See for instance Green (2000); for the applications of BVAR methods see in particular Ciccarelli and Rebucci (2003).

[7] Through Bayes' theorem, the prior distribution and the probability distribution assumed on the data – also called likelihood – are combined to obtain a posterior distribution. The more the prior distribution differs from empirical evidence, the more the posterior distribution deviates from the prior distribution. The appropriate statistics of the posterior distribution will provide the estimates of the parameters of interest and their variability.

BVAR models thus combine:

- The historical behaviour of all the variables of interest, taking into account their interrelationships.
- The analyst's prior knowledge of the future values of either the parameters or the variables, according to the specification of the model.

Early BVAR models featured a large number of parameters to be estimated, with the consequent need to formulate many hypotheses on the prior distribution. As a result, the estimation of the model was not straightforward. The first step towards the solution of this problem was suggested by Litterman (1986) with the introduction of the *Minnesota prior* distribution. This distribution, defined over the whole matrix of regression coefficients, is merely a normal distribution in which the mean and the variance are determined with a predefined algorithm.

Although the Minnesota prior reduces the problems related to the definition of the parameters of the prior distribution, it provides no information on the equilibrium state of the VAR.[8] In this context, Villani (2009) proposes a Bayesian criterion for the estimation of a steady-state BVAR model, in which the unconditional mean of the process is explicitly modelled. As the predictions of the model converge asymptotically to the unconditional means, formulating an a priori distribution on this mean is equivalent to providing a view on the long-term trend of the variables. This is a benefit of the steady-state formulation, as it allows the analyst to impose her a priori knowledge on items that are easier to interpret, such as the long-term averages of the variables. The BVAR specification referred to in this chapter is the one proposed by Villani (2006, 2009).

3.2 *The SAA Simulation Model*

For its SAA, the Bank of Italy employs a BVAR model in the steady state specification. BVAR implementation starts from the identification of the asset classes to be simulated. They must encompass the investable universe of a central bank, while keeping the complexity of the model under control. The choice is based on two factors:

(a) The capability to express a view on the long-term trend of each variable.
(b) The robustness of the estimated coefficients and the stability of the model.

For the first aspect, reference is made to the experience of the analyst, to market data, and possibly to equilibrium models. The second aspect is essential for the convergence of projections to the unconditional mean. For parsimony reasons, the number of variables in the BVAR is kept at the minimum necessary to simulate the

[8] If the generating process is stationary, VAR and BVAR projections generally converge over the medium- or the long term to the unconditional mean, or equilibrium state, of the process.

Table 2 Variables modelled within the Bayesian VAR

1	Euro area overnight rate
2	5-year euro swap rate
3	Euro area 10-year government bond rate
4	US 10-year government bond rate
5	Japan 10-year government bond rate
6	UK 10-year government bond rate
7	Euro area corporate bond excluding financials option-adjusted spread (OAS)[a]
8	Euro area equity
9	World ex euro area equity
10	Euro area GDP
11	Euro area inflation
12	Gold
13	Euro/United States dollar exchange rate
14	Euro/Japanese yen exchange rate
15	Euro/British pound exchange rate

[a]The spread measures the difference in yield between a bond with an embedded option and the swap rates

expected returns of the integrated balance sheet items. The variables selected for the Bank of Italy's SAA are shown in Table 2.

Table 3 presents the descriptive statistics of the time series used in the BVAR, from the introduction of the single monetary policy in 1999 to the end of 2022. The sampling frequency is quarterly since it shows good statistical properties for long-term applications, thanks to a fair signal-to-noise balance. Even if a large part of the sample is characterized by accommodative monetary policies, the average yields to maturity of government bonds are influenced by their levels before the 2008 financial crisis. The same is true for overnight rates and other variables. For equity indices, the average quarterly returns are relatively small; periods of recession are in fact offset by the expansion phases of the economic cycle. On the foreign exchange market, the average quarterly percentage change of almost all currencies is close to zero. As expected, equity indices show the greatest volatility, followed by gold, foreign exchange rates, and interest rates. The variables with the lowest dispersion are the 10-year Japanese government bond rate and the euro area corporate bond spread with respect to the risk-free rate.

To make the model robust for the presence of outliers recorded during episodes of market turbulence, extreme values are removed from historical data through a process called winsorization. For a given value α, winsorization consists in imposing that observations exceeding the value of the level quantiles $\alpha/2$ and $1 - \alpha/2$ are set

Table 3 BVAR Time Series Descriptive Statistics (Quarterly data from Q1 1999 to Q4 2022; percentages). Interest rates and OAS are expressed on annual basis; the other variables are expressed as quarterly returns (Source: own calculations on Bloomberg Finance L.P. data)

	Euro area inflation	Euro area GDP	Euro area overnight rate	5Y euro swap rate	OAS euro corp. bond excl. financials	Euro area 10Y govt. bond rate	US 10Y govt. bond rate	Japan 10Y govt. bond rate
Minimum	−0.7	−12.4	−0.6	−0.5	0.5	−0.2	0.7	−0.2
1st percentile	−0.6	−8.6	−0.6	−0.4	0.5	−0.1	0.7	−0.2
5th percentile	−0.3	−1.5	−0.5	−0.3	0.5	0.1	1.5	−0.1
25th percentile	0.2	0.1	−0.3	0.3	0.8	1.2	2.2	0.1
50th percentile	0.5	0.4	0.6	2.5	1.1	3.5	3.1	1.0
75th percentile	0.7	0.7	2.7	3.8	1.4	4.1	4.3	1.4
95th percentile	1.4	1.2	4.6	5.1	2.2	5.3	5.8	1.8
99th percentile	3.0	8.0	5.0	5.6	3.4	5.5	6.3	1.9
Maximum	3.6	11.8	5.2	5.6	3.7	5.5	6.4	1.9
Mean	0.5	0.3	1.4	2.2	1.2	2.9	3.3	0.9
Standard dev.	0.6	2.0	1.8	1.9	0.6	1.7	1.4	0.7
Skewness	1.7	−1.0	0.5	0.1	1.7	−0.4	0.3	−0.1
Kurtosis	9.6	31.1	1.9	1.6	7.6	1.8	2.2	1.6

	UK 10Y govt. bond rate	Euro area equity	World ex euro area equity	Gold	EUR/USD exchange rate	EUR/JPY exchange rate	EUR/GBP exchange rate
Minimum	0.2	−32.9	−24.4	−25.8	−12.0	−16.6	−8.3
1st percentile	0.2	−31.1	−23.6	−20.3	−11.6	−16.1	−8.3
5th percentile	0.5	−22.1	−15.6	−9.2	−7.9	−11.2	−5.0
25th percentile	1.6	−2.8	−1.2	−3.0	−3.1	−2.8	−2.0
50th percentile	3.4	2.7	2.5	3.0	−0.2	1.4	0.1
75th percentile	4.7	7.3	6.7	7.4	3.3	3.3	2.2
95th percentile	5.3	16.9	14.1	12.0	7.9	8.1	5.8
99th percentile	5.6	22.9	18.1	14.3	11.9	12.7	13.9

(continued)

Table 3 (continued)

	UK 10Y govt. bond rate	Euro area equity	World ex euro area equity	Gold	EUR/USD exchange rate	EUR/JPY exchange rate	EUR/GBP exchange rate
Maximum	5.6	26.3	18.3	15.0	12.9	13.3	18.8
Mean	3.1	1.0	1.4	2.0	0.0	0.1	0.3
Standard dev.	1.7	10.5	8.6	6.8	4.9	5.6	3.8
Skewness	−0.2	−0.9	−0.8	−0.8	0.0	−0.6	1.1
Kurtosis	1.6	4.3	3.7	4.5	2.8	3.7	7.5

equal to the latter. The effect of this transformation on the time series is illustrated in Fig. 1.[9]

Following winsorization of the historical time series and the definition of the parameters of the prior distributions, it is possible to estimate the model coefficients with a sampling methodology that, in the case at hand, involves 10,000 iterations. Such methodology is based on the Gibbs sampler, a Markov chain Monte Carlo algorithm that extracts the posterior distribution of the parameters (unlike a single value as for the frequentist VARs) where the posterior density function does not take the form of any well-known density. Given the posterior distributions, it is possible to simulate over time all the variables included in the BVAR without further processing (such as bootstrapping in the case of frequentist models).

The reference time horizon for the SAA is 10 years, for the following reasons:

- It is an adequate horizon for the identification of a strategic portfolio.
- It is not excessively long, avoiding the risk that the model predictions lose their significance.
- If the model is stable, this horizon allows sufficient time for the BVAR variables to converge to the equilibrium values.

The variables simulated through the BVAR do not necessarily coincide with the expected returns of the asset classes of interest. If this is the case for equities, whose expected returns are directly simulated, this does not happen for bonds, as the simulation output is the level of interest rates.[10] For these variables, it is thus necessary to process the data on rates to obtain returns. Table 4 shows the set of asset classes whose expected returns are used for the SAA.

[9]Unlike trimming in which the extreme observations are removed, winsorization does not reduce the sample size while preserving large part of historical information. The value of α used in Fig. 1 is 20 per cent.

[10]This is strictly true for local currency equities, while non-euro equities need to be converted into euro using the simulated exchange rates.

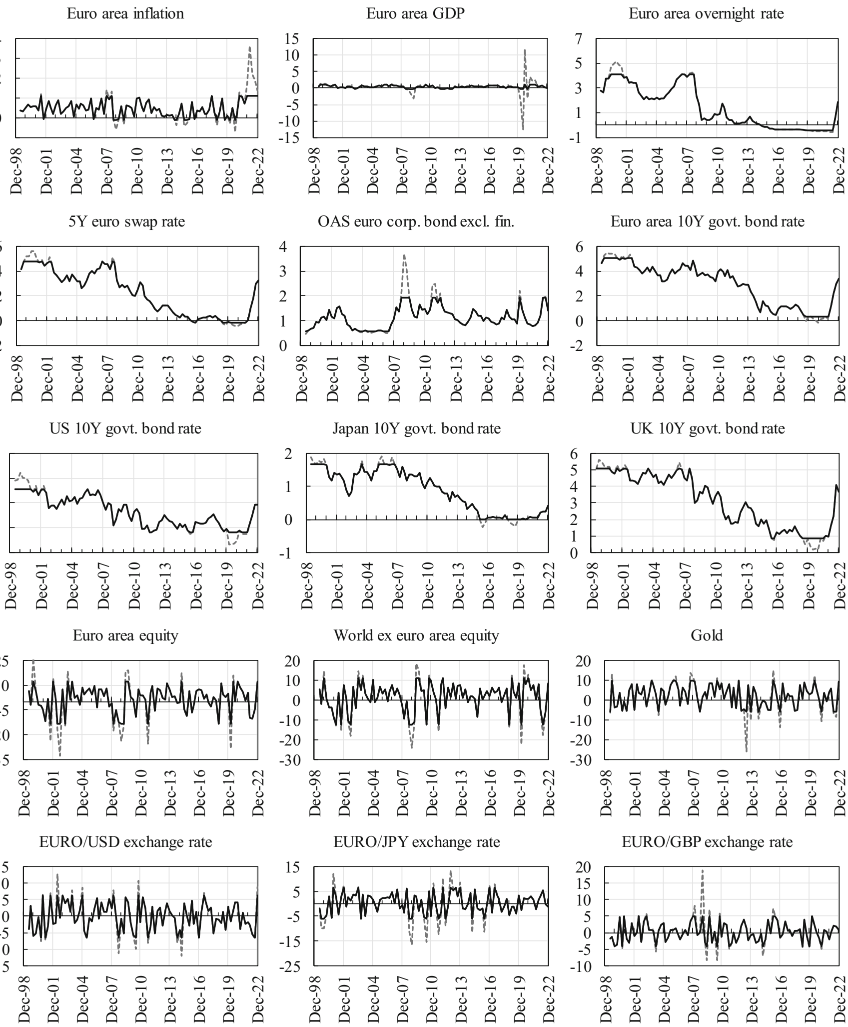

Fig. 1 BVAR Time Series (Quarterly data from Q1 1999 to Q4 2022; percentages). Interest rates and OAS are expressed on annual basis; the other variables are expressed as quarterly returns. Grey dotted lines represent original time series whereas black lines represent winsorized time series (Source: own calculations on Bloomberg Finance L.P. data)

A central bank's investment strategy is tilted towards a conservative risk attitude (Sect. 4). This implies that financial returns in adverse macroeconomic and financial scenarios play a key role in driving portfolio allocation. Thus, the Bank of Italy assesses the optimality of portfolio allocation with reference to the most adverse scenarios.

The analysis of the returns simulated with the BVAR model prompts some considerations, which are reflected in the optimal strategic choices. As shown in

Table 4 The SAA asset classes

#	Description
1	10-year euro area government bonds
2	10-year US government bonds (in euro)
3	10-year Japanese government bonds (in euro)
4	10-year UK government bonds (in euro)
5	5-year euro corporate bonds excluding financials
6	Euro area equities
7	World ex euro area equities (in euro)
8	Gold (in euro)

Table 5 Expected change of economic variables and expected returns of asset classes under different economic and financial scenarios (Annual values on a 10-year horizon; percentages). Expected returns of all asset classes are expressed in euro (Source: own calculations)

	Euro area economic cycle		Euro area consumer prices	
	Recession	Expansion	Deflation	Inflation
Euro area GDP	−1.9	2.9	0.4	0.2
Euro area inflation	2.3	2.1	0.5	4.2
EUR/USD exchange rate	0.4	2.2	0.4	1.8
10-year euro area govt. bonds	3.8	3.0	3.7	3.3
10-year US govt. bonds	3.5	1.1	3.0	2.2
10-year Japanese govt. bonds	−3.6	−1.3	−2.6	−2.4
10-year UK govt. bonds	2.3	2.8	4.5	1.6
5-year euro corp. bonds ex fin.	4.9	3.8	4.0	4.9
Euro area equities	−4.4	10.7	6.7	−2.0
World ex euro area equities	−2.9	8.8	6.0	−2.7
Gold	−3.9	7.9	0.0	−3.4

	EUR/USD exchange rate	
	Depreciation	Appreciation
Euro area GDP	0.3	0.7
Euro area inflation	2.0	2.4
EUR/USD exchange rate	−11.4	14.4
10-year euro area govt. bonds	3.6	3.4
10-year US govt. bonds	16.3	−9.7
10-year Japanese govt. bonds	1.1	−6.9
10-year UK govt. bonds	7.6	−1.4
5-year euro corp. bonds ex fin.	4.3	4.8
Euro area equities	5.1	−0.8
World ex euro area equities	14.5	−9.7
Gold	6.6	−6.1

Table 5, in a simulated recessionary phase, inflation in the euro area is slightly above the ECB target, the euro is substantially stable, and the most profitable asset classes are the euro-denominated fixed-income instruments followed by the US government bonds. In an expansionary phase, equities and gold benefit from the performance of the real economy, whereas the performance of fixed-income asset classes is subdued. The table also shows the effects of alternative hypotheses on the dynamics of prices and exchange rates. In deflationary scenarios, economic growth is limited, the euro appreciates marginally and equity is favoured. Inflation scenarios in the euro area are associated with a slow-paced economic growth, while euro-denominated bonds benefit more than equities from the expansionary phase of the cycle. As concerns the exchange rate, a depreciation of the euro is associated with a low GDP growth rate and mild inflation, making foreign currency investments more attractive. An appreciation of the euro corresponds to an expansionary economic phase with rising price dynamics, in which all euro-denominated investment classes are favoured.

4 Portfolio Optimization

The distribution of economic and financial variables obtained with the BVAR model yields, by means of appropriate valuation formulas, the distribution of the 10-year terminal values of assets and liabilities of the integrated balance sheet; the terminal distribution of the Bank of Italy's net economic capital is obtained by difference.

The evolution of assets and liabilities can generally be inferred directly from the BVAR simulations. However, some items are represented through 'replicating portfolios' that either approximate their actual composition (for example, the monetary policy portfolio) or simulate their dynamics based on the relationship with simulated macroeconomic and financial variables (as is the case for monetary income). In particular, the monetary policy portfolio includes mainly Italian government bonds and, to a lesser extent, supranational and corporate bonds, with different maturities and credit ratings. The replicating portfolio is obtained from the BVAR variables that best approximate the future evolution of the portfolio's risk and return, namely, the yield on euro-area government and corporate bonds.

4.1 The Objective Function

The SAA goal is to define the optimal allocation of foreign exchange reserves and of the investment portfolio[11] that maximizes the Bank of Italy's net economic capital in the long term (10 years) and in adverse scenarios. In other words, the aim is to define

[11] The investment portfolio includes financial investments in euros and in foreign currencies not related to monetary policy. It includes government bonds of the euro area and other public institutions, corporate bonds, shares, and other equity instruments.

the allocation that minimizes the 10-year expected shortfall ($ES\alpha$) of the net economic capital at a given percentile α[12]:

$$\begin{aligned}
&\max_{\boldsymbol{x}_{PI}} E_\alpha\{EC_0(\boldsymbol{x}_{PI}^T\boldsymbol{R}_{PI} + \boldsymbol{x}_{\bar{PI}}^T\boldsymbol{R}_{\bar{PI}}) - \boldsymbol{dividend}^T\}\\
&\text{s.t.}\\
&\boldsymbol{x}_{PI} \geq \boldsymbol{0}\\
&\boldsymbol{x}_{PI}^T\boldsymbol{1} + \boldsymbol{x}_{\bar{PI}}^T\boldsymbol{1} = 1
\end{aligned} \tag{1}$$

where

- $E_\alpha[\boldsymbol{X}] = E[\boldsymbol{X}| \boldsymbol{X} \leq q_\alpha]$ is the expected value of net economic capital conditional on the portion of the distribution below the α-th percentile; if the first percentile of the distribution is used, the expected value is indicated as ES99%.
- EC_0 is the initial net economic capital, obtained as the difference between the assets and liabilities of the integrated balance sheet.
- n is the total number of asset classes.
- $\boldsymbol{x}_{PI}$ is the $m \times 1$ vector containing the weights of the $m \leq n$ asset classes of the investment portfolio and foreign exchange reserves.
- $\boldsymbol{X}_{\bar{PI}}$ is the $h \times 1$ vector, complementary to the vector $\boldsymbol{x}_{PI}$, representing the weights of the $h \leq n$ asset classes in the replicating portfolio of monetary income and monetary policy purchase programmes.
- $\boldsymbol{R}_{PI}$ is the $m \times k$ vector representing the exponential of the ten-year cumulative logarithmic expected returns of the $m \leq n$ asset classes of the investment portfolio and foreign exchange reserves under k simulated scenarios.
- $\boldsymbol{R}_{\bar{PI}}$ is the $h \times k$ vector representing the exponential of the ten-year cumulative logarithmic expected returns of the $h \leq n$ asset classes that make up the replicating portfolios of monetary income and monetary policy purchase programmes in the k simulated scenarios.
- ***dividend*** is the $k \times 1$ vector of the dividend to be paid to the Government and to the shareholders[13] in case of achievement of an accounting profit, estimated for each of the k simulated scenarios.[14]

Equation (1) defines the optimal weights of the m investment classes which minimize the 10-year expected loss on net economic capital in the worst-case scenarios (α-th percentile), given their risk and return profile and their relationship with other items of the integrated balance sheet.

[12] Adverse scenarios are identified with respect to the distribution of terminal values of net economic capital.

[13] These are mainly banks, insurance companies and social security institutions that have accrued the right to a dividend in accordance with the provisions of the Statute of the Bank of Italy, reformed with law no. 5 of 29 January 2014.

[14] Dividend is calculated on the profit arisen from the traditional balance sheet items, not on the economic result of the integrated balance sheet.

4.2 Optimization Constraints

The optimization problem includes a set of constraints to keep short-term financial and accounting risks under control and to maintain an adequate level of foreign exchange reserves.

The first financial constraint requires that one-year ES99% calculated on the foreign exchange reserves, the gold holdings, the investment portfolio and the monetary policy portfolio, all evaluated at market values, does not exceed a certain threshold. The second constraint has an accounting nature, against the possibility that accounting losses from the investment activity lead to a negative income statement over a one-year horizon. Specifically, the one-year ES99% calculated on the expected losses of financial assets recorded at market prices (gold, foreign exchange reserves, shares, and marketable bonds not classified as 'held to maturity'), in excess of the respective revaluation accounts, should not exceed the general risk provision.[15] Any excess would result in a loss in the income statement.

The optimization exercise is integrated with considerations about the adequacy of official reserves, i.e. assets held in foreign exchange currencies and gold. The importance of official reserves is primarily related to the possibility that the ECB may request, upon the occurrence of certain conditions, the transfer of additional reserves. Official reserves held in foreign currencies also enable the Bank of Italy to service the foreign currency-denominated debt on behalf of the Treasury, avoiding any impact on the foreign exchange market, and to fulfil the obligations towards international organizations such as the IMF. Finally, as an integral part of the Eurosystem's reserves, official reserves help to support the credibility of the ESCB.

The main objective of foreign currency reserve management is to preserve their value and liquidity. Financial results of foreign reserve management contribute to the profit and loss account, influencing the capital strength of the Bank of Italy. Gold reserves have the additional function of reinforcing confidence in the stability of the domestic financial system and the single currency. Their role becomes more important when geopolitical conditions or the international economic factors generate severe risks for financial markets (as in the case of currency or financial crises; Panfili et al. 2015).

The optimization exercise foresees a minimum level of currency and gold investments, defined on the basis of the empirical model of Obstfeld et al. (2010). Accordingly, the minimum desired level of official reserves in relation to GDP for a country is obtained through a regression against economic and financial variables of a such country.

The optimization problem includes two further constraints. The first provides that the weight of each asset class cannot depart by more than ±50 per cent from the

[15] According to the Bank of Italy's Statute, the general risk provision covers risks connected with the Bank of Italy's overall activity, including those that cannot be determined individually or allocated objectively (Bank of Italy 2022b).

Table 6 SAA indications

	ES99%	ES95%	ES90%	Mean
Euro-area government bonds	⬇	⬇	⬇	⬇
Euro corporate bonds	⬇	⬇	⬆	⬇
Equity	⬆	⬆	⬆	⬆
Foreign exchange reserves	⬆	⬆	⬆	⬆

current weight. The second foresees the physical quantity of gold to be held constant, while the monetary value changes according to its price.[16]

5 The SAA: An Application

Here we present the main results of the optimization exercise applied to the integrated balance sheet of the Bank of Italy at the end of 2022. Securities held for monetary policy purposes are projected over the simulation horizon based on the available information on the evolution of the asset purchase programmes of the Eurosystem. The expected returns employed in the optimization are obtained using the BVAR model, with the time series updated to the fourth quarter of 2022.

The optimization function minimizes the average 10-year expected loss in a percentile α of the distribution of net economic capital (see Sect. 4.1). Although the adverse scenarios are concentrated in the first percentile (ES99%), for robustness purposes it is useful to evaluate changes in the composition of the optimal portfolio using other percentiles. Therefore, three further measures of simulated net economic capital are analyzed: ES95% (fifth percentile), ES90% (tenth percentile), and the mean value of the distribution. The alternative percentiles enable to compare the results of the SAA exercise with respect to different levels of risk aversion of the central bank.

Table 6 shows the main results of the optimization. The model tends to favour greater portfolio diversification, with an increase in the share of equities and foreign exchange reserves for all levels of risk aversion, and a decrease in the share of government bonds. The share of corporate bonds is expected to decline for almost all levels of central bank risk aversion.

The interpretation of these results requires an understanding of the euro-area macroeconomic and financial environment under the simulated extreme scenarios. They feature low economic growth, low inflation, and potential stress on the financial markets. In this context, foreign exchange reserves are preferred because

[16] Gold is historically held by central banks. It performs the function of protecting their financial strength in extreme scenarios. The share of gold that central banks should hold is a subject of debate. Zulaica (2020) shows that, in addition to purely financial reasons, qualitative considerations play a fundamental role in this choice.

the value of foreign currency assets is less sensitive to adverse conditions in the euro area and therefore it offers more favourable returns compared to other asset classes. Although equities may suffer losses in these extreme scenarios, they tend to improve the overall risk and return profile of the portfolio, due to the lower correlation with the largest items in the integrated balance sheet.

6 Sustainability Principles and Investment Decisions: The Experience of the Bank of Italy

In recent years, the fight against climate change and the adoption of sustainability principles have become of key importance for institutions, businesses, and people. Public institutions and companies are increasingly promoting policies that place the protection of the ecosystem, human rights, and socially responsible business conduct at the centre of economic decisions. In economics and finance, sustainability is identified empirically along three dimensions: environmental, social, and corporate governance (ESG). Companies that adopt ESG best practices can achieve significant benefits, including economic benefits (see Chap. "The Commitment to Sustainability in Financial Investments").

In managing their investments, central banks that allocate more resources to companies with the best sustainability practices can set an example for investors and contribute to stable, fair, and inclusive growth that does not compromise environmental equilibrium (Visco 2019). As shown in Chap. "The Commitment to Sustainability in Financial Investments", in recent years the Bank of Italy has integrated sustainability factors into its investment decisions to improve the management of financial and reputational risks, safeguarding its capital strength and signalling the commitment to sustainable growth (Cipollone 2021). Sustainability factors were initially applied to the internally managed equity portfolio and subsequently extended to investments in corporate and supranational bonds. The integration of the new criteria into the investment strategy has led to an overall improvement in the sustainability profile of the portfolios (see Chap. "The Exposure of Investments to Climate and Environmental Risks"; Bernardini et al. 2021).

6.1 The Integration of Sustainability Principles

Sustainability criteria for securities of private issuers are taken into consideration in the second stage of the SAA process. Sustainability factors are applied on a granular basis to investments related to private issuers, namely, equities and corporate bonds. Security allocation privileges issuers who:

- Are committed to the responsible use of natural resources and the effects on ecosystems.

Table 7 Criteria for the sustainability in investments and risk management

Responsible investment charter • Vision • Principles • Commitments
International agreements • United Nations Global Compact (UNGC) • United Nations' Sustainable Development Goals for 2030 Agenda (SDGs) • Paris Agreement on climate change • Recommendations of the Network for Greening the Financial System (NGFS) • Eurosystem's common stance for climate change-related sustainable investments in non-monetary policy portfolios
Exclusion criteria • Fundamental conventions of the International Labour Organization (ILO) • International treaties on controversial weapons, Treaty on the non-proliferation of nuclear weapons • Protocols of the convention prohibiting or restricting the use of certain conventional weapons
Investments in equities and bonds • High ESG profile • Low carbon intensity
Leading indicators of climate risk • Total greenhouses (GHG) emissions • Weighted Average Carbon Intensity (WACI) • Companies' decarbonization targets and commitments

- Maintain adequate conditions of safety, health, justice, equality, and inclusion.
- Adhere to ethical principles and implement best management practices.

For its investment strategy, the Bank of Italy adheres to the principles of international and European agreements[17] on sustainability and applies exclusion criteria based on labour and arms conventions.[18]

Table 7 provides a summary of the sustainability considerations adopted in the Bank of Italy's investment strategy.

[17] The Bank's sustainable investment policy refers to: (a) the principles of the United Nations Global Compact, the Sustainable Development Goals of the United Nations 2030 Agenda and the 2015 Paris Climate Agreement; (b) the recommendations of the NGFS; (c) the common position of the Eurosystem for NMPPs (see, Bank of Italy 2021; the press release by the ECB, 'Eurosystem agrees on common stance for climate change-related sustainable investments in non-monetary policy portfolios', 4 February 2021).

[18] Exclusion criteria are based on: (a) the eight fundamental conventions of the International Labour Organization (ILO) that require compliance with fundamental rights, including the elimination of forced labour, freedom of association, the abolition of child labour and of discrimination in employment; (b) international treaties on chemical, biological and nuclear weapons, anti-personnel mines, cluster munitions, weapons with non-detectable fragments, incendiary weapons and blinding laser weapons. Tobacco producers are also excluded.

6.2 Sustainability in the Management of Securities Issued by the Private Sector

The equity portfolio is geographically diversified between Italy, other euro-area countries, the USA, and Japan; it is managed against market indices. The sub-portfolios of Italian stocks (Italy Portfolio, IP) and other euro stocks (Euro Portfolio, EP) are managed directly. While the US and Japan sub-portfolios are invested via ETFs that track sustainable market indices, the Bank is directly responsible for the stock selection of IP and EP. Below we describe the Bank's procedure for integrating market neutrality and sustainability considerations in the management of IP and EP.

The market neutrality principle of investment is implemented by setting limits for:

– The tracking error volatility (TEV) of each portfolio with respect to the relevant market index.[19]
– The deviation of each sector's exposure compared with the index.
– The deviation of the weight of the selected stocks compared to their weight in the index.

Sustainability considerations are introduced by applying the exclusions set out in the Bank of Italy's Responsible Investment Charter and overweighting companies with the best ESG scores and climate profiles. These profiles take into account backward-looking and forward-looking variables. Backward-looking variables include current carbon intensity (the ratio of greenhouse gas emissions to turnover) and its change during the last three years (momentum). Forward-looking variables include mid-term estimates (expected carbon intensity emissions in the next few years) and long-term estimates (decarbonization commitments and transition plans of companies).

IP replicates a tailored index of the Italian market made up of companies with an average capitalization above a given threshold. The portfolio is composed of all the companies in the index with a weighting scheme based on sustainability criteria (tilting strategy). EP tracks a broadly diversified market index. To reduce transaction and operating costs, the portfolio makes a sample replication with only a subset of the securities in the index. The replicating strategy applies the aforementioned sustainability criteria and excludes securities with an ESG score below a predefined threshold (best-in-class strategy).[20]

[19] TEV is a measure of a portfolio's risk relative to a benchmark, calculated as the standard deviation of the portfolio's differential returns relative to that of the benchmark over a given time-horizon.

[20] The indices for IP and EP, as well as the replicating portfolios, exclude the shares of banks and insurance companies, to avoid possible conflicts of interest. For IP, the shares of the media sector are also excluded.

The stock selection for IP and EP is based on an econometric model inspired by the arbitrage pricing theory, based on five macroeconomic factors (BIRR model; see Burmeister et al. 2003).[21]

The optimization is conducted separately for IP and EP; it yields the weights of the securities in each replicating portfolio, i.e. the weights that minimize the TEV of the portfolio. The TEV is obtained by pre- and post-multiplying the security-level variance-covariance matrix obtained from the BIRR model by the vector of differential weights between the replicating portfolio and the market index.

The optimization involves financial and sustainability constraints. The former limit idiosyncratic and systematic risks. The sustainability constraints aim at the improvement of the ESG score and 'climate score' of the portfolio vis-à-vis the index and, possibly, the existing portfolio.[22]

The climate score of each firm is a weighted average of three indicators: current carbon intensity; expected carbon intensity in the next few years; and a composite indicator for the decarbonization efforts. The decarbonization indicator in turn has two components: (i) the change in carbon intensity over the past few years (momentum component); and (ii) the level of ambition of the announced climate targets (horizon and implied temperature rise) and their scientific soundness (transition plan component).

In analytical terms, the optimal composition of each replicating portfolio is expressed in differential terms between the weights of the securities in the replicating portfolio and in the market index used as a benchmark. It is a multivariate quadratic optimization problem with linear constraints:

$$
\begin{aligned}
&\min_{x} \boldsymbol{x}^T \boldsymbol{\Sigma}_{\text{total}}\, \boldsymbol{x} \\
&\text{s.t.} \\
&\boldsymbol{x}^T \mathbf{1} = 0 \\
&\left|\textstyle\sum_{i=1}^{n(s)} x_{i|\text{sectors}=s}\right| \le \overline{\delta} \\
&\boldsymbol{lb} \le \boldsymbol{x} \le \boldsymbol{ub} \\
&\boldsymbol{w}_{\text{port}}^T \boldsymbol{ESG} \ge \overline{ESG} \\
&\boldsymbol{w}_{\text{port}}^T \boldsymbol{IC} \le \overline{IC} \\
&\boldsymbol{w}_{\text{port}}^T \boldsymbol{IC}_{t+N} \le \overline{IC}_{t+N} \\
&\boldsymbol{w}_{\text{port}}^T \boldsymbol{DEI}_{t+N} \ge \overline{DEI}
\end{aligned}
\tag{2}
$$

where

[21] BIRR is an acronym for Burmeister, Ibbotson, Roll, and Ross.

[22] The methodology for constructing ESG scores is based on the analysis of indicators referring to different macro areas for each of the three pillars: the environmental pillar (E); the social pillar (S); and the corporate governance pillar (G). The final score is determined by weighting all indicators with weights defined at the level of each firm, although largely equal for firms in the same sector. Carbon intensity is measured by the ratio between tons of greenhouse gas emissions and turnover.

- $\boldsymbol{x} = \boldsymbol{w}_{\text{port}} - \boldsymbol{w}_{\text{bench}}$ is the $n \times 1$ vector containing the weight differentials of each security (x_i), obtained as the difference between the vector of weights in the replicating portfolio $\boldsymbol{w}_{\text{port}}$ and the vector of weights in the benchmark $\boldsymbol{w}_{\text{bench}}$
- $\boldsymbol{\Sigma}_{\text{total}}$ is the $n \times n$ variance-covariance matrix of the securities in the benchmark obtained on the basis of the BIRR model
- $\cdot$ is the dot product of vectors
- $\overline{\delta}$ is the maximum deviation for each sector s, with $n(s)$ equal to the number of securities that make up the sector and $x_{i \mid \text{sector} = s}$ equal to the differential weight of the i-th security belonging to sector s
- $\boldsymbol{lb}$ and $\boldsymbol{ub}$ are the $n \times 1$ vectors containing, respectively, the lower and upper limits of the differential weight of each security
- $\boldsymbol{ESG}$, $\boldsymbol{IC}$, and $\boldsymbol{IC}_{t+N}$ are the $n \times 1$ vectors containing the ESG score and the (current and expected in N-years, respectively) carbon intensities of each stock
- $\boldsymbol{DEI}$ is the $n \times 1$ vector containing the composite indicator regarding the decarbonization efforts for each stock
- $\overline{ESG}$ is the minimum desired ESG score at the portfolio level
- $\overline{IC}$, $\overline{IC}_{t+N}$ are the maximum desired (current and expected in N-years, respectively) carbon intensities at the portfolio level
- $\overline{DEI}$ is the minimum desired value of the indicator regarding the decarbonization efforts at the portfolio level.

The US and Japanese equity portfolios consist of units of collective investment undertakings selected among those that implement passive management of ESG market indices. The management of the corporate bond portfolios is also based on the replication of ESG indices; it is carried out internally for euro-denominated securities and through external managers for US-denominated securities. The selection of the equity collective investment undertakings and the investment guidelines for the corporate bond portfolios reflect the principles and constraints applied for the internal management of the equity portfolios. Such guidelines aim at achieving a low TEV vis-à-vis the market indices and an adequate sustainability profile.

7 Conclusions

The strategic asset allocation of central banks has the ultimate goal of contributing to the achievement of their institutional objectives, by supporting credibility and independence. The implementation of SAA requires a careful calibration of the assumptions in relation to the institutional and economic context. SAA by central banks has thus distinct features compared with the portfolio allocation process by any other investor.

The central bank's SAA aims at capital strength in adverse economic and financial scenarios with a medium- to long-term orientation. In these scenarios, it is essential that the central bank has adequate capital resources to pursue the objective of price stability and to preserve the country's financial stability. These goals may lead to the adoption of unconventional monetary policy measures, as has been the case since the inception of the Great financial crisis in 2007. These measures have caused the transfer of a sizeable share of the financial risks of the economy onto the balance sheet of the central bank, the only institution which faces no liquidity constraints.

The implementation of the ECB's unconventional monetary policy measures, up to the adoption of PEPP, has thus caused important changes in the structure of the Bank of Italy's balance sheet. The risks associated with climate change and the transition to a sustainable development model have also had important financial implications, potentially affecting the achievement of the institutional objectives.

In this context, SAA suggests to increase financial assets, such as those in foreign currency and equities, that diversify the large volume of government bonds in the monetary policy portfolios, and to favour assets with higher ESG scores and a lower carbon footprint. These considerations help to explain the changes in the volume and composition of the Bank of Italy's investments in recent years.

Appendix: The Evolution of the Bank of Italy's Financial Assets

Since 2014, the launch of the APP by the ECB and the development of refinancing operations have caused a strong growth in the assets linked to the implementation of monetary policy in the balance sheet of the Bank of Italy (Fig. 2). Between 2015 and 2021, the overall size of assets more than doubled, from 587 to 1538 billion of euros.

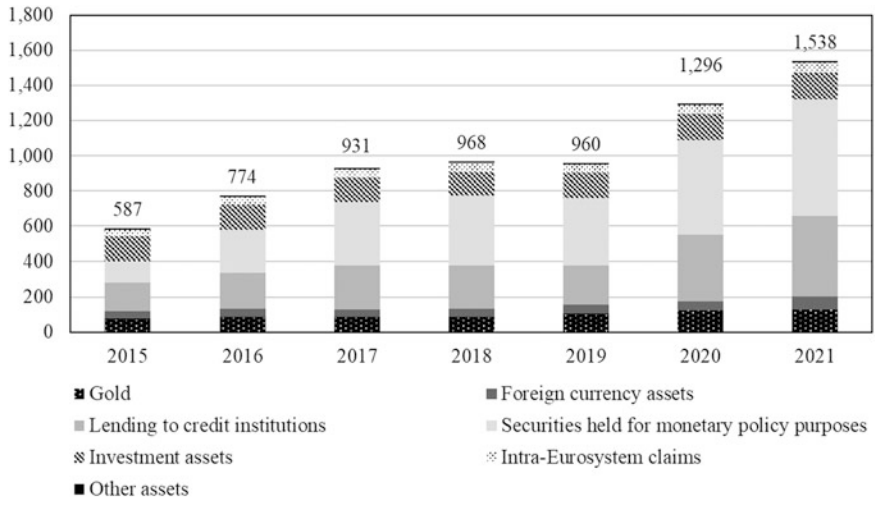

Fig. 2 Bank of Italy's financial assets (2015–2021, billions of euros)

Table 8 Bank of Italy's Investment Portfolio and Foreign Exchange Reserves (2015–2021, accounting values in billions of euros, percentages in brackets)

	2015	2016	2017	2018	2019	2020	2021	Change 2021–2015
Investment portfolio:	136.3	140.8	138.1	133.8	137.3	144.1	147.3	11.0
	(79.3)	*(80.0)*	*(80.5)*	*(78.1)*	*(76.7)*	*(76.7)*	*(75.0)*	*(−4.3)*
- Government bonds and other public sector securities	123.0	128.0	124.5	121.2	123.4	127.1	125.1	2.1
	(71.5)	*(72.7)*	*(72.5)*	*(70.7)*	*(68.9)*	*(67.7)*	*(63.7)*	*(−7.8)*
- Other bonds	3.1	3.0	3.0	3.0	2.4	2.5	2.6	−0.5
	(1.8)	*(1.7)*	*(1.7)*	*(1.7)*	*(1.3)*	*(1.3)*	*(1.3)*	*(−0.5)*
- Equity shares, other participating interests, ETFs and shares/units of CIUs	10.2	9.8	10.6	9.6	11.5	14.4	19.6	9.4
	(5.9)	*(5.6)*	*(6.2)*	*(5.6)*	*(6.4)*	*(7.7)*	*(10.0)*	*(4.1)*
Foreign exchange reserves	35.7	35.1	33.5	37.6	41.8	43.8	49.1	13.4
	(20.7)	*(20)*	*(19.5)*	*(21.9)*	*(23.3)*	*(23.3)*	*(25.0)*	*(4.3)*
Total	172.0	175.9	171.6	171.5	179.1	187.9	196.4	24.4
	(100.0)	*(100.0)*	*(100.0)*	*(100.0)*	*(100.0)*	*(100.0)*	*(100.0)*	

Italic values are percentages (as of total of portfolio for columns from 2 to 8, and as relative changes for the last column)

In the same period, the composition of the NMPPs of the Bank of Italy has gradually changed, taking into account the SAA indications, complemented by institutional considerations. While the value of government bonds, mainly Italian, increased by 2.1 billion of euros, their weight over the aggregate item consisting of the investment portfolio and currency reserves decreased by 7.8 percentage points (Table 8), in favour of shares and foreign exchange reserves, which increased by 4.1 and 4.3 percentage points, respectively.

The equity component consists mainly of shares of Italian listed companies and of other euro-area countries, as well as a smaller portion of shares in US and Japanese collective investment undertakings. Within foreign reserves, the share of the US dollar has been raised (Table 9).

Table 9 Composition of Bank of Italy's Foreign Exchange Reserves[a] (2015–2021, percentages)

	2015	2016	2017	2018	2019	2020	2021
US dollars	67.5	68.1	68.6	68.4	70.5	68.5	71.4
British pounds	10.9	9.2	9.2	8.2	8.0	7.4	7.1
Japanese yen	13.7	14.7	12.6	14.3	12.7	13.1	11.0
Australian dollars	4.2	4.3	5.8	5.0	4.9	6.0	5.5
Canadian dollars	2.9	3.0	3.0	2.6	2.5	3.6	3.5
Other currencies[b]	0.9	0.8	0.8	1.6	1.5	1.5	1.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a]Excluding net assets vis-à-vis the IMF (denominated in SDRs)
[b]Includes Chinese renminbi and South Korean won

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Machine Learning, ESG Indicators, and Sustainable Investment

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1 Introduction

Finance can make a key contribution to the sustainability objectives embedded in the United Nations 2030 agenda, in particular by channelling resources into adaptation and mitigation measures. The integration of sustainability criteria in investment decision-making is fostered by regulators, corporate practices, and investors. This trend has accelerated during the outbreak of the Covid-19 pandemic, with inflows to sustainable investment outpacing those of the standard financial instruments (Ferriani and Natoli 2021). The COP26 held in Glasgow in 2021 recorded a widespread commitment of the private financial sector, representing globally more than USD 130 trillion, to support energy transition and the fight against climate change. The decrease in global carbon emissions due to the Covid outbreak and the shift in renewable energy development (Adebayo et al. 2022) was short-lived. More efforts and capital are needed to mitigate environmental degradation and accelerate the energy transition (Fareed et al. 2022). The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has highlighted the need for urgent action to tackle the already apparent consequences of climate-related acute and chronic events, by fostering investments in mitigation and adaptation measures (IPCC 2022).

According to Global Sustainable Investment Alliance, the global assets managed with sustainability criteria have increased to USD 35 trillion at the beginning of

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2021, almost double than in 2016, ranging from traditional instruments to new assets such as green bonds. This market trend is also driven by the search for long-term investments with less volatile risk-return profiles. An extensive literature shows that sustainable investment leads in most of the cases to risk-adjusted market returns that are often higher than those achieved using traditional financial models (Atz et al. 2022; Friede et al. 2015).

The importance of the environmental, social, and governance (ESG) profiles has been underlined since the 2004 UN Global Compact report ‘Who Cares Wins’ (Global Compact 2004). The integration of ESG principles into corporate management can innovate business practices and provide firms with a competitive edge. It contributes to reducing operating, legal and reputational risks; it leads to a more efficient allocation of resources, which can be shifted from risk management to productive activities, and a more motivated workforce. This favours in turn a better operational and market performance, thus lowering the cost of capital.

ESG scores have become popular among investors as a tool for setting sustainable investment strategies and selecting instruments and market indices in the equity and bond space. For this reason, scores are very important in driving the choices of market participants. However, the assessment of ESG practices embedded in these scores raises some concerns. ESG scores are computed using the information provided by private firms using heterogeneous methods. In particular, the representation of each ESG pillar has different levels of complexity, with the E component being usually less heterogeneous and controversial owing to the greater availability of quantitative data and conceptual models. Furthermore, there are neither broadly accepted rules for ESG data disclosure by individual firms nor auditing standards for the verification of the reported data. ESG score providers rely heavily on voluntary disclosure by firms and on proprietary methodologies to select, assess, and weigh individual ESG indicators. As a result, ESG scores of individual firms show a large heterogeneity across agencies compared, for example, with credit ratings. There is also evidence of significant biases in ESG scores, which tend to overestimate the score of companies that are larger and belong to specific industrial sectors and geographic regions.

This chapter investigates the sensitivity of stock returns to ESG information. We propose to (partially) overcome the current inconsistencies and fill the gaps in the ESG scores by using Machine Learning (ML) techniques to spot the most significant E, S, and G indicators that better contribute to the construction of efficient portfolios. ML does not need a model-based methodology, unlike portfolio theory. Our strategy applies ML techniques using over 220 ESG indicators from two of the largest data providers, Refinitiv-Asset 4 and MSCI ESG Research, for around 250 listed companies in the euro area in the period from 2007 to 2019, and sheds light on the main ESG indicators associated with risk and return differentials. The novelty of this study is threefold: (a) we analyze a very large array of ESG indicators; (b) we employ a model-free ML methodology; and (c) we disentangle the additional contribution of ESG indicators to portfolio performance, beyond the traditional style, and macroeconomic factors.

The study shows that a European equity market investor who had developed the proposed ML technique in 2016 and applied it using the ESG indicators in the period from January 2017 to April 2019 would have achieved an average annualized extra return between 0.5 and 1.2 percentage points (depending on the different risk/return objectives), compared with the Eurostoxx index. Applying ML techniques to the environmental indicators only, the extra return would have been between 0.8 and 1.8 percentage points.

Even taking into account the contribution of standard Fama-French (FF) (2015) style factors and, alternatively, of macroeconomic factors, the information content extracted from ESG indicators with ML significantly contributes, economically and statistically, to portfolio performance.

The rest of the chapter is organized as follows. In Sect. 2, we review the literature on equity returns, introduce the notion of ESG investing and some key evidence, discuss the current ESG data gaps and present some ML applications for investment purposes. Section 3 describes our data set (index constituents and return time series) and ESG indicators, with a focus on the treatment of missing data. In Sect. 4, we present the setting of the ML technique together with the framework for portfolio construction. Section 5 shows the results and presents a set of robustness checks. Section 6 concludes and discusses possible avenues for future research.

2 Literature Review

This section deals with the juncture of three different topics: modern portfolio theory and portfolio construction, ESG integration, and applications of ML in portfolio allocation.

We can find a vast literature about how factors, both fundamental and macroeconomic, affect stock returns and the relevant tests. Two of the most important studies for our work are those by Fama and MacBeth (1973) and Burmeister et al. (2003). ESG data have become prominent in sustainable investment decision-making, although there is no uniform definition of sustainability. According to Meuer et al. (2019), there are over 33 definitions of corporate sustainability. ESG data can be generally defined as every information and indicator of environmental, social, and governance profiles related to corporate operations. ESG scores have become popular sustainability indicators among financial professionals. Based on information obtained from publicly available documents, questionnaires, data or news archives, and other sources, some private-sector data providers have developed ESG scores of firms relating to areas not strictly connected to their core business. By aggregating these elements, weighted according to different criteria to obtain a single final score, the providers sell valuations in two areas: (1) the firm's ability to deal with risks stemming from these three dimensions, e.g. market risks arising from climate regulation, risk of litigation with consumers or of penalties for illegal conduct, reputational risks, etc.; (2) the firm's capacity to seize new opportunities, in terms of innovation and efficiency in its processes and of competitiveness of its products, through sound practices, like internalizing negative environmental externalities with low levels of waste or having a high share of women in managerial positions.

Some studies show the effectiveness of ML techniques in filling the sustainable data gap, such as Nguyen et al. (2021). Other studies perform textual analysis of the ESG investing literature as Kumar et al. (2022). To the best of our knowledge, the possibility of combining ESG data with ML techniques for portfolio construction seems unexplored. A study by Feiner (2018) considers that such a link might exist and focuses on the effectiveness of ML in retrieving ESG information. In applying ML techniques, we look inside the ESG scores and try to enhance the understanding of the materiality of the individual ESG raw indicators for investment purposes. We employ decision trees, which are simply framed and easy to interpret in economic terms.

2.1 Risk Factors for Equity Returns

The first factor model relies on macroeconomic variables and was originally proposed by Burmeister et al. (2003) (hereafter BIRR) for the US equity market. We apply the model to the euro area market as proposed by Carboni (2017). The second-factor model is based on financial variables and is inspired by Fama-French (1993). The two models are derived from the general Asset Pricing Theory model by Ross (1976), according to the following equation:

$$r_i(t) - R_{rf}\ (t) = \beta_{i,1}[P_1 + f_1(t)] + \ldots + \beta_{i,k}[P_k + f_k(t)] + \varepsilon_i(t) \tag{1}$$

where the return of security i in excess of the risk-free rate R_{rf} in period t is explained by several factors f_k (t) to which the security is exposed through the factor coefficients, β_i, with ε_i as an idiosyncratic error term.

The models are described below. They help disentangle the contribution of the ESG variables, and check whether their role is not already captured by macro or financial factors identified by literature.

The BIRR model considers changes in fundamental economic variables such as investor confidence, interest rates, inflation, real business activity, and a market index as in the CAPM. Burmeister et al. (2003) suggest the adoption of the risk factors shown in Table 1.

In the FF five-factor model, the firm's profitability and cash flows may have a material effect on stock returns, as in Gordon's model (Farrell 1985). Other factors that may generate outperformance are profitability (as in Novy-Marx 2013), share buy-backs (Mohanty et al. 2008), and growth (Mohanram 2008). Furthermore, small companies are generally less liquid and riskier than big ones (size effect), and companies with a high book-to-market price ratio generally outperform companies with a low ratio (value effect).

The FF five-factor model for the present analysis employs the following equation for the excess return (the time reference is omitted for simplicity):

Table 1 Risk factors in the Birr model

Risk factor	Unanticipated change in	Measurement
Confidence $f_1(t)$	Investors' willingness to undertake risky investments	Rate of return of relatively risky corporate bonds minus government bonds (20-year maturities)
Time horizon $f_2(t)$	Investors' desired time to payouts	Twenty-year government bond minus 30-day treasury bill
Inflation $f_3(t)$	Short-run and long-run inflation rates	Actual inflation for the month minus predicted
Business cycle $f_4(t)$	Level of real business activity	Change rate between the expected value of a business activity index at the beginning and at the end of the month
Market timing $f_5(t)$	Part of total return of the market portfolio which is not explained by the other risks and the intercept	Change rate between the value of regressed index at the beginning and at the end of the month

Source: Burmeister et al. (2003)

$$R_i - R_{rf} = a_i + b_i\left(R_{mkt} - R_{rf}\right) + s_i\mathrm{SMB} + h_i\mathrm{HML} + r_i\mathrm{RMW} + c_i\mathrm{CMA} + \varepsilon_i \quad (2)$$

in which R_i is the asset return, R_{rf} is the risk-free rate, a_i is the excess return over the benchmark, b_i is the market factor loading (exposure to market risk, different from the CAPM beta), R_{mkt} is the market return, s_i is the size factor loading (the level of exposure to size risk, SMB), h_i is the value factor loading (the level of exposure to value risk, HML), r_i is the profitability (RMW) factor loading, and c_i is the investment (CMA) factor loading (Mohanty 2019).

2.2 *Sustainable Investment: Foundations and Issues*

The investors' interest in Socially Responsible Investing (SRI) is a recent phenomenon and is growing fast. According to the Global Sustainable Investment Alliance (GSIA 2020), since 2016 sustainable investment has almost doubled and it has reached USD 35 trillion at the beginning of 2021 (around 36 per cent of professionally managed funds), one-third of which is located in Europe.

The rationale for the positive impact of ESG profiles on stock return is that a sustainable company will face less risk related to environmental issues, regulation, or lawsuits and can benefit more from the opportunities stemming from good ESG practices. Some studies find that the companies that adopt sustainable production methods are generally on the frontier of productive efficiency and benefit from a competitive advantage, e.g. from process/product innovation and customer satisfaction, with a lower exposure to operational, reputational and legal risks. These companies achieve a lower cost of capital; they get higher valuation assigned by the investors which translates into superior market performance (Clark et al. 2015).

ESG scores are widely used in sustainable finance for selecting financial instruments, building investment portfolios, creating market indices, and reporting (Bernardini et al. 2021a, b). The growing use of ESG scores goes together with a high heterogeneity among the scores computed by different providers for the same company. This phenomenon depends primarily on the different viewpoints of the providers as concerns the risk exposure to and risk management of the sustainability factors. Besides, the divergence stems from different procedures for data collection and selection of ESG indicators, as well as different assessment methodologies. Overall, this leads to some confusion (Berg et al. 2022).

Sustainability data have been studied in the literature from many angles, including, but not limited to, risk and return. Cheng et al. (2014) show that firms that score well in Corporate Social Responsibility (CSR) parameters have better access to finance at a lower cost. As concerns risk management, Godfrey et al. (2009) show that there is an insurance-like property of CSR activity in case of negative events such as legal/regulatory actions.

Integrating sustainability issues into portfolio management is a complex matter even from a theoretical point of view. As pointed out by Hoepner (2010), initially researchers viewed sustainability as a purely ethical choice, leaving aside any link with the traditional risk-return framework. According to this view, responsible investment is limited to *screening* the securities in the portfolio; at best this would lead to a portfolio as efficient as the unscreened one, since adding constraints to a portfolio optimization problem can never improve diversification and investment choices (Fama 1970). Although the previous general principle has been considered for many years as the ‘inescapable conclusion’, more recently Arnott (2013) has shown that a series of equally weighted random portfolios of sample stocks taken from a benchmark outperform the same cap-weighted benchmark over 40 years. This leads to the consideration that the reduced universe portfolios have to carefully adapt the weighting scheme for risk- and return-based factors. For practical purposes, there is a tipping point in the threshold of the sustainability filter beyond which the constraint is too strong and can significantly reduce the investment universe, with a negative impact on diversification and performance.

Two further considerations are in order. As argued by Hoepner (2010), the risk reduction due to diversification can be decomposed into three elements: the number of securities, their correlation, and their specific risk. If a good ESG score is associated with lower specific risk and this component offsets the negative effect of screening on the first two elements, it is possible to avoid the ‘inescapable conclusion’. Sustainability should then be considered in a risk-return framework. Some empirical results are provided by Verheyden et al. (2016).

As pointed out by Schoenmaker and Schramade (2018), a substantial limitation of traditional analysis with the risk-return framework is that it involves mainly time-series analysis, which is *backward-looking*. Sustainability assessment is inherently *forward-looking*, partly owing to its long-term perspective. This criticism is compatible with the hypotheses of adaptive markets, incomplete information, and not completely rational behaviour.

Other approaches to sustainable investing have been put forward recently. For example, under *impact investing* the investor not only seeks a financial objective, but he also aims at a social or environmental impact. This choice should not be considered superficially. A growing literature argues that corporations should have a broader objective than simple profit maximization. Hart and Zingales (2017) argue that it is often too narrow to identify shareholder welfare with market value and that 'money-making and ethical activities are often inseparable' therefore 'companies should maximize shareholder welfare not market value'. An enlightening example is about the shareholders of a company selling high-capacity gun magazines. If the shareholders are concerned about mass killings, it would be more efficient for them to ban the sales of ammunition rather than reinvest the profits made by the company in gun control. This principle explains the increasing popularity of impact funds, where investors can pursue financial returns while addressing social and environmental challenges.

An alternative is *ESG integration*, the one investigated in this study, which consists in making investment decisions that include ESG factors within the traditional financial modelling framework: ESG indicators are thus treated like other financial indicators to explain risk and return.

Although the literature on the effect of ESG factors on returns is not unanimous, research conducted by Khan et al. (2016) shows that firms with a fair rating on sustainability issues tend to outperform firms with poor ratings.[1] Giudici and Bonventura (2018) conduct a similar study for the European market and show that firms with better practices in all of the three ESG pillars exhibit higher returns; strategies that combine the ESG tilt with fundamental indicators, like the price-earning ratio, seem more efficient.[2]

A review of this vast literature is beyond the scope of this chapter. We just recall the two meta-analyses published by Friede et al. (2015), reviewing over 2000 studies and by Atz et al. (2022), reviewing over 1000 studies from 2015 and 2020. The latter finds a positive relationship for 58 per cent of the studies on the corporate performance (proxied by ROE, ROA, and stock return), and 59 per cent of the studies on the investment performance (measured by alpha and Sharpe ratio).

[1] Unfortunately applying those results to our work is not straightforward for two reasons, the first is that this study was conducted on data from Sustainalytics, but its reporting methodology changed recently, hence we have a limited time series to use with the new methodology and the coverage for European equities is rather limited. The second reason is that materiality was assessed through SASB tables, which have been originally designed for the US firms and it might be arguable to squarely apply them to European firms.

[2] This is a problem in graph theory that consists in finding the clique with the maximum number of edges in a bipartite graph. Rewriting the problem in terms of adjacency matrix (or, more properly, biadjacency matrix) we obtain the reductions needed to show the equivalence with our problem.

2.3 ESG: The Silver Bullet for Sustainable Investment?

While initial research on corporate social responsibility dates back to the 1970s (e.g. Bowman and Haire 1975), the ESG acronym was introduced in 2005. Only recently has ESG reporting become regular and granular, such as to allow statistical analysis at firm level. The ESG approach has the desirable property of providing the investor with a score, or a rating, that factors in a large amount of information about how a firm performs along several sustainability dimensions. Integrating ESG factors into equity investments is becoming a common responsible investment practice and there is a general agreement on its benefits. But how reliable is the information content of ESG scores? In a provocative article, Allen (2018) expresses doubts on the investors' awareness of the information they are employing, creating a false sense of confidence on ESG figures. The IMF (2019) expresses concern regarding the quality and consistency of the information in ESG scores and calls for a standardization of terminology and definitions.

The lack of generally agreed methodologies in compiling ESG data and of auditing standards to verify what is reported by the firm is a pressing concern for the quality of ESG information. Besides, ESG score providers rely on voluntary disclosure by firms, which they complement with their own estimates. The providers apply subjective methodologies to select, assess, and weight individual ESG indicators, which add to the arbitrary nature of ESG scores. As a result, ESG ratings show a rather low correlation, between 0.4 and 0.7 (Chatterji et al. 2016; Table 2). This is in sharp contrast with the high correlation among credit ratings, which is above 0.9.

There is also evidence of possible biases in ESG scores, which tend to give prominence to companies that have a larger size and belong to specific industrial sectors and geographic regions (Doyle 2018). Most of the disagreement is due to different measurement techniques; a different weight of the individual E, S, and G components also plays a part, together with the a priori bias of the rating companies (Berg et al. 2022). There is clearly a gap between ESG indicators and other standard accounting variables that follow well-established principles (e.g. GAAP) and lead to lower variability between accounting data providers. With our innovative technique, we try to overcome these problems, thus providing a useful tool for decision-making.

With all the above caveats, ESG scores are key to designing a portfolio that factors in the sustainable practices of the firms. ESG scores contain a wealth of data

Table 2 ESG score providers' cross-correlations

	Sustainalytics	MSCI	Robeco SAM	Bloomberg ESG
Sustainalytics	1	0.53	0.76	0.66
MSCI		1	0.48	0.47
RobecoSAM			1	0.68
Bloomberg ESG				1

Source: State Street Global Advisors (2019)

Table 3 ESG score cross-correlations

	Robeco SAM	Sustainalytics	Refinitiv-A4
Euroarea-exItaly			
MSCI	0.42	0.46	0.32
RobecoSAM		0.58	0.56
Sustainalytics			0.41
Italy			
MSCI	0.54	0.54	0.60
RobecoSAM		0.67	0.53
Sustainalytics			0.56

Source: Own calculations on ESG scores

that can complement the investors' information and play a role in shaping a thorough asset pricing on the markets.

Burmeister et al. (2003) warn against using accounting data for reasons that can also partially apply to ESG data. Our data samples are large enough for regressing each sector separately, choosing indicators for each sector according to its business peculiarities. Thanks to the continuous improvement of data feeds, we can overcome the largest differences among reports of different companies.

After checking that we have a similar low correlation issue in our data (Table 3), we devise a strategy that applies ML techniques to the raw ESG data to set up a heuristic selection process and create sample portfolios on the basis of their financial and sustainability performance.

2.4 Machine Learning in Finance

Even if the use of ML on ESG data for portfolio choice is little explored, it is sometimes used for text mining, e.g. by Feiner (2018) as previously recalled, and by Kumar et al. (2022). ML has become popular in recent years. One can find instances in which Machine Learning techniques are mentioned with regard to sustainable finance (Allen et al. 2017) or applied to ESG indicators for investment purposes (Erhardt 2020) or to ESG scoring (Sokolov et al. 2021), although there is not always a transparent specification of the methods (De Franco 2019).

The application of ML to portfolio choices is a wide field (see for example Chan et al. 2011). In the development of our model, we face some general issues. The first one is that we would like its results to be easily interpretable. If we have a strong a priori belief that sustainable investing will lead to better results in the long term, we cannot rely on a model which might suggest to invest in 'unsustainable' firms. Second, while many applications of ML employ high-frequency data and have a short-term use, we have a long-term orientation.

3 Data

The data for the analysis are time series at the company level on stock returns and ESG indicators. For both data types (returns and ESG data), the first step is the treatment of missing values. Below we explain the techniques to overcome this issue.

3.1 Returns and Indices

The sample is composed of the stocks in the EURO STOXX 300 index, which tracks the top 300 stocks in the euro area by capitalization. From the constituent stocks, we exclude the companies of the financial sector due to their business model, which differentiates them from non-financial firms. We first use the monthly total return of each stock starting from 31 December 2000 to 30 April 2019.

The sample includes the stocks in the index as of 31 December 2010. This choice requires some caution. Let us hypothesize for a moment to start the analysis on 31 December 2000, using the stocks in the index on the last date, 30 April 2019. A comparison of the cap-weighted index with the equal-weighted index reveals that the latter outperforms the cap-weighted index by 30 percent (Fig. 1).

This is the result of the well-known *survivorship bias*, because we are picking stocks based on information that is only available ex-post. Knowing that a stock is going to enter the index of the top 300 companies by capitalization in future years implies that its price will grow more than the price of the stocks which are currently in the index. Besides, we do not need to select the sample as of the end of 2000, since the reporting of ESG data was absent on that date. We use the sample as of the end of 2010. Figure 1 (right) shows that from 31 December 2010 onwards the equally weighted and cap-weighted portfolios do not show a significant return difference.

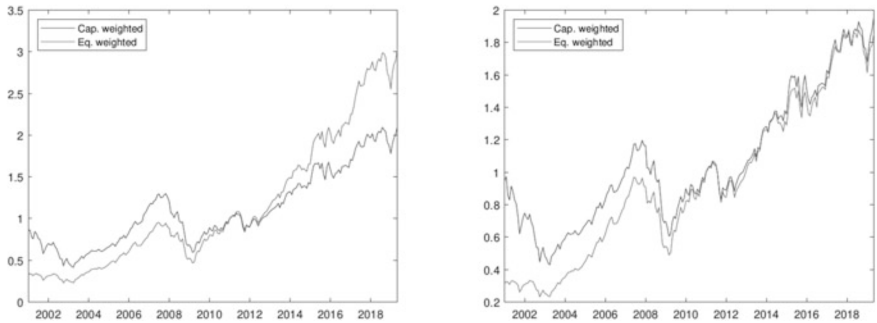

Fig. 1 We compare the return of the equal-weighted index with that of the index weighted by capitalization. On the left panel, the sample of stocks is chosen on the final date; on the right panel, the sample is chosen on 31 December 2010. The index value is normalized to 1 as of 31 December 2010. The data are those from EURO STOXX 300

We thus decided to use the 252 stocks that were in the index at the beginning and at the end of the period. We employ the time series from 31 December 2006 to 30 April 2019, i.e. 125 observations.

3.2 ESG Data

Refinitiv-Asset 4

Refinitiv has expanded its offer of financial data with ESG ratings since 2009 with the acquisition of the Swiss provider Asset4, devoted to environmental, social, and governance data. After the acquisition, Asset4's ESG rating methodology was revised and improved. The Refinitiv ESG team of 165 analysts covers about 1700 companies in Europe, and its ESG time series start from 2002. For each company, two numerical scores are drawn up, the 'ESG score' and the 'ESG combined score'; for both a literal rating is also provided. The ESG score measures the performance, commitment, and effectiveness demonstrated by companies regarding the environmental, social, and governance dimensions. The ESG combined score complements the ESG score with the assessment of companies' controversies on ESG issues. This framework divides the three pillars E–S–G into ten categories, each of which is evaluated through a variable number of indicators based on the industry to which they belong to, and selected from a set of 178 indicators. To this end, the 54 industry groups of the Thomson Reuters Business Classification (TRBC) are used as reference. In our study, after the initial selection of 100 distinct reported ESG variables (such as the E, S, and G scores, the level of carbon emissions, the number of accidents that occurred to employees, etc.) available for our investment sample of 252 companies, we added some economic variables (such as revenues, EBITDA, employees, etc.). We observe that some fields are missing (reported as 'Not a Number' or NaN) for some dates. After some data cleansing, we are left with 105 variables to explore.

We decided to modify some variables to compare different companies on a fair ground. Variables such as CO_2-equivalent emissions, waste, hazardous waste, environmental expenditures, energy use, coal energy purchased, coal energy produced, natural gas energy purchased, natural gas energy produced, oil energy purchased, oil energy produced, and water used total were normalized using firm revenue. The injury rate, employee accidents, employees leaving, and training costs were normalized by the number of employees. Contractor accidents were normalized by the number of internal employee accidents.

MSCI

The other data provider is MSCI ESG Research, which produces 172 ESG variables. MSCI ESG Research is a subsidiary of MSCI Inc., created in 2010 after the acquisition of RiskMetrics Group and the reorganization of the companies Innovest and KLD, both devoted to ESG research. MSCI ESG Research is organized with a team of around 185 analysts covering approximately 1500 companies in Europe. The ESG rating time series covers 20 years. MSCI ESG Research is currently the largest ESG rating provider; its analysis is used for the construction of around 600 equity and bond indices. MSCI provides a literal ESG rating scale from AAA to CCC grade that summarizes the exposure of companies to the risks and opportunities arising from key issues on the environmental, social, and governance profiles and the ability to manage these issues. The rating is expressive of the company's ESG profile in comparative terms, as it results from the comparison of the scores of firms operating in the same industry. The MSCI framework divides the three E–S–G pillars into ten themes; in turn, these are divided into 37 key issues of risks and opportunities. For our study, the data is available from January 2007 to June 2018. The reporting dates for ESG scores are not necessarily regular and are not the same for every stock. As in the case of Refinitiv, a score for the E, S, and G components is also provided. The other variables are defined as 'key issues' (for example, raw material sourcing, product carbon footprint, etc.). Key issues have an overall score which is obtained by aggregating a risk-exposure score with a risk-management score; among the variables we also count the weight that is given to the key issue in the evaluation of a company. We decided to exclude the weight of the key issues in our evaluation and we only employ the three scores and the key issues for a total number of 112 ESG indicators.

3.3 First Trials with Standard Approaches

The first plain-vanilla ML approach was not very promising because of missing data. Standard approaches work with full rectangular matrices of factors. Because of changes and improvements in methodologies and reporting, our matrices lack several fields. When dealing with missing values, we should be careful in trying to understand the reason for the absence. Usually, it is either because a reported variable does not apply to the sector under consideration, or because the firm has not disclosed relevant information. We often observe that many firms in the same sector have similar missing variables. In the case of a firm not reporting the relevant information, the reason might be that the firm does not have the necessary resources to disclose, even in the cases in which the information would be 'good'. Another reason could be that the firm prefers to provide no news rather than bad news. Against these possible explanations, we have chosen to delete missing information rather than filling NaNs with some value as is often done in previous empirical studies (filling with zeros, extending the last available observation, and using the sector average or the overall average).[3] This choice implies that with standard approaches, to obtain a rectangular matrix without missing data, we will have to discard some pieces of information that are available to us.

To obtain a fully rectangular matrix, we start from the available data, and whenever we get a NaN, we either delete its row (time observations) or column (ESG indicator) until the submatrix that is left contains no missing value. The problem of excluding as few available data as possible is not trivial. As shown by Peeters (2003), it can be reduced to the maximum edge biclique problem, which is NP-complete.

We used the MATLAB built-in regression learner to try several alternative regressions. Our dataset is the result of the heuristic selection applied to the full 56,134 × 96 original regression matrix (given by the combination of securities, dates, and indicators). To select fewer rows, we eliminate a row if its NaN ratio was greater than the NaN ratio of each column at the power of 0.1. The selection left us with 41 variables and 2841 observations. After the selection, a constant column was added, as well as a dummy with a different value for each firm, a dummy with a different value for each sector and a variable with the return of the sector, yielding 45 variables in total. To estimate the goodness of fit we considered the RMSE on an eight-fold validation, where an RMSE of 0.35054 is obtained using only the constant value. The best RMSE (0.2817) was reached in the regression with bagged trees with the single variable sector return, which was by far the best explanatory variable. The same method with all the variables gave a slightly worse RMSE (0.29615).

The fact that these initial results were not promising does not imply that the data has no explanatory power, that is ‘absence of evidence is not evidence of absence’. We suspected that several aspects might have negatively impacted these preliminary results. First of all, some data was lost in the construction of the rectangular matrices. In addition, any regression analysis affects only indirectly the portfolio choice and thus it might not capture some properties that emerge only when stocks are grouped in a portfolio. In addition to this, we wanted to have the possibility to study different portfolio indicators, like the Sharpe ratio, variance, and mean return. This led us to develop a specific ML method.

4 A Tailored Machine Learning Approach

This section describes the approach that we have used to select the ESG factors, the reasons that led us to the specific development, and the practical choices we have made.

[3] Henriksson et al. (2019) carry out an interesting analysis aimed at finding the ESG exposure for a company that does not report ESG information; however, the results could hardly apply at granular level.

4.1 The Proposed Approach

A standard practice in the literature consists in creating portfolios where stocks are equally weighted and selected according to the ESG scores of the providers, and portfolios are rebalanced annually. This allows us to make a first comparison of the best ESG performers versus the worst ESG performers, factor by factor. We decided to create portfolios by dividing the stocks into 'best' and 'worst' performers where 'best' and 'worst' refer, respectively, to the top and the bottom quartile of the ESG score distribution. We found that the aggregate ESG scores computed by the data providers systematically led to lower returns for the most ESG-compliant companies. This happened also when we separately considered the 'Environmental', 'Social', and 'Governance' variables instead of considering the aggregate ESG variable. However, the same experiment done with single ESG variables (e.g. CO_2 emissions divided by revenue), yielded opposite results, i.e. the portfolio of the less polluting companies performed better than the portfolio of the most polluting ones.

To keep the model simple and informative, we stick to the equally weighted portfolios. We notice that a more flexible choice of the thresholds (rather than the standard quartile choice used in other studies) could lead to slightly different results. For example, a particular choice of thresholds could lead to a group of highest-scoring companies on the Refinitiv Environmental score performing better than a group of lowest-scoring companies, even though the choice of the quartile is showing the opposite situation. We set out to automatically find those thresholds to obtain the highest possible performance for the ESG-compliant companies. We note that, although this choice could increase the risk of false positives, it could be the only way to appreciate the information embedded in 'weaker factors' (according to the standard quartile method). This approach is fundamentally different from selecting the threshold subjectively. By automatically selecting the best ones, we put all our ESG variables on the same level playing field.

4.2 Tree-Based Approach, the General Idea

Our ML approach for portfolio construction has two steps: (1) we use an optimized algorithm to select the ten most meaningful ESG indicators in three types of trials, for different financial objectives; (2) we combine those indicators to select and weight stocks to construct portfolios, which are tested afterwards.

To systematically find the most significant ESG indicators that could provide portfolio extra performance, we check for the indicators that can help towards stock selection aimed at maximizing the best–minus–worst (BmW) differential in terms of three financial indicators on a 12-month horizon, namely:

– mean absolute return;
– variance; and
– Sharpe ratio.

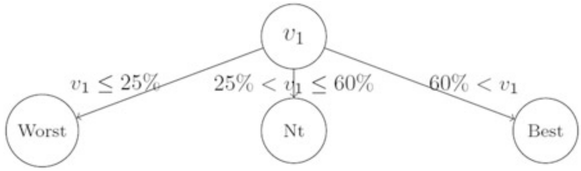

Fig. 2 The first split of decision tree. The lower threshold is 25 per cent, meaning that all the stocks that have a score (given by the variable v_1) that falls in the lower quartile are assigned to the 'worst' portfolio. While the stocks with a score in the top 40 per cent are assigned to the 'best' portfolio

From our initial trials, a tree-like structure arises naturally as one of the best ways to automate our research and keep the model as simple as possible, allowing the decision-maker to understand the economic meaning of the results. This addresses one of the greatest concerns about ML solutions, which is the lack of interpretability of the results.[4] Our idea consists in building trees by setting thresholds that aim at the optimization of a variable that is not the RMSE, but a portfolio financial variable. Specifically, we maximize (minimize) the mean absolute return and the Sharpe ratio (the variance).

To go in the 'ESG direction', we impose the tree to allocate the stocks to the *best* and the *worst* portfolio (where the stocks in the best portfolio are more sustainable than the stocks in the worst). The choice of the ESG variable and the relevant thresholds for the split is made by our ML approach. This yields the best optimization result for the chosen portfolio metric, after having tried all the possible variables with all the possible thresholds in the set. These are 20, 25, 30, 35, 40, 45, and 50 per cent for the lower bound and, as a complement, 80, 75, 70, 65, 60, 55, and 50 per cent for the upper bound. A simple optimization argument allows the algorithm to be linear instead of quadratic in the number of different thresholds.

With decision trees, we start from a root (graphically it is often at the top) and we create splits that generate new branches. We explain hereafter what our trees do by starting from the meaning of the first split.

The first split consists in dividing the stocks in the best percentile and comparing them to the ones in the worst percentile (Fig. 2). We write on each branch the values of the thresholds. We highlight that, unlike the most used decision or regression trees, our splits are not necessarily binary (i.e. with only two branches per split) but allow for a 'neutral' node in which we put all the stocks which are neither in the best nor in the worst portfolio.

The power of the decision tree approach stems from the interaction between the variables, which can be grasped by adding more splits at each node. However, adding too many splits could complicate the understanding of the model. We thus decided to limit our structure to a 2-level tree for the benefit of interpretability. We added a second split identical to the first one, to sort our stocks with respect to a

[4] Early work on the use of decision trees for corporate governance factor selection can be found in Misangyi and Acharya (2014).

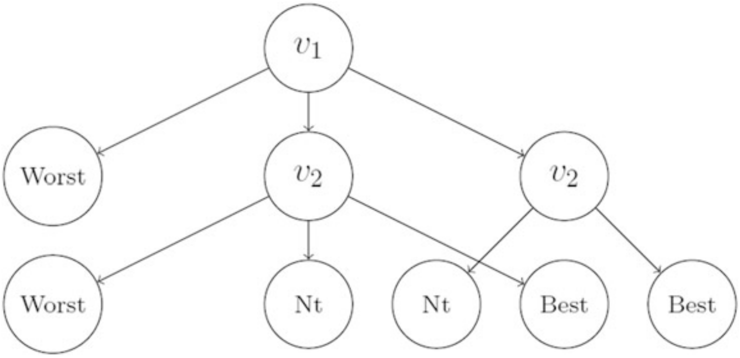

Fig. 3 The second split for decision trees

second ESG variable starting from the neutral node. This split can promote stocks that were put in the neutral portfolio after the first split; if the score relating to the second variable is high from the ESG viewpoint, the split can leave the stocks in the neutral zone or put them in the worst portfolio if the score is low. A third split (on the same level) is added by using the second variable, to introduce the possibility to downgrade to neutral (but not to worst) stocks that were put in the best portfolio at the first step (Fig. 3). The idea behind these choices is to leave space for the second variable to 'correct' the sorting of the first one, by leaving to the first variable the leading role in the decision.

The strength of this approach is twofold: (i) it looks straight at portfolio performance rather than at indirect indicators that could suggest a good portfolio performance; (ii) all the available data are used at each time. The model allows us to grasp a simple interpretation of the results. Despite the strong appeal of the empirical results, the explanations and possible correction mechanisms are left to the choice of the interpreter of results. Unlike some recent uses of ML in finance, our approach has the advantage of being tailored for long-term performance rather than the study of high-frequency data, since the objective has been set up as one-year performance.

Overall, although we tried to keep our exercise as parsimonious as possible, the burden of numerical calculation is quite significant as it involves 252 stocks, 125 dates, and 217 ESG indicators with 7×2 (best and worst) thresholds; in addition, every combination is repeated three times, according to the three financial objectives.

4.3 Training the Trees

We have chosen the period 2007–2016 as the training period, while the test period is 2016–2019.

Once the best first split for each ESG variable is found, the best ESG variables in the second split are selected, and only afterwards are the best thresholds for the third split computed. We have given a score to weight each ESG factor according to its importance in this process. To include the impact of a variable also in interaction with other variables, we compute the base score as the difference between the best and the worst portfolio for the chosen financial variable at the first split. We add to this base score one-third of the increase in score given at every positive contribution at the second or third split, excluding those contributions that leave in the last 5 years less than five stocks in any portfolio (best or worst).

Finally, the ESG variables are sorted by their overall score and the worst and the best portfolios are constructed using the top and bottom ten variables, selecting the stocks classified as best first split for each variable and weighted with respect to the score of the variable in such a way that, starting from equal weight, no difference in score could provide a tilt greater than one-fourth of the weight in each portfolio.

The same analysis was repeated afterwards using only environmental variables to focus on the profiles that attract a growing consideration of the investors as an important source of climate-related risks.

Finally, the portfolios are tested in-sample and out-of-sample for each of the portfolio financial indicators, and the returns are regressed to the FF five factors and with the macroeconomic variables in the BIRR model. As expected, we find a strong correlation with the market portfolio. This is not surprising, since we are working inside the universe of the benchmark. The alpha intercept in each regression is always larger for the best portfolio, with the highest statistical significance for the mean absolute return optimizations.

5 Results

We present the results of our analysis separately for the three indicators of risk/return considered as the objective of portfolio construction, namely:

– mean absolute return
– variance
– Sharpe ratio.

By using Eq. (2), we test if portfolios built upon the ML-selected ESG indicators show a return or risk differential between the Best–minus–Worst (BmW) portfolios not fully explained by the Fama-French risk factors (or style factors), such as market, size, value (B/M), operating profitability, and conservativeness; then we test whether the residual extra-return can be attributed to the alpha generated by the ESG key indicator.[5] A similar factor analysis is performed to disentangle the contribution of macroeconomic variables of the BIRR model from the BmW portfolios' risk and return indicators using Eq. (1).

For each case, we provide information about the ESG indicators (the first exercise, commented in Sect. 5.1) and the environmental indicators only (second exercise in Sect. 5.2) that we found as the most significant. For both exercises, we show the following information:

– the tables with the ten ESG indicators, showing the score (weight) of each indicator in combination with another indicator or alone, whether the indicator is a bivariate variable or not, the type (environmental, social, or governance), the threshold we found as significant for discriminating best over worst portfolios at the first and second split, the minimum size (number of securities) of the best and worst portfolios;
– the graphs of the price return and the number of stocks for the best and worst portfolios, which show the overall simulation and in- and out-of-sample exercises;
– the value of the monthly return, variance, Sharpe ratio, and maximum drawdown for the best and worst portfolios, over a one-year horizon, for both in- and out-of-sample exercises; and
– the statistics for the regressions of the best/worst portfolio returns with the factor models (FF five-style factors and BIRR) to assess the additional contribution of the ESG indicators (where the intercept of the regression can be considered as the alpha of the ESG component) and their significance (p Value and other statistics).

We found that the best portfolios in-sample were the best also out-of-sample, with better results in each portfolio variable. Only the out-of-sample return of the best portfolio obtained by optimizing the difference BmW in variance was below the out-of-sample return of the worst portfolio. Good results were obtained also for the drawdown, which was always smaller for the best portfolios than for the worst ones, both in-sample and out-of-sample.

5.1 *Results for ESG Indicators*

The analysis of portfolio construction with ten ESG indicators shows that those selected for maximizing the difference BmW of absolute return provide a positive outcome; this holds true in-sample and out-of-sample, with a yearly return difference of around 4.5 per cent and 1.2 per cent, respectively (38 and 10 basis points, or bps,

[5]The F–F five factors for the regressions of our portfolios are taken from the Kenneth French data library for Europe available on his website and converted in EUR terms with the correspondent USD/EUR rates (https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/ data_library.html).

Table 4 ESG indicators

	Absolute return		Variance		Sharpe ratio	
	In-sample	Out-of-sample	In-sample	Out-of-sample	In-sample	Out-of-sample
Return BmW (annualized)	4.5%	1.2%	1.2%	−0.6%	2.4%	0.5%
Variance BmW (annualized)	0.01%	−0.02%	−0.12%	−0.09%	−0.18%	−0.09%
Sharpe ratio BmW	0.07393	0.03856	0.02661	0.02058	0.04853	0.046937
Alpha FF BmW	3.66%		0.81%		1.70%	
Alpha Birr BmW	3.28%		0.23%		1.07%	

on a monthly basis; Table 4). Given a very small increase in the variance, the Sharpe ratio difference BmW improves by 0.039 (see Appendix 1).

Looking at the factor contribution with the FF model, we note that the alpha generated by the ESG indicators provides an annualized return difference BmW of 3.7 per cent (31 bps per month) and a similar magnitude with the BIRR model (3.3 per cent). Both are statistically significant. The graph on the right shows that the number of stocks of the best and worst portfolios increases over time, as more data at security level are available for the selected ESG indicators. This pattern is similar through all the exercises we have carried out and it underscores how helpful it would be for the investors to broaden the universe of disclosing companies.

In the optimization of the difference BmW for the variance, the results show that the ten ESG indicators contribute to the construction of the best portfolios which slightly lower the variance both in-sample and out-of-sample (−12 bps and −9 bps on a yearly basis, respectively) and also display a better Sharpe ratio (by 0.02 out-of-sample), as the return is substantially similar. In disentangling the factor contribution with the FF factor model and BIRR model, the alpha generated by the ESG construction provides an annualized difference BmW of 0.8 per cent (7 bps per month) and 0.2 per cent (2 bps per month), respectively, which are both statistically significant for the best portfolios.

For the maximization of the difference BmW of the Sharpe ratio the in-sample and out-of-sample results are similar, with a difference of 0.049 and 0.047, respectively; this case also yields positive results in the return difference BmW (+2.4 per cent yearly in-sample and +0.5 per cent out-of-sample) and in annualized variance (−18 bps and −9 bps). Disentangling the factor contribution with the FF factor model and BIRR model shows that the alpha generated by the ESG indicators provides an annualized difference BmW of 1.7 per cent annualized (14 bps per month) and 1.1 per cent (9 bps monthly), respectively, which are both statistically significant for the best portfolios.

Among the most material ESG indicators in our portfolio construction, 9 out of 17 are related to environmental issues. This finding highlights the relevance of the environmental issues for equity portfolio performance. The environmental indicators relate not only to carbon emissions (via the carbon intensity) but also to waste

Table 5 The most significant ESG indicators

	Return	Variance	Sharpe	Tot	Biv	Type
CO_2 emissions/revenue	0.037744	−0.0081091	1.0305	3	0	ENV
Waste/revenue	0.033685	−0.013162	0.85332	3	0	ENV
Hazardous waste/revenue	0.016597	−0.012686	0.49405	3	0	ENV
Employee accidents	0.011874	−0.0023094	0.20353	2	0	SOC
Specific board skills	0.011174	−0.00026921	0.29618	2	0	GOV
Controversial sourcing exposure	0.0099531	−0.00038647	0.29592	2	0	SOC
Total injury rate	0.0095307	−0.0025926	0.17775	2	0	SOC
Bribery, corruption, fraud controversies	0.0082332	−0.0074764	0.33058	2	1	SOC
Nuclear	0.0054778	−0.0085057	0.20614	2	1	ENV
Energy use/revenue	0.0049003	−0.0035541	0.22408	2	0	ENV
Eco-design products	0.014168	0.0014373	0.12906	1	1	ENV
Long-term compensation incentives	0.0086402	−0.00011075	0.10977	1	0	GOV
Environmental score	0.0083413	0.00071022	0.073592	1	0	ENV
Waste recycling ratio	0.0072689	0.00011708	0.2286	1	0	ENV
Board diversity	0.0063854	−0.00026604	0.24095	1	0	GOV
Women employees	0.0053944	−0.0022783	0.18377	1	0	SOC
Animal testing	0.0029715	−0.0053909	0.10969	1	1	ENV

Note: Tot: number of financial objectives for which the indicator is significant; Biv:flag for bivariate indicator; Type: indicator's group (E, S, or G)

management, recycling, and eco-innovation. Interestingly, the environmental score of one of the providers is identified as material but it is not on the first ones. Of the other indicators, five are related to social profiles (mainly about employee safety) and three to governance factors, with a prominent role for diversity. Only four ESG variables are bivariate (Table 5).

The exercises with the 17 indicators show that the Best portfolio over-performed the Worst portfolio both in-sample and out-of-sample for the three financial objectives, with a lower over-performance for the objective of variance optimization (out-of-sample), while positive results are provided with the objective of Sharpe ratio difference maximization. Remarkably good results are obtained for the objective of absolute return, where also the variance (out-of-sample) and alphas are clearly in favour of BmW.

Our findings, obtained with a novel ML approach, are consistent with previous evidence from several studies which apply alternative models and techniques. In particular, these studies find extra performance for stocks with better indicators relating to environmental issues (carbon intensity, as in Bernardini et al. 2021a, b; Mats et al. 2016; In et al. 2019), social profiles (employee satisfaction, as in Edmans 2011), governance structure (Li and Li 2018), and gender diversity (Nguyen 2020). The empirical relevance of ESG factors in building efficient portfolios, as shown in our study, is in line with the findings of Kaiser (2020), Kumar et al. (2016), Giese et al. (2019), and Maiti (2021). Other studies find mixed results (Billio et al. 2021) or show opposite results (Pedersen et al. 2021; De Spiegeleer et al. 2021).

5.2 *Results for Environmental Indicators*

The analysis of portfolio construction with ten environmental indicators, besides those identified in the previous section, finds some complementary indicators. The maximization of the difference BmW of absolute return shows that the environmental indicators bring larger differential return out-of-sample compared with the ESG indicators, with an annualized return difference of 1.8 per cent (compared with 1.2 per cent for ESG indicators), lower variance, and thus a higher Sharpe ratio (0.07, see Appendix 2). Besides, the in-sample results show a positive BmW difference for the return (+2.8 per cent on annual basis) and Sharpe ratio (0.04). The analysis of the factor contribution shows that the alpha generation by constructing portfolios with environmental indicators is significant both with the FF model (2.8 per cent annually and 24 bps monthly) and with the BIRR model (2.0 per cent annually and 17 bps monthly; Table 6).

The optimization of BmW difference in variance shows that the ten environmental indicators contribute not only to reducing the variance but also to a positive annualized return difference (0.2 per cent in-sample and 0.8 per cent out-of-sample) and a Sharpe ratio increase (+0.08 and +0.05, respectively). The alpha provides mixed results, as it is positive with the FF factor decomposition (+0.63 per cent annualized) and slightly negative with the BIRR model (−0.19 per cent), which is statistically more significant.

The maximization of the difference BmW for the Sharpe ratio shows very positive results in-sample and out-of-sample for all the financial measures: the annualized return increase is 3.2 per cent and 1.8 per cent, respectively; the variance reduction is 26 bps and 10 bps; the Sharpe ratio increase is 0.07 and 0.09. The factor contribution exercise shows that the alpha generated by the environmental indicators is remarkably large: it is 2.9 per cent on an annualized basis with the FF factor model

Table 6 Environmental indicators

	Absolute return		Variance		Sharpe ratio	
	In-sample	Out-of-sample	In-sample	Out-of-sample	In-sample	Out-of-sample
Return BmW (annualized)	2.8%	1.8%	0.2%	0.8%	3.2%	1.8%
Variance BmW (annualized)	0.03%	−0.05%	−0.06%	−0.07%	−0.26%	−0.10%
Sharpe ratio BmW	0.04461	0.06908	0.00802	0.04786	0.07063	0.08947
Alpha FF BmW	2.84%		0.63%		2.91%	
Alpha Birr BmW	2.01%		−0.19%		1.37%	

Table 7 The most material environmental indicators

	Return	Variance	Sharpe	Tot	Biv
Waste/revenue	0.013808	−0.0072546	0.35684	3	0
CO2 emissions/revenue	0.013171	−0.0057402	0.35125	3	0
Hazardous waste/revenue	0.0051957	−0.0079682	0.16283	3	0
Climate change theme score	0.00338	−0.0016526	0.11476	3	0
Waste recycling ratio	0.0080097	8.1759e−05	0.2737	2	0
Prod. Carbon footprint score	0.0041826	0.0002437	0.14035	2	0
Prod. Carbon footprint Mgmt	0.0038396	0.00025081	0.14645	2	0
Emission reduction objectives	0.0038287	−0.00071986	0.071566	2	1
Water use/revenue	0.0018263	−0.00064089	0.1227	2	0
Eco-design products	0.0075791	0.0014373	0.10354	1	1
Environmental score	0.0068444	0.00079796	0.083197	1	0
Energy use/revenue	0.0030538	−0.0021816	0.095028	1	0
Opportunities in renewable energy score	0.0029098	7.8753e−05	0.11179	1	0
Nuclear	0.0025489	−0.0031798	0.068439	1	1
Opportunities in clean tech score	0.0024122	0.00036662	0.11353	1	0
Opportunities in renewable energy Exp	−0.00052838	−0.00047105	−0.011381	1	0
Animal testing	−0.0026548	−0.0018501	−0.077037	1	1

and 1.4 per cent with the BIRR model, and the best portfolios are statistically significant.

Among the most significant environmental indicators, besides those already found in the ESG case study, some are based on the assessment of providers. This highlights the role of forward-looking evaluation of the environmental issues and climate-change risks. In turn, this strengthens the notion that corporates should manage such risks and move forward adaptation techniques, like renewables and clean technologies (Table 7).

6 Conclusions

ESG investing is enjoying a remarkable growth in terms of supply and demand. This creates a general interest in the transparency and consistency of the ESG assessment of firms. In the absence of standardized methodologies, the providers of ESG scores and ratings adopt a variety of proprietary techniques, which results in the low correlation of the ESG scores across different providers. Our research proposes a model-free approach that overcomes some of the limits of ESG scores. We identify a strategy that directly employs ESG indicators, and more specifically environmental factors, to build equity portfolios that generate efficient financial results, with superior return and lower risk than those obtained with traditional factor models of the stock market.

The risk and return differentials are statistically and economically significant even after taking into account the contribution of the standard Fama-French model with style factors and of the BIRR model with macroeconomic factors. Among the risk/return indicators we have chosen—return, Sharpe ratio, and variance—our strategy provides the best results for the first two, while the contribution to variance is mixed. Our results are consistent with previous evidence, showing a positive performance differential for stocks with better indicators for the ESG profiles.

Our findings indicate that an investor in the European equity market who had developed the proposed ML technique in 2016 and applied it in the period from January 2017 to April 2019 would have achieved on average an extra annualized return between 0.5 and 1.2 percentage points over the Eurostoxx index, depending on the different risk/return objectives, and using the ESG indicators identified for portfolio construction; the extra return would have been between 0.8 and 1.8 percentage points using the environmental indicators only.

These findings prompt three remarks. First, the direct use of ESG indicators seems to have a significant payoff in terms of financial performance. Second, our findings support the notion that quantitative information on the company sustainability profiles is quite important and should be improved, by means of greater corporate disclosure, possibly via regulation aimed at wider consistency and comparability. Useful information may be extracted from the available ESG indicators other than the scores sold by professional providers. Among the ESG variables selected with our ML technique, half are environmental and some refer to the company exposure and ability to manage climate change risk. Among the selected environmental variables, only one corresponds to the environmental score of a provider. This means that the ESG scores do not exhaust the information available in the data disclosed by the firms.

As we were not able to measure the extent to which the evaluation by providers integrates climate-related scenarios, if at all, future research could investigate additional firm-level indicators based on climate scenarios and possibly perform a stress test analysis under different transition pathways.

Since the proposed ML methodology is fairly new, more can be done to test its robustness. Our validation was done by comparing the results of training in the first period with the out-of-sample results. Future research could try some form of cross-validation. As an alternative, one could try a shorter training period. The disentangling methodology to detect the specific contribution of ESG and environmental indicators was implemented by means of the Fama-French and BIRR models. A test for a naive portfolio could be carried out in future research. Furthermore, an analysis of the relevance of the ESG variables by sector could be carried out. Finally, a deeper understanding of our model would be warranted by experimenting with different methodologies in splitting and variable choice. For instance, one can develop a bootstrap technique that suits the portfolio construction (bagging) and experiment with restrictions on the number of variables at each split (random forest).

Appendices

Appendix 1: Portfolios Obtained with ESG Indicators

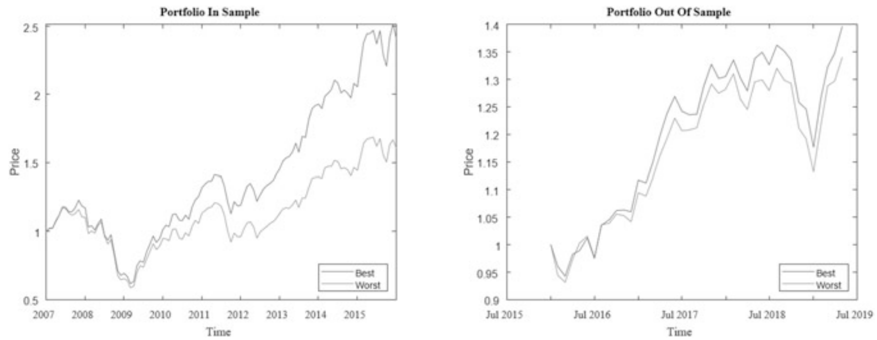

Fig. 4 Cumulative returns, in sample and out of sample, of best and worst portfolios built by optimizing return

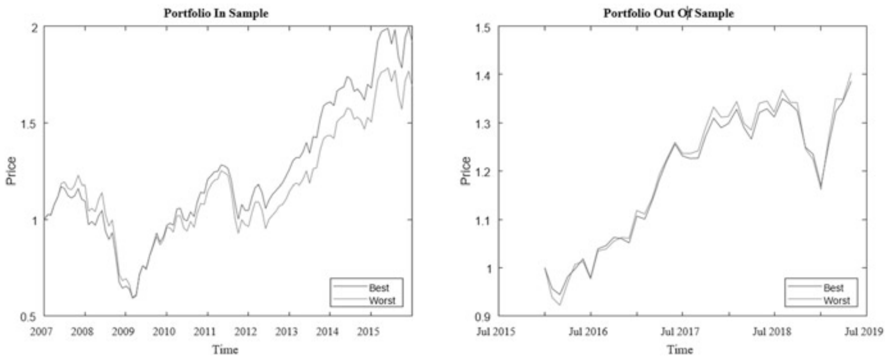

Fig. 5 Cumulative returns, in sample and out of sample, of best and worst portfolios built by optimizing variance

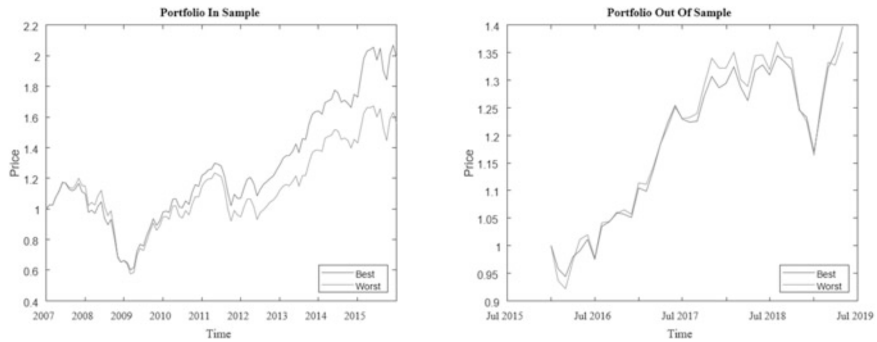

Fig. 6 Cumulative returns, in sample and out of sample, of best and worst portfolios built by optimizing Sharpe ratio

Appendix 2: Portfolios Obtained with Environmental Indicators

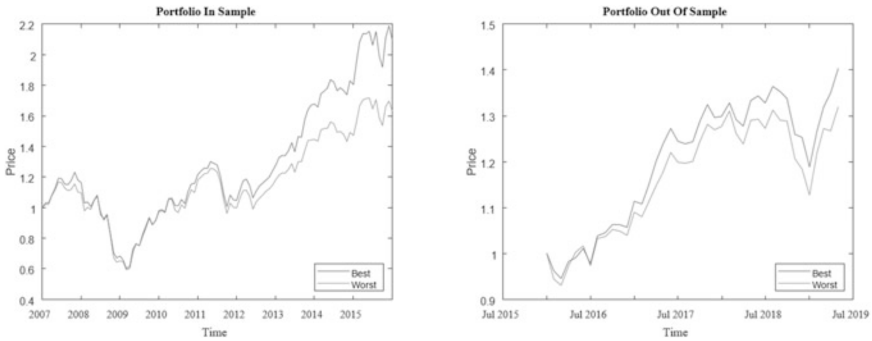

Fig. 7 Cumulative returns, in sample and out of sample, of best and worst portfolios built by optimizing return

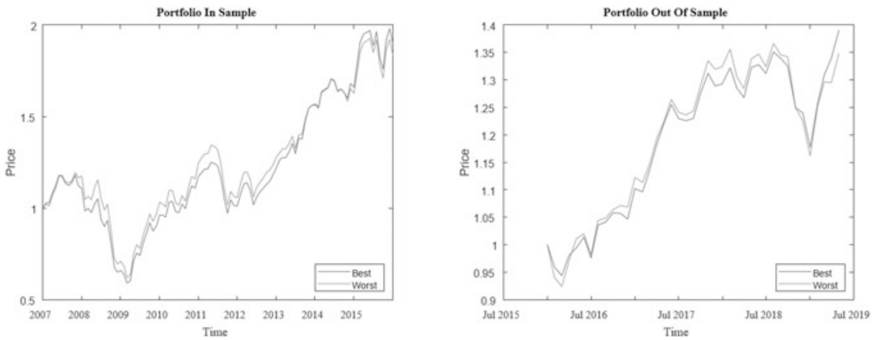

Fig. 8 Cumulative returns, in sample and out of sample, of best and worst portfolios built by optimizing variance

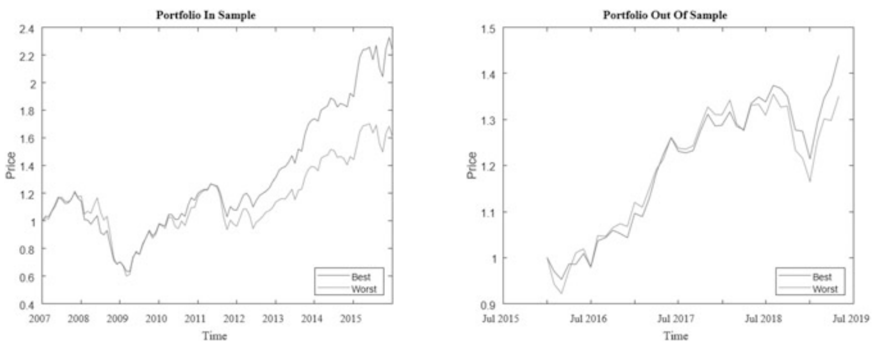

Fig. 9 Cumulative returns, in sample and out of sample, of best and worst portfolios built by optimizing Sharpe ratio

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The Global Green Bond Market

Danilo Liberati and Giuseppe Marinelli

1 Introduction

Climate change and its impact on financial markets and institutions have recently become a significant topic in the economic debate.[1] The development of a transitional economic model allowing sustainable growth is one of the key challenges for policymakers, economic agents, and financial markets in the coming years. The pandemic crisis brought about a wake-up call on the correct assessment of climate-related risks, as pointed out by Schumacher (2020) and Schnabel (2020):

> The pandemic is therefore a stark reminder that preventing climate change from inflicting permanent harm on the global economy requires a fundamental structural change to our economy, inducing systematic changes in the way energy is generated and consumed.

The *green finance gap*, i.e. the lack of the necessary financial resources that can be directed towards green investments, is a significant limitation for the green structural change of the economy. Apparently, green projects can be judged as not sufficiently attractive for investors due to the seemingly low rate of return[2] and the associated risks.[3] Nevertheless, the rapid growth of the environmental, social, and

[1] See the 2015 Paris Agreement and the 2030 Sustainable Development Agenda.

[2] See Yoshino et al. (2019).

[3] Hafner et al. (2020) claims that investors' reluctance regarding green investments depends on several factors: lack of confidence given the technology risks; lack of information and experience; unstable energy policies; and high transition and commercialization costs.

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governance (ESG) bond[4] market suggests that a vigorous interest of investors does exist. ESG bonds are debt securities whose proceeds are invested by the issuer to pursue environmental, sustainability, and social purposes such as the reduction of CO_2 emissions, the increase of energy efficiency, the enhancement of health care and of workers' conditions in terms of safety or inclusion. The increasing importance of such instruments is shown by the fact that the main stock exchanges across the world have launched sustainable/green market segments and/or participate in the Sustainable Stock Exchanges initiative.[5]

The ESG bond market can be analyzed under several aspects. A first area of interest concerns the implications that the environmentally sustainable finance has on the issuers' value. ESG bond issues are generally more expensive than those of standard securities due to the external and independent reviewer cost to certificate that the use of the proceeds of the green bonds is aligned to ESG criteria. Conversely, issuing ESG debt securities sends a positive signal in terms of transparency and the firm value may increase in the long run,[6] benefiting from the reduction of information asymmetry.

Second, green bonds may turn out to be a convenient source of funding. Many studies have tried to check for the existence of a *greenium*, i.e. a negative premium on ESG debt securities,[7] implying that investors obtain lower returns from such instruments when compared to the standard counterparts. At the same time, this would result in lower borrowing costs for issuers offering ESG instruments to investors.

Third, the transition to a low-carbon economy can be favoured by the role of policymakers like central banks and market regulators. Hence, both macroprudential and non-standard monetary policies might affect investments in climate-friendly or sustainable assets mitigating CO_2 emissions and favouring green projects financing. This claim has become even more important since 2020, when the Covid-19 shock hit the global economy and slowed down green investments, as shown by Guérin and Suntheim (2021). A special role could be played by governments leading and managing the ecological transition[8]: following the positive experience of Germany

[4] We will be using 'ESG bonds' and 'ESG debt securities' interchangeably throughout the chapter when referring to the whole set of debt securities with the ESG label and belonging to the commonly known sustainable market. Indeed, green bonds represent 85 per cent of our ESG dataset; in a few cases, we find a misclassification between sources for the same security, in particular for green and sustainable securities.

[5] See https://sseinitiative.org and https://www.climatebonds.net

[6] The *greenwashing* phenomenon may arise when the communication of firms to enhance their environmental reputation is not supported by data and results, or it is consciously used to distract investors from the true profile of the company.

[7] The expression *greenium* is usually referred to green bonds, but for the sake of brevity we will be using it for the entire set of ESG bonds.

[8] See also the recent remarks by Bank of Italy Governor at the 'Financing Carbon Neutrality' Round Table of the annual conference of the Boao Forum for Asia and the presentation of theG20 TechSprint 2021 on sustainable finance.

and France in March 2021, to finance public expenditure with a positive environmental impact, Italy successfully issued its first green bond with an enthusiastic response from investors.[9]

The remainder of this chapter is structured as follows. Section 2 provides a review of the literature on ESG instruments; Section 3 describes the construction of the data set; Sections 4 and 5 focus on the features of the global supply of ESG bonds and on Italian residents' holdings, respectively. Section 6 provides a discussion of the *greenium* puzzle.

2 Literature Review

Green bond markets can play a pivotal role in financing the transition to a low-carbon economy and sustainable growth (Sartzetakis 2021). This process can be supported by financial intermediaries: in spite of the increase in green bond issues, banks do not seem to play a significant role in the promotion of green projects. Xiao et al. (2021) show that the regulatory arbitrage mechanism is a more important motivation for Chinese commercial banks to issue green bonds rather than the climate goal. Barua and Chiesa (2019) look at the factors affecting the amount of funds raised through the green bond supply. They find that the average funding size is significantly lower for high-grade bonds, whereas no significant effects are found in the case of banking issuances. Based on the maturity mismatch between the asset and liability sides of banks' balance sheets and the comparable costs between green and standard security issues, Gianfrate and Lorenzato (2018) indicate best practices to promote capital allocation towards green projects by non-bank financial institutions, such as mutual funds and insurance companies. Furthermore, Riedl and Smeets (2017) find that social preferences and signalling play a more important role than the financial motives for socially responsible investment (SRI) decisions. Hartzmark and Sussman (2019) point out that sustainability can be viewed as positively predicting future performance in the US mutual fund market, even if no evidence supports the conjecture that highly sustainable funds outperform lowly sustainable ones.[10]

Nowadays, climate-related objectives can be found in the agenda of central banks for macroprudential policy and monetary policy purposes (Bernardini et al. 2021). On the macroprudential side, attention is paid to the effects of the so-called *brown penalizing factor*, i.e. a setup where carbon-intensive assets are penalized with a relatively higher risk weight in the calculation of capital requirements, in contrast to the *green supporting factor*, that adjusts capital requirements for green bonds (Thomä and Gibhardt 2019). A critical review of the current prudential framework

[9] See the MEF Press Release.

[10] See also ECB (2020) (Box 7) for an overview of the performance and resilience of the euro-denominated ESG funds and green bonds.

is provided by D'Orazio and Popoyan (2019), who find that a unique instrument for all scenarios does not exist, even if the buffers built during the carbon-intensive credit cycle could be beneficial. From a monetary policy perspective, by using a stock-flow-fund ecological macroeconomic model, Dafermos et al. (2018) provide evidence of climate-induced financial instability, with a rise in defaults and an asset price deflation process that might be reduced with a green quantitative easing (QE) programme. Significant effects in reducing harmful emissions are found by Ferrari and Nispi Landi (2020). They run a temporary green QE in a DSGE model based on the assumption that green and conventional bonds are not perfect substitutes. Returns on the two types of securities may be affected by exogenous shocks such as the Covid-19 pandemic. Yi et al. (2021) find that the pandemic shock increased the cumulative abnormal returns of the Chinese green bond market due to the production stop—in particular for industries financed by green bonds—which caused both a decrease of the demand for green energies and an increase in the duration of green bond projects. A recent analysis by Ayaydin et al. (2021) argues that, following the Covid-19 pandemic, the performance of green securities may outperform that obtained by brown bonds. Based on the Morningstar ESG risk scores—measuring firms' exposure to ESG-related risks—Ferriani and Natoli (2020) show that after the Covid-19 outbreak, investors preferred to invest in low-ESG-risk funds (that have performed better than their peers) to hedge against further market downturns.[11]

The empirical literature on the existence and sign of a premium for investing in ESG bonds focuses on the green market and on the commonly denominated *greenium*, with mixed results.[12] By examining data on US green bonds as reported by Bloomberg at the end of 2017, Zerbib (2019) estimates a negative yield differential between a small sample of green bonds and a group of standard securities. Similar conclusions are reached by Ehlers and Packer (2017) for the primary market, even though they find no difference in performance between green and conventional bonds in the secondary market.[13] A negative premium is estimated by Baker et al. (2018) for US municipal bonds after-tax adjustments, and by Gianfrate and Peri (2019) for euro-denominated green bonds. Nonetheless, security and issuer characteristics can play a role in determining the existence of a *greenium*. Fatica et al. (2021) find a negative and significant *greenium* when issuers are supranational institutions or corporates, but no such evidence arises if the issuer is a financial institution; similar results are found by Kapraun and Scheins (2019). Alessi et al. (2019) show that the risk premium related to green finance is also negative when one considers the companies' greenhouse gas emissions and the quality of their

[11] See Faiella and Malvolti (2020) for an assessment of the climate risk for Italian finance.

[12] For surveys on this topic see Liaw (2020) and Cheong and Choi (2020).

[13] Ehlers and Packer (2017) point out that issuing green bonds is a costly transaction due to the requirement of third-party validation to reduce informational asymmetry and the risk of greenwashing (Baker et al. 2018). Hyun et al. (2020) examine the green bond market investors' pricing, by finding that green bonds have lower yields than the conventional ones.

environmental disclosures. Tang and Zhang (2020) find no significant premium in favour of green bonds in a sample of securities drawn from Bloomberg and the Climate Bond Initiative (CBI). This result is confirmed by Larcker and Watts (2020) for US municipal securities. In the case of government bonds, Doronzo et al. (2021) find that the yields of green and standard issues in the primary and secondary markets are aligned, even during the Covid-19 crisis. Higher returns for green bonds are found by Bachelet et al. (2019), who also check whether the volatility and liquidity of green assets are affected by the presence of a third-party green certification for the bonds. Higher returns for green bonds are also found by Karpf and Mandel (2017) by using the Oxaca-Blinder decomposition over a large sample of US municipal bonds.

3 Data

A register of ESG bonds does not exist. According to the International Capital Market Association (ICMA),[14] ESG data providers do not usually disclose the securities' standard identification codes, such as ISIN, nor do they allow for a massive filtering based on the green label. Furthermore, ESG bonds can be labelled or not: the green bond label is only assigned to instruments that meet specific criteria defined by international guidelines such as those published by ICMA and CBI. Data providers may publish information on labelled and unlabelled ESG bonds and/or use different certification standards.[15] To overcome such practical issues, we construct a unique multi-source database by exploiting public information on ESG bonds with no distinction on the type of certification standard used to assign the ESG flag. Detailed information on the features of securities and issuers were subsequently obtained from structured databases such as the Centralised Securities Database, the Securities Holdings Statistics, and the intermediary supervision statistical reporting.

[14] For more details see the summary of Green/Social/Sustainable Bonds Databases.

[15] Evaluation steps and methodologies to label a bond as 'green' may change. Generally, on a voluntary basis ESG issuers try to design their ESG framework/bonds to respect the most important criteria and guidelines such as the Green, Social and Sustainability-Linked Bonds Principles (https://www.icmagroup.org/sustainable-finance/), the Climate Bonds Standard (https://www.climatebonds.net/market/best-practice-guidelines), or the recent release of the EU Green Bond Standard. Validation provided by independent external reviewers can be distinguished in different types of services (Second Party Opinion, Verification, Certification, or Bond Scoring/Rating) based on the tightness, timing (before or after the issuance) and focus of the evaluation. For more details see Ehlers and Packer (2017) and the Guideline for the external reviewers published by the ICMA.

3.1 Identification of ESG Bonds

The first component of our comprehensive list is the ESG debt securities which were quoted on dedicated bond market segments of the main exchanges around the world at the end of 2021. The initial list of ESG debt securities comprised 15,529 ISIN codes. The largest fraction of ESG securities has been compiled thanks to a web-scraping procedure that extracts the ISIN codes[16] of the debt securities listed on the specialized segments of the online market platforms. Since sustainable bonds are a recent phenomenon, and owing to their long maturity, our dataset contains virtually all the securities issued and/or exchanged on the relevant markets. Almost all of them have an ESG label and have favourable pre-issuance external reviews.

The second block of our list was hand-collected exploiting information on ESG bonds published by providers such as CBI, Environmental Finance (EF), and ICMA.[17] The information on the issuer (such as the residence country and the type) and on the issue (face value, currency, issue, and maturity dates), obtained from the issuers' official websites and the main financial market platforms, enabled us to find the relevant ISIN codes.[18]

The third component of the list was derived from the basket composition—if available at ISIN level—for the leading green indexes, such as the Solactive Green Index or the China Green Bond Index, or the sample definitions of previous studies of investment banks and research institutes. Finally, we exploited information from the websites of the main national and supranational institutions reporting their ESG issues and programmes.

The relative importance of a source can be understood through the number and volume of listed ESG securities. The same security may be listed on different platforms and employed in more reports (Table 1). In the Luxembourg Stock Exchange, the green segment included 961 ESG securities for a nominal value of EUR 475 billion, in which green and sustainable bonds have the largest share. Other significant sources were the German and the Italian exchanges, reporting ESG securities for a total volume of EUR 260 billion each (Table 2). An additional source of information is Euronext, which listed ESG bonds from exchanges in Amsterdam, Brussels, Dublin, Lisbon, Oslo, and Paris.

[16] In some cases, ISIN codes are not available. In particular, for US and Canadian securities we employ the CUSIP codes—identifiers used in North America—and convert them into ISIN codes by using the Luhn algorithm specified in ISO/IEC 7812-1.

[17] See the Appendix.

[18] The platform Cbonds is a tool for global bond market screening. It provides detailed information on securities from 180 countries (100 per cent coverage of Eurobonds worldwide) and attaches the 'green bond' label where applicable. In the presence of US municipalities a useful instrument to obtain the securities' identifiers and to control for the multi-tranche cases is the Electronic Municipal Market Access (EMMA) Dataport, from where all official statements of issues by US municipalities can be downloaded.

Table 1 Number of ESG bonds. This table reports statistics on the number of ESG debt securities broken down by market or information provider. The following classification is applied. GRE: green bonds aligned to the social and/or sustainable principles as well as infrastructure green, transition, climate action, climate resilience, climate awareness, environment, and blue bonds; SOC: social bonds include infrastructure social, health and microfinance ones; SUS: sustainable bonds include infrastructure sustainable, sustainable awareness, SDG-linked and Covid-19 ones; CSDB: number of securities found in the ECB CSDB. Volumes: outstanding amount, EUR billion

Source	Total	GRE	SOC	SUS	CSDB	Volumes
CBI/ICMA/EF	16,393	13,804	1463	1126	5546	2014
Nasdaq	6391	5527	824	40	627	140.4
Green indexes	2432	2432	0	0	2138	1169.8
Luxembourg	1334	717	105	512	1201	669.6
Research institutes	1048	814	136	98	922	379
Euronext	574	504	28	42	531	330.1
Nordic	503	501	0	2	461	37.2
Frankfurt	412	412	0	0	388	372.8
London_stock_exchange	364	258	12	94	348	147.2
Singapore	345	209	38	98	311	130.6
Eurex_Green_Bond_GC_basket	245	245	0	0	241	372.9
BIX_Malaysia	232	232	0	0	231	1.9
Other	211	160	37	14	179	56.6
ACMF	206	172	5	29	192	15.7
Borsa_Italiana	201	100	23	78	190	398
World_Bank	192	192	0	0	82	6.7
Taipei	90	71	7	12	87	8.1

3.2 *Information on Securities*

After the identification of the ESG bonds, we used other databases to obtain details on the instruments and their issuers. We drew information from the Bank of Italy's Securities Data Base and the European Central Bank's Centralised Securities Data Base (CSDB), from which we obtained the country and the institutional sector of the issuer, and the price, maturity, and currency of the security. Since CSDB provides information on securities issued by EU residents and/or held and transacted by EU residents, as well as securities denominated in euro, some ESG bonds (mainly issued by US municipalities) were excluded once we merged the ESG list with the CSDB. Remarkably, many US ESG bonds were issued by municipalities or were asset-backed securities issued by government-sponsored agencies such as Fannie Mae or Freddie Mac.

Once we identified an ESG bond and its features, we investigated if, and in which amount, it was held in the portfolios of Italian residents. The third component of our data set is based on data drawn from the Bank of Italy's supervisory statistics on individual banks and mutual funds. Data on banks have been aggregated at banking

Table 2 ESG bond volumes (EUR billion and percentage values) by Purpose of the Proceeds. This table reports statistics on the number of ESG debt securities broken down by market or information provider. The following classification is applied: GRE: green bonds that are also aligned to the social and/or sustainable principles as well as infrastructure green, transition, climate action, climate resilience, climate awareness, environment and blue bonds; SOC: social bonds include infrastructure social, health and microfinance ones; SUS: sustainable bonds include infrastructure sustainable, sustainable awareness, SDG-linked and Covid-19 ones; CSDB: number of securities found in the ECB CSDB. Volumes: outstanding amount, EUR billion

	Outstanding amounts				Share		
Source	Total	GRE	SOC	SUS	GRE	SOC	SUS
CBI/ICMA/EF	2014	1468.8	275.4	269.8	72.9	13.7	13.4
Nasdaq	140.4	116.4	18.3	5.7	82.9	13	4
Green indexes	1169.8	1169.8	0	0	100	0	0
Luxembourg	669.6	280	137.4	252.2	41.8	20.5	37.7
Research institutes	379	335.8	23.8	19.4	88.6	6.3	5.1
Euronext	330.1	242.7	68.6	18.8	73.5	20.8	5.7
Nordic	37.2	37.1	0	0.1	99.7	0	0.3
Frankfurt	372.8	372.8	0	0	100	0	0
London_stock_exchange	147.2	120	4.9	22.3	81.6	3.3	15.1
Singapore	130.6	81.6	14.6	34.5	62.4	11.2	26.4
Eurex_Green_Bond_GC_basket	372.9	372.9	0	0	100	0	0
BIX_Malaysia	1.9	1.9	0	0	100	0	0
Other	56.6	46.6	4	6	82.4	7	10.5
ACMF	15.7	5.2	0.2	10.3	32.9	1.4	65.7
Borsa_Italiana	398	215.4	94.2	88.3	54.1	23.7	22.2
World_Bank	6.7	6.7	0	0	100	0	0
Taipei	8.1	5.9	0.5	1.8	72	5.6	22.4

group level when applicable.[19] Such information is collected at the security level, which enabled us to detect the ISIN codes belonging to the list of ESG bonds. We complemented data on banks and mutual funds with those drawn from the Bank of Italy Securities Holdings Statistics (SHS) to exploit the information on the portfolios of other institutional sectors, like insurance companies, pension funds, households, and non-financial companies. Finally, we used the official harmonized statistics on sectoral financial accounts compiled by the Bank of Italy on a quarterly basis (Bank of Italy 2018) to scale the sectoral issues and holdings of ESG bonds and compare the dynamics of sectoral portfolios.

[19]The observational unit is the banking group or the stand-alone bank if not affiliated to any banking group. For the sake of brevity, we will be using the term 'bank' to indicate the above-mentioned observational unit.

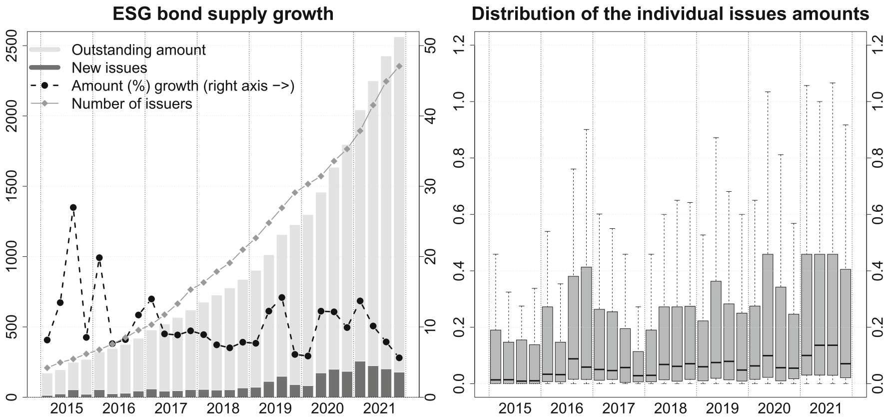

Fig. 1 ESG bond supply. The left-hand-side panel of the figure shows the outstanding amount in EUR billion, the corresponding quarter-on-quarter growth rate and the number of issuers of ESG debt securities between 2015 and 2021. In the right-hand-side panel, the box and whiskers plot show the distribution of the value of individual ESG bond issues between 2015 and 2021. The three lines of the box show, from the bottom to the top, the 25th, 50th, and 75th percentiles of the distribution in a given quarter, whereas the lower and the upper whiskers show the 5th and 95th percentiles. (Source: Own calculations on data from the ECB Centralised Securities Data Base)

4 ESG Bond Supply

Based on the information of the ESG securities in the SHS archive, we note that the supply of ESG bonds has experienced a dramatic increase in the last few years (Fig. 1). At the beginning of 2015, the outstanding amount of ESG bonds was equal to EUR 193 billion; at the end of 2021, it was EUR 2500 billion. The annual flows were EUR 104 billion in 2015 and 860 billion in 2021. In the same time span, the number of issuers has grown from 204 to over 1600 (Table 3a).[20] The distribution of the nominal value of the securities was rather dispersed (Fig. 1, right panel), reflecting the variety of countries and sectors whose bonds are covered in our sample. The median volume of the bonds was always below EUR 100 million, whereas the 75th percentile ranges between EUR 100 and 450 million.

Leaving aside the role of supranational issuers, a geographical overview of the ESG security issuers in our data set is illustrated in Fig. 9. In our sample, Europe accounted for almost half of the amount issued; China came second with a share of

[20] The 'climate awareness bond', issued by the European Investment Bank (EIB) in 2007, is generally considered as the first green bond. Tang and Zhang (2020) and Lebelle et al. (2020), among others, show that the sustainable instruments market became significant only after 2013, due to the increase of issues by commercial banks and corporations and the publication of the Green Bond Principles by ICMA.

Table 3 ESG bond supply characteristics over time. Panel *a* reports summary statistics on ESG bond market supply between 2015 and 2021. Total outstanding amount and new issues are in EUR billion. Panels *b, c,* and *d* report summary statistics on Italian residents' holdings of ESG debt securities. Data are drawn from the harmonized Securities Holdings Statistics (SHS). In panel *b* the outstanding amount, net of Bank of Italy's holdings, is in EUR billion, original and residual maturities are in years. Listed share is the percentage proportion of ESG debt securities that are listed and traded on a financial exchange. In panels *c* and *d* the outstanding amount, net of Bank of Italy's holdings, is reported in EUR billion and the subsequent columns report the percentage share issued by resident and non-resident institutional sectors according to the ESA 2010 classification

			Number of:		Currency share:		Share of bonds issued by residents in:				
Reference date	Tot amount	New issues	Bonds	Issuers	USD	EUR	US	CN	DE	FR	IT
(a) The global supply											
2015 Q4	283.9	103.9	892	285	6.8	27.7	2.4	48.2	10.8	6.1	0.1
2021 Q4	2562.8	178.3	7870.0	2354.0	26.6	46.4	8.4	11.8	12.4	11.5	2.3

Reference	Total	Number of:			Maturity		Currency share		Listed
date	amount	Bonds	Issuers	Countries	Original	Residual	EUR	USD	share
(b) Italian residents' holdings of ESG bonds									
2015 Q4	2.7	134	68	25	10.5	8.5	85.5	5.6	98.9
2021 Q4	54.6	1590	704	83	11.0	9.1	93.2	4.9	84.7

		Residents' issuers			Non-residents' issuers			
		Non-financial corporations	Deposit-taking institutions	General government	Non-financial corporations	Deposit-taking institutions	General government	
Reference date	Total amount	S.11	S.122	S.13	S.11	S.122	S.13	Other
(c) Italian residents' holdings of ESG bonds by issuer sector								
2015 Q4	2.7	1	0	0	7.7	3.8	71.8	15.6
2021 Q4	54.6	9.5	12.9	7.6	17.5	10.1	19.2	22.0

Reference date	Total amount	Non-financial corporations S.11	Deposit-taking institutions S.122	Investment funds S.124	Insurance corporations S.128	Pension funds S.129	General government S.13	Households and NPISH S.14 + S.15	Other
(d) Italian residents' holdings of ESG bonds by holding sector									
2015 Q4	2.7	1.2	65.6	12.4	0	4	0.6	15.3	1
2021 Q4	54.6	0.9	33.6	15.7	38.4	5.0	1.4	4.4	0.6

14 per cent.[21] Other important countries in ESG bond supply were the USA, South Korea, Japan, and Canada. As already mentioned, the relative importance of the countries represented in our sample reflects the fact that the initial list of securities was merged with the CSDB, thus leading to a loss of non-euro-denominated securities or of other securities which were not held by euro area residents. In Europe, whose securities made up almost half of the volume in our sample, the main countries were Germany and France (Fig. 2). At the end of 2021, the largest amount of ESG securities were issued by Germany (EUR 318 billion), followed by China and France (Table 4). The median volume of security tranches was below EUR 100 million; the average maturity was rather long, matching the long duration of the projects financed by green bonds.[22] The ESG securities issued in the UK (19.6 years), the USA (13.4 years), and Canada (12.3 years) tended to have longer maturities; residents in Asian countries—China (7.7 years), Republic of Korea (5.3), and Honk Kong (7.7)—tended to issue shorter maturity instruments. When considering the median value of the ESG bonds, French, German and US issuances stood out for their lower value—below EUR 50 million; Dutch, Italian, and Belgian issues are ten times bigger (EUR 500 million). The number of issuers was in the hundreds in China, the USA, and Japan; it is contained in Italy (47) and Spain, while in France and Germany lies in the middle.

Most of the securities in our sample were denominated in euro and US dollars (Table 3a). In 2021, over two-thirds of ESG bonds were euro- or US dollar-denominated. Italian issuers represented 2.3 per cent of the total, whereas German and French issuers were about 24 per cent of the total. Interestingly, the Chinese sustainable market showed a very significant role since the beginning of the sample period. Table 5 reports information about the ESG bond supply by country and sector of the issuer. Overall, financial issuers had a prominent role in the issuance of ESG bonds. The picture was more nuanced across countries. On the one hand, in Germany and France, the government played a pivotal role, following the national green finance strategy. On the other hand, in China and the USA, the private sector prevailed and over 50 per cent of the bonds were issued by non-financial corporations. In Italy, we noted a balance between financial and non-financial private institutions. The government launched its first green bond (*Green BTP*) in March 2021.[23]

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[21] The China Green Bond Index provided by the Luxembourg Stock Exchange includes bonds which are compliant with different green bond principles. The minimum share of the proceeds to be used in green projects to distinguish a security as 'green' ranges between 50 per cent (in the case of the People's Bank of China—PBOC—Green Bond Endorsed Project Catalogue and the National Development and Reform Commission—NDRC—Green Bond Guidelines) and 95 per cent (in the case of CBI Climate Bonds Standards). This explains the higher coverage of our sample for Chinese bonds over those reported on the CBI platform. For more details on the differences between international and domestic standards see also Clifford Chance (2020).

[22] In August 2019, a French State-owned company issued the world's first ever 100-year green bond.

[23] For more details, see Bank of Italy (2021).

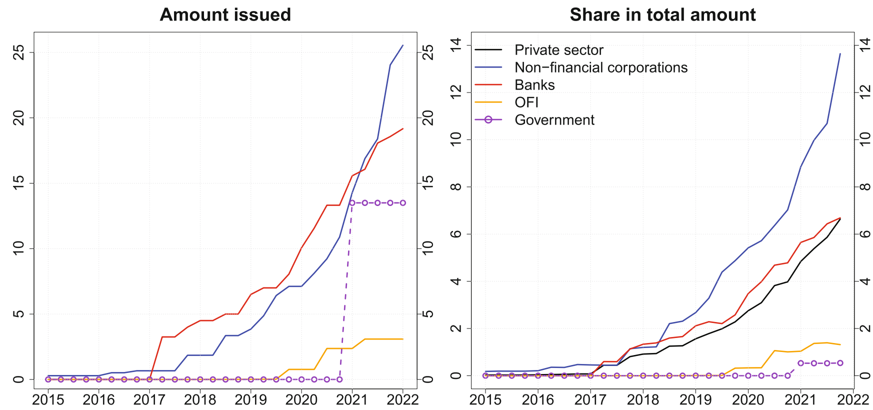

Fig. 2 ESG bonds issued by Italian residents. The figure reports data on the amount of ESG bonds issued by Italian residents (right-hand side panel) and the share of this amount in total volumes of debt securities issued by issuer sector. (Source: Own calculations on Bank of Italy's Financial Accounts)

The ESG bond supply by Italian residents has expanded at the same pace as the global one. The total amount of ESG debt securities issued by Italian residents has jumped to EUR 55 billion in 2021. The largest issuers were non-financial corporations and the banking sector with EUR 25 and 20 billion, respectively (Fig. 2, left-hand side panel). Over the total amount of debt securities issued by the private sector, ESG bonds reached 6 per cent in 2021 (Fig. 2, right-hand side panel). Such share was larger for non-financial corporations and banks.

The risk profile of the ESG bonds supply was skewed towards the lower-risk area when compared to conventional bonds. The top panel of Fig. 3 shows that the rating distribution of ESG bonds was more concentrated in the investment grade area than their conventional counterparts. The bottom panel of Fig. 3 shows the comparison between euro-denominated and USD-denominated securities within the ESG subsample. The rating distribution of euro-denominated bonds was more concentrated in the investment grade area, around the A-level. The rating distribution of USD-denominated ESG bonds features less pronounced peaks in the investment grade area. Low-risk corporations or triple-A governments may be more willing to issue ESG bonds, as they are considered more credible in their commitment to use the bond proceeds in green or sustainable projects. Hence, we hypothesize that the lower risk profile of ESG bonds merely reflects a self-selection bias.

5 Italian Residents' Holdings of ESG Bonds

Debt securities are a key component in the portfolio of Italian residents, with an average share over total financial assets equal to 19 per cent in the last two decades. Households held over 40 per cent of Italian residents' debt securities before the Great

Table 4 ESG Bond Supply Characteristics by Issuer Country—December 2021. This table reports summary statistics on ESG bond market supply by residence country of the issuer at the end of 2021. Total, median and per-issuer amounts of the issues are reported in EUR billion, original and residual maturity are expressed in terms of years. The sectors are the ESA 2010 institutional sectors, i.e. S.11, S.122-S.129, S.13, as reported in Table 5

Country	Total amount	Median amount	Number of: Bonds	Issuers	Amount for issuer	Number of sectors	Maturity Original	Residual
DE	318.1	0.0	381	65	4.9	6	9.1	7.5
CN	302.6	0.1	817	373	0.8	5	7.7	4.0
FR	293.6	0.1	503	90	3.3	7	11.3	8.9
US	214.9	0.0	1447	380	0.6	9	13.4	10.5
NL	154.6	0.5	231	61	2.5	6	10.4	8.1
GB	85.3	0.1	251	96	0.9	7	19.6	14.8
KR	71.6	0.1	323	75	1.0	6	5.3	3.8
JP	63.9	0.1	494	179	0.4	7	10.4	8.9
ES	61.7	0.3	146	46	1.3	4	8.4	6.4
IT	59.2	0.5	107	47	1.3	7	8.8	6.9
SE	46.6	0.0	561	116	0.4	6	5.5	3.8
CA	39.6	0.3	112	52	0.8	7	12.3	10.1
CL	31.1	0.5	44	15	2.1	5	17.8	16.1
HK	29.5	0.5	69	29	1.0	5	7.7	6.1
DK	27.8	0.5	42	15	1.9	4	11.9	10.1
NO	27.3	0.1	158	61	0.4	6	6.1	4.5
LU	26.5	0.1	104	42	0.6	7	7.3	6.1
BE	24.7	0.5	36	20	1.2	6	10.6	9.1
KY	22.6	0.3	67	40	0.6	6	7.1	5.6
AU	21.1	0.2	54	30	0.7	7	8.1	5.7
IE	18.2	0.5	29	16	1.1	5	8.5	7.4
MX	17.0	0.5	37	16	1.1	6	10.8	8.3
FI	13.7	0.3	40	21	0.7	4	9.2	7.4
IN	13.1	0.3	50	20	0.7	4	7.8	5.5
SG	11.4	0.2	41	22	0.5	6	7.8	5.8
ID	10.0	0.7	17	8	1.3	3	9.5	7.2
TH	10.0	0.1	59	18	0.6	4	6.9	5.7
AT	9.7	0.0	53	23	0.4	4	9.4	7.2
MU	9.0	0.4	25	13	0.7	3	5.3	3.0
VG	7.9	0.2	35	22	0.4	3	6.9	5.5

financial crisis; this share has gradually come down, to below 10 per cent in 2021 (Fig. 4, left-hand side panel). Banks, insurance companies and pension funds have replaced households as the leading sectors in bond holdings with a share of 25 and 30 per cent, respectively, in 2021. Banks have raised the weight of bonds in their portfolios from 10 to 20 per cent (Fig. 4, right-hand side panel); the portfolio share of insurance companies and pension funds has remained stable around 60 per cent; that of investment funds has fallen from 80 to below 50 per cent.

Table 5 ESG bond supply by country and sector of the issuer—December 2021. This table reports data on the breakdown of ESG debt securities by residence country and sector of the issuer excluding supranational institutions. Outstanding amounts are reported in EUR billion. The sectors are the ESA 2010 institutional sectors; their codes are reported in the headers

	Non-financial corporations	Deposit-taking institutions	OFI	Financial auxiliaries	*Captive institutions*	Insurance corporation	General government
Country	S.11	S.122	S.125	S.126	S.127	S.128	S.13
DE	25.1	76	0	0.1	1.7	2.8	212.4
CN	236	25.2	9.2	11.7	0	0	20.5
FR	52.7	47.2	1.3	2.6	0	1.2	188.4
US	106.1	8.8	53.5	10	5.3	0.4	30.4
NL	28	53.5	3.4	6.1	47.9	0	15.7
GB	15	8.9	24.1	0.7	5.7	0.3	30.7
KR	27.5	22	17.8	1	0	1.2	2.1
JP	28.3	7.9	18.2	1.3	0	0	7.8
ES	17.6	22.8	0.8	0	0	0	20.4
IT	24	18.6	0.2	1	0	1.9	13.5
SE	21.8	15.7	0.2	0.6	0.1	0	8.2
CA	9.6	6.5	8.1	0.2	0	1.3	12.8
CL	7.2	0.3	0.7	0.1	0	0	22.8
HK	2.5	10.3	6.8	0.1	0	0	9.8
DK	5.5	10.9	0.8	0	0	0	10.7
NO	6.6	19.2	0.7	0.4	0	0.3	0.1
LU	0	3.5	1.8	0.5	18.4	0	1.5
BE	1.9	0.5	1.2	1.8	0.6	0	18.8
KY	14.2	1.9	5.1	0.1	0.6	0	0
AU	2.5	7.8	1.8	0.2	0.1	0.2	8.7
IE	1.8	0	0.7	3	5.9	0	6.9
MX	5.8	1	7.8	0.2	0	0	2

(continued)

Table 5 (continued)

Country	Non-financial corporations S.11	Deposit-taking institutions S.122	OFI S.125	Financial auxiliaries S.126	*Captive institutions* S.127	Insurance corporation S.128	General government S.13
FI	6.1	5.9	1.6	0	0	0	0.1
IN	8.7	0.2	3.8	0.5	0	0	0
SG	0.7	7	1.3	1.1	0.1	0	1.2
ID	1.5	0.7	7.7	0	0	0	0
TH	3.7	0.3	0	0.1	0	0	5.9
AT	3.1	3.9	0	0	2.1	0.6	0
MU	0.8	0	6.1	2.1	0	0	0
VG	0.2	0	7.5	0	0.3	0	0
Total	697.6	407.6	203.2	49.7	89.3	10.5	676.6

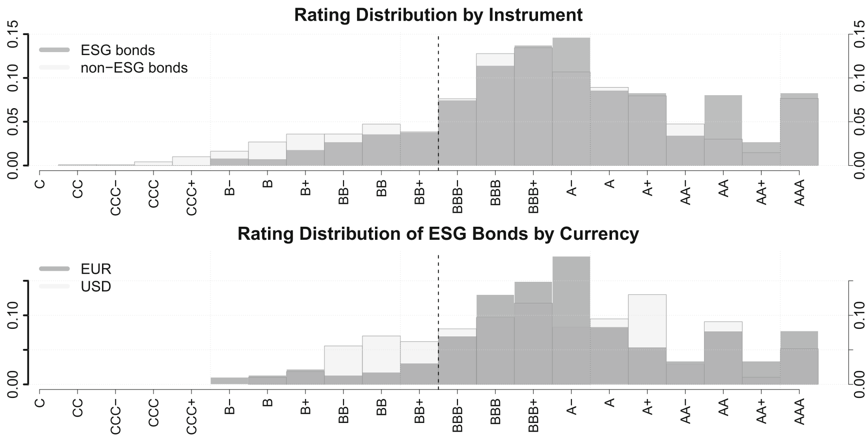

Fig. 3 Debt Securities Ratings—December 2021. This figure depicts the distribution of ratings across categories of securities in the sample. The dotted vertical line at BBB- delimits the investment grade region from the non-investment grade one. (Source: Own calculations on data drawn from the ECB Centralised Securities Data Base)

Against this background, the rise of the global supply of ESG bonds has been mirrored by their growth in the portfolios of Italian residents. The value of ESG instruments in these portfolios, which was negligible in 2016, has steadily increased to EUR 16.6 billion in 2019, and it has more than tripled in the following two years, reaching EUR 55 billion in 2021 (Table 3b). The share of ESG bonds in the total holdings of debt securities amounted to 2 per cent in 2021. The vast majority of the ESG instruments was denominated in euro (93 per cent) and it was exchanged on regulated markets (85 per cent). The portfolios were diversified in terms of issuers (over 700), securities (almost 1600), and countries. The ESG securities issued by Italian residents made up below one-third of the portfolios (Table 6); among the non-resident issuers, France, the Netherlands, Germany, and Spain covered 40 per cent of the total. Other prominent ESG issuers in these portfolios were the supranational entities, namely, the European Union (EU), the International Bank for Reconstruction and Development (IBRD), and the European Investment Bank (EIB). The share of ESG instruments exchanged on regulated markets was close to 100 per cent for securities issued by non-residents, while it falls to two-thirds for those issued by residents.

Almost 70 per cent of the portfolios of Italian residents was made of securities issued by non-resident institutions (Table 3c). Instruments issued by supranational entities[24] and non-resident financial intermediaries were almost one-fourth of the ESG bond portfolio, followed by those issued by foreign non-financial corporations

[24]The European Union, the European Investment Bank (EIB), and the World Bank (WB).

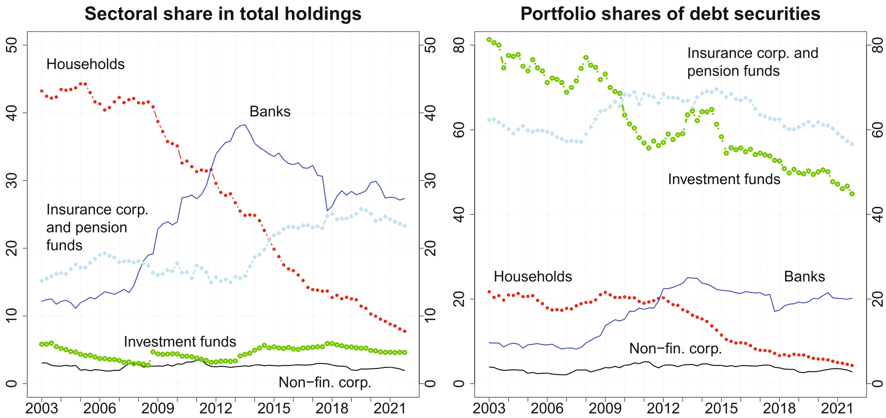

Fig. 4 Debt securities held by Italian residents. The left-hand side panel of the figure shows the sectoral share in total debt securities held by Italian residents between 2003 and 2021. The right-hand side panel shows the portfolio share of debt securities across Italian sectors between 2003 and 2021. (Source: Bank of Italy's Financial Accounts)

and general governments. Domestic banks, non-financial corporations, and non-resident banks had lower shares.

At the end of 2021, the most significant ESG bond-holding sectors were the insurance corporations (38 per cent) and the banking sector (34 per cent), thus accounting for almost three-quarters of all the ESG debt securities held by Italian residents (Table 3d). Other important ESG bond holding sectors were the investment funds (16 per cent) and, to a lesser extent, households and pension funds (4–5 per cent). Yet, since two-thirds of investment fund shares in Italy were held by households, the total holdings of ESG bonds were higher due to the indirect holdings.

The risk profile of Italian residents' ESG portfolios was moderate-to-low. Most of the securities held by Italian residents were in the investment-grade category[25] (Fig. 5). The risk profile was rather similar across sectors, with insurance corporations holding a slightly higher share of investment-grade securities.

The weight of ESG bonds in the portfolio of Italian banks has risen in the last few years. The share of ESG bonds in total bond holdings has reached 2.5 per cent in 2021, from 0.5 in 2019 (Fig. 6, left-hand side panel). This growth is even more remarkable if the holdings of ESG bonds are scaled by the holdings of debt securities issued by the private sector, yielding 6 per cent in 2021 (from 1 per cent in 2019). Similarly, the number of banks holding ESG bonds has surged from less than 20 in 2015 to over 60, out of 165 banks holding debt securities (Fig. 6, right-hand side panel). At least one-fourth of the banks holding ESG bonds had a portfolio share of 12 per cent. Bigger banks were the largest ESG investors. In the previous two years, a number of medium-sized banks had also invested in ESG securities.

[25] Securities with a BBB- or higher rating are considered as investment grade.

Table 6 Italian residents' holdings of ESG bonds by issuer country. This table reports summary statistics on Italian residents' holdings of ESG debt securities at the end of December 2021. Data are drawn from the harmonized Securities Holdings Statistics (SHS). The outstanding amount, net of Bank of Italy's holdings, is reported in EUR billion, original and residual maturities are expressed in years. Listed share is the percentage proportion of ESG debt securities that are listed and traded on a financial exchange

			Number of:			Maturity		Currency share		
Country/Institute	Total amount	Amount share	Bonds	Issuers	Countries	Original	Residual	EUR	USD	Listed share
IT	17.1	31.3	89	34	9	8.0	6.3	100.0	0.0	54.7
FR	9.0	16.4	197	72	8	10.3	8.1	98.6	1.4	99.4
Other	5.5	10.0	471	293	8	13.4	11.8	80.5	16.8	99.1
NL	4.6	8.3	173	57	8	8.7	6.8	97.6	1.9	95.1
DE	4.3	7.9	124	49	8	13.1	11.3	98.6	1.0	98.2
ES	3.7	6.7	79	30	8	7.5	5.7	99.9	0.0	97.3
EU	3.3	6.0	12	1	8	15.4	14.5	100.0	0.0	100.0
IBRD	1.7	3.2	139	1	8	7.4	4.7	25.9	38.0	95.2
IE	1.0	1.8	21	14	8	8.9	7.7	99.3	0.5	100.0
EIB	1.0	1.7	42	1	8	11.8	7.4	50.5	43.0	100.0
CL	0.8	1.4	22	8	7	19.1	17.8	83.9	15.9	100.0
UK	0.8	1.4	59	42	8	9.0	6.2	74.4	0.2	99.9
BE	0.8	1.4	20	11	7	11.2	9.5	100.0	0.0	100.0
US	0.7	1.3	134	88	8	11.2	9.5	61.5	38.5	93.9

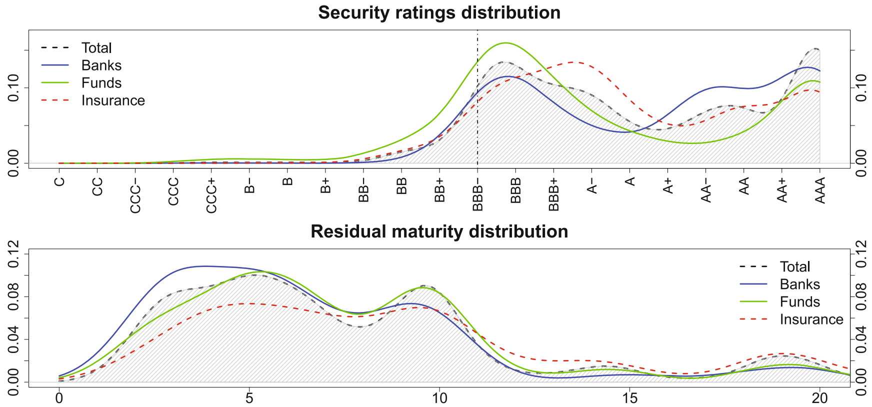

Fig. 5 Holdings characteristics by sector. The top panel shows the distribution of the ratings and of the residual maturity of ESG debt securities held by Italian residents. The 21 categorical rating classes of the three main rating agencies—Moody's, Fitch and Standard & Poor's—have been mapped into a sequence of integers going from 1 (C rating) to 21 (AAA rating). The curves have been obtained through weighted kernel density estimation with the portfolio share as the weight. The vertical line at BBB- in the top panel figure delimits the investment grade area from the non-investment grade one. (Source: Own calculations on data drawn from the Bank of Italy Securities Data Base)

Mutual funds have experienced a similar growth of ESG debt securities in their portfolios. Their share in total holdings of debt securities was 7 per cent in 2021, with a share in the total holdings of debt securities issued by the private sector of 10 per cent (Fig. 7, left-hand side panel). The share of mutual funds that invested in ESG bonds had increased to 40 per cent. All asset management companies offered a green bond mutual fund (Fig. 7, left-hand side panel). The number of ESG bond funds has risen to 500 in 2021 (Fig. 7, right-hand side panel).

As already mentioned, insurance corporations are the sector with the largest share of ESG debt securities among Italian residents. The portfolio share invested in ESG bonds amounted to nearly 3.5 per cent, and the ratio to the holdings of debt securities issued by the private sector is above 7 per cent in 2021 (Fig. 8, left-hand side panel). Three-quarters of Italian insurance corporations invested in ESG bonds and for half of them the portfolio share was above 7 per cent (Fig. 8, right-hand side panel).

6 ESG Bond Yields and the *Greenium* Puzzle

In the previous sections, we have documented the significant growth of the ESG bond global supply and described its main features, looking in particular at ESG bonds in the portfolios of Italian residents. In this section, we illustrate a much-debated issue in the ESG empirical studies. Based on anecdotal evidence and econometric estimation, the question is whether, all other financial features being

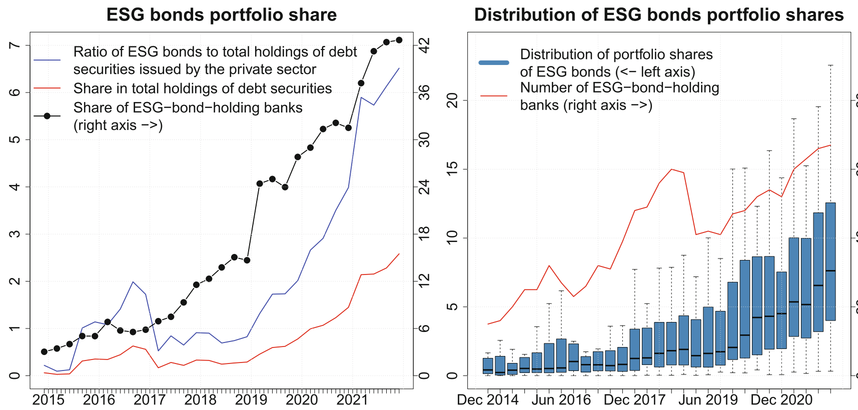

Fig. 6 Banks' holdings of ESG bonds. This figure shows the share of ESG debt securities in bank portfolios between 2015 and 2021 at aggregate level (left-hand side panel). In the right-hand side panel, the box and whiskers plot show the distribution of ESG debt securities share in banks' portfolios. The three horizontal lines of the box represent, from the bottom to the top, the 25th, 50th, and 75th percentile of the distribution in a given quarter, whereas the lower and the upper whiskers show the 5th and 95th percentiles (Source: Own calculations on Bank of Italy Supervision Statistics)

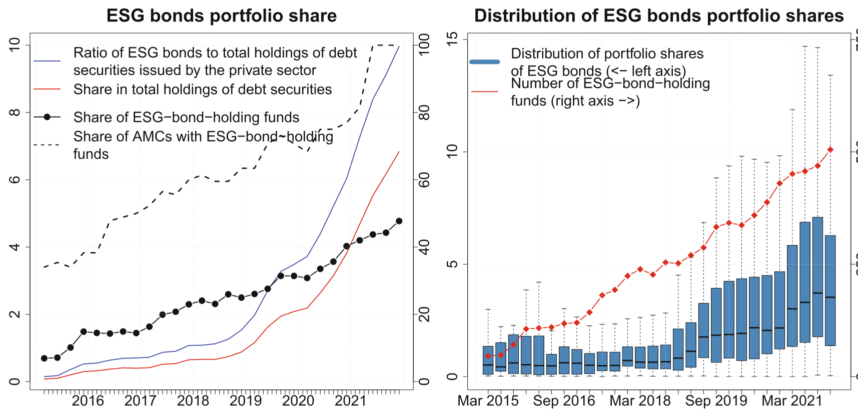

Fig. 7 Investment funds' holdings of ESG bonds. This figure shows the share of ESG debt securities in banks' portfolios between 2015 and 2021 at aggregate level (left-hand side panel). In the right-hand side panel, the box and whiskers plot show the distribution of ESG debt securities share in funds' portfolios. The three horizontal lines of the box represent, from the bottom to the top, the 25th, 50th, and 75th percentile of the distribution in a given quarter whereas the lower and the upper whiskers represent the 5th and 95th percentiles. (Source: Own calculations on Bank of Italy Supervision Statistics)

equal, there exists a negative premium on green bonds, i.e. whether these bonds offer a lower yield than the conventional ones. Financial theory predicts that securities with the same characteristics, for example in terms of liquidity and risk, should have equal returns in equilibrium. Any deviations can be explained with the hypothesis

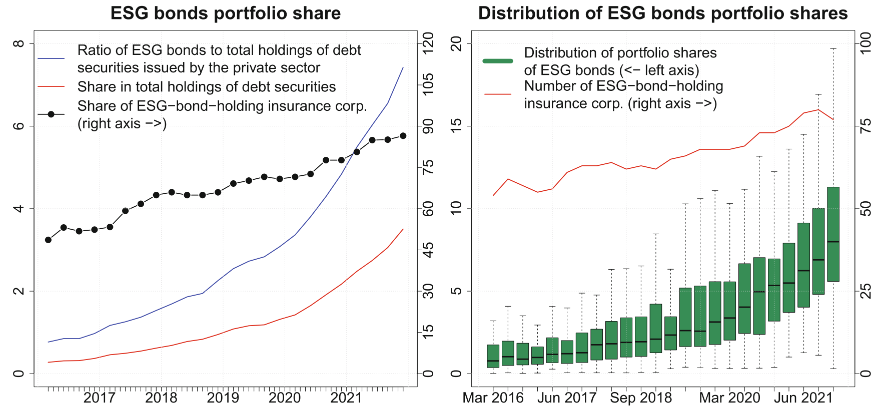

Fig. 8 Insurance corporations' holdings of ESG bonds. This figure shows the share of ESG debt securities in banks' portfolios between 2015 and 2021 at aggregate level (left-hand side panel). In the right-hand side panel, the box and whiskers plot show the distribution of ESG debt securities share in insurance corporations' portfolios. The three horizontal lines of the box represent, from the bottom to the top, the 25th, 50th, and 75th percentile of the distribution in a given quarter whereas the lower and the upper whiskers represent the 5th and 95th percentiles. (Source: Own calculations on Bank of Italy Supervision Statistics)

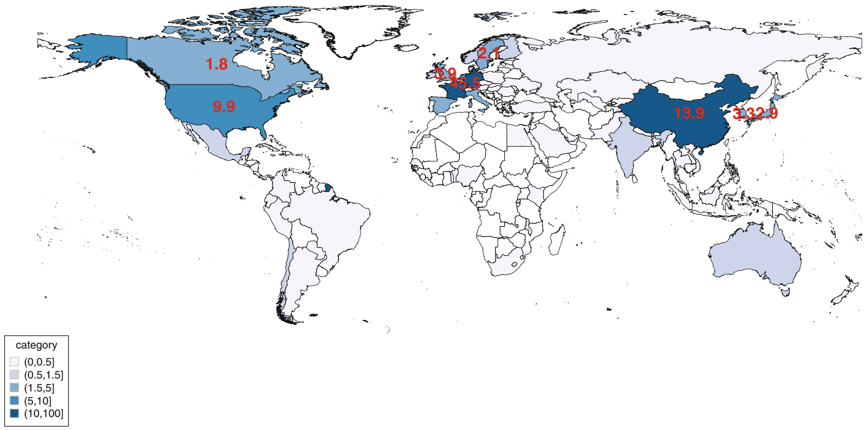

Fig. 9 Share of ESG bonds supply by country—amount issued. This figure shows the world share of the outstanding amount of ESG debt securities by country at the end of December 2021. Data on the outstanding amounts of the securities and on the country of residence of the issuer are drawn from the ECB Centralised Securities Data Base (CSDB). Supranational entities are excluded from the calculation of the country shares

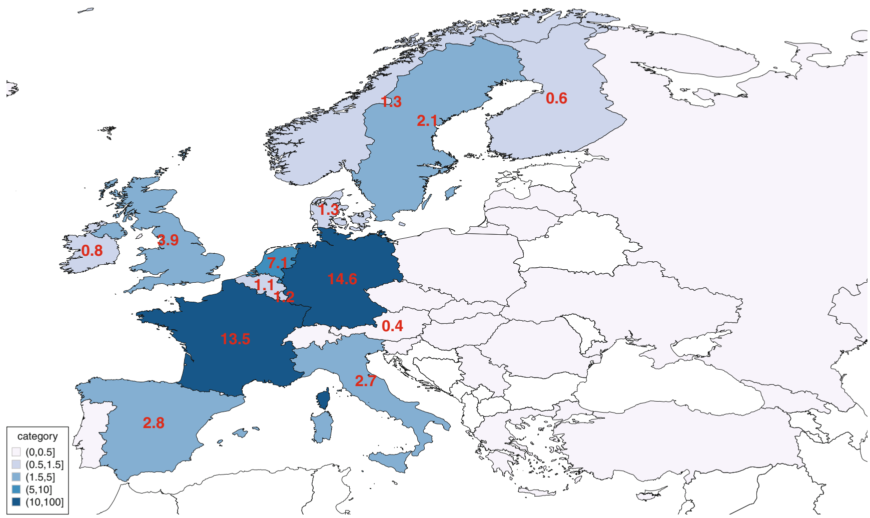

Fig. 10 Share of ESG bonds supply by country in Europe—amount issued. This figure shows the world share of the outstanding amount of ESG debt securities by country at the end of December 2021. Data on the outstanding amounts of the securities and on the country of residence of the issuer are drawn from the ECB Centralised Securities Data Base (CSDB). Supranational entities are excluded from the calculation of the country shares

that portfolio allocation depends not only on risk and return but also on investor's preferences, as it happens for the demand of consumer goods. Other hypotheses can be traced back to the Arbitrage Pricing Theory, where ESG securities stand out for a lower level of risk related to climate change in the medium and long term. A recent study (Liberati and Marinelli 2022) estimates the *greenium* using a non-parametric procedure. It exploits a dataset with security-level observations between 2017 and 2021 and uses the Nelson and Siegel (1987) specification to estimate monthly yield curves for ESG and non-ESG securities by currency (euro and US dollar) and sector (non-financial and financial corporations). The securities included in the estimation are classified as investment grade, i.e. their rating is BBB- or better. The *greenium* is measured by comparing the yields of the two curves estimated over all the maturities from 1 month to 20 years, obtaining the differential at different maturities. The negative premium on ESG bonds is estimated at 9 basis points on average for non-financial corporations, for euro-denominated and US dollar-denominated securities; the differential is directly related to the residual life of the securities. The estimation for financial corporations leads to an average *greenium* equal to 2.5 and 20 basis points, respectively, for securities denominated in euro and in US dollars. The *greenium* on euro ESG bonds has an inverse relationship with their residual life; the opposite is true for USD-denominated ESG bonds.

7 Conclusions

ESG bonds are a key instrument for channelling financial resources towards green, sustainable, and social projects. In the last 5 years, the issuance of such instruments by corporations and governments has rapidly increased, in terms of volume and number of issuers. We compiled a comprehensive list of ESG securities, partly web-scraped and partly hand-collected, by exploiting publicly available information from a variety of sources. We merged this list with microdata used for official statistics such as financial accounts, security holdings, and banks' and investment funds' asset holdings.

We show that the euro area, China, and the USA are three leading areas in the global supply of ESG bonds. Among European countries, Germany and France are by far those with the largest share of ESG bond supply, mainly owing to the role of the government sector. The growth in the supply of ESG instruments is matched by the increase of their weight among the assets of financial intermediaries, exceeding 4 per cent in the funds' portfolios and 2 per cent for banks and insurance corporations.

Finally, we reviewed some recent evidence on the yields of ESG debt securities as a contribution to the debate on the *greenium* puzzle, that is the negative premium on ESG bonds vis-à-vis conventional bonds with the same financial features.

Appendix: Information Sources

CBI reports a 'Bond Library' which provides an overview of new green bond issuers entering the market; we check for repeated issues by using the 'Market Blogs Archive', where CBI highlights a summary of the green bond market with the list of new and repeated issuers as well as the excluded and pending bonds starting from 2018; even if subsequent issues are not reported before 2018, we check for them. This information is linked to the 'Labelled Green Bonds Database' and the 'Certified Bond Database', where CBI publishes the full list of new and repeated green bonds in the last 3 months, and the list of all bonds aligned to the certification scheme under the Climate Bonds Standards, respectively (to meet Climate Bonds Standards securities must be certified by third-party approved verifiers and fulfil tighter criteria ensuring consistency with the goals of the 2015 Paris Agreement to limit warming below 2 °C). A similar exercise is carried out by using the daily updated 'EF bond database' listing the 25 most recent ESG bond issues (categorized as green, sustainable, sustainability-linked, and social bonds) and augmented with the list of issuers reported by the 'Sustainable bonds database', published by ICMA on a monthly basis.

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The Exposure of Investments to Climate and Environmental Risks

Ivan Faiella, Enrico Bernardini, Johnny Di Giampaolo, Simone Letta, Davide Nasti, and Marco Fruzzetti

1 Introduction

The latest report by the Intergovernmental Panel on Climate Change (IPCC 2021) has confirmed that some effects of climate change are unprecedented, irreversible over periods of hundreds of years, and unequivocally linked to human activity; only a rapid and sizeable reduction in greenhouse gases can limit some of these effects. The growing awareness about the impact of climate change on economic and financial variables is witnessed by the attention to the sustainability profiles of financial investments. This phenomenon is due to the commitment to tackle climate change undertaken by the governments that signed the Paris Agreement on Climate and to the notion that corporate value creation can only be durable if it is oriented to the long term and takes into due consideration the claims of the various stakeholders: shareholders, customers, suppliers, and other agents in the social, institutional, and regulatory context in which the company operates. Attention to climate and environmental sustainability of sovereign debt issuance has also recently increased. In the last few years, central banks have stepped up their efforts in the measurement and

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disclosure of the exposure to climate and environmental risks of their investment function (NGFS 2019b, 2020b) as well as of other institutional functions (NGFS 2018, 2019a, 2021a; Bolton et al. 2020).

Exposure to climate risks materializes through two channels: (a) the damage to infrastructures and the properties of firms and households, caused by climate-related events (physical risk); (b) the consequences for the economic and financial system stemming from the transition to a low-carbon economy (transition risk). Although the environmental risks are closely connected to climate-change risks, they derive from wider phenomena and stem from the economic and financial effects relating to an overuse or degradation of natural resources (e.g. resource depletion, deforestation, and pollution), biodiversity loss, and the degradation of ecosystem services (NGFS 2021b; Dasgupta 2021). In the case of environmental risks as well, the transmission channels are represented by both physical damage to economic activities and structures, and by the consequences associated with mitigation policies, technological change, or the behaviour of economic agents in response to environmental events. In 2020, the Covid-19 pandemic confirmed that extreme events can have unexpected and asymmetrical effects on several economic sectors, with similar impacts to those relating to transition risk, and reinforced the arguments in favour of an appropriate identification of 'tail risks', namely, those events that have a low probability of occurrence, but significant impacts (NGFS 2020a).

This chapter contributes to the ongoing debate on the methodologies for the assessment of exposure to climate risks by providing a framework for the possible solutions. Through an international comparison of data and methodologies, the chapter reviews the indicators that can be used to assess the exposure of public sector issuers and corporates. It also shows the results from the application of the proposed indicators for measuring the exposure to climate- and environmental risks of the Bank of Italy's investments in equities, government and corporate bonds of the euro-denominated portfolio and to the government bond investments of the foreign exchange reserves.

The assessment of investment exposure to climate risks is a complex exercise due to the uncertainty relating to the multiple interactions between the risk sources, mainly connected with physical and transition risk. If the evaluation is carried out for a portfolio of securities, complexity increases owing to the possible interactions between the risk effects on several asset types in the portfolio. This chapter does not address the estimation of the cross-correlation of climate risks of individual countries or companies, which has not been explored in the literature due to its complexity.

The measurement presented below is carried out separately for each asset class. Some precautions are taken to avoid the well-known problem of double counting in the measurement of emissions: the portfolio indicators are calculated separately for public sector issuers and corporate issuers and, for the latter category, the measurement takes into account all sources of capital for a company. Furthermore, the focus is mainly on transition risks, not because physical risks are not important, but because at present there are substantial data gaps about securities' exposure to physical risks[1] and the coverage provided by insurance.

An initial assessment of climate risks can be based on a review of the backward-looking indicators; they can also provide a useful basis for a forward-looking assessment. The information content of backward-looking indicators may however be limited because future climate policies (or the effects of climate change, when dealing with physical risk) may be different from the past. For this reason, forward-looking indicators are usually based on climate scenarios, i.e. on hypotheses about the policies that will be undertaken to combat the increase in emissions (Bernardini et al. 2021).

For the assessment of individual companies, two simple methods do not employ scenarios and are based instead on forecasts of the alignment path of emissions compared with the targets of climate policies. The first method considers corporate emissions over time; the second one tries to assess whether the future emission trend is consistent with the reduction commitment that the company is directly or indirectly subject to, based on the sector and the country.

The measurement of greenhouse gas (GHG) emissions, which provides information on exposure to transition risks, is based on historical data on corporate emissions. Even with this simplification, measuring exposure to climate risks requires the solution of some issues:

1. What is the perimeter of emissions?[2] Should we consider only those relating to production activities (direct or scope 1) or even those deriving from energy uses (indirect or scope 2)? Should we also include emissions that are generated by the entire value chain of the firm, including those relating to the uses of the final products (scope 3)?[3]

[1] For example, it is extremely complex to assess the exposure of a country to physical risks, because they tend to be concentrated in specific areas of a country. The international comparison is even more complex. For a European comparison, see Peseta IV; for an international comparison, see Notre Dame Global Adaptation Initiative.

[2] The emission classification standard is defined by the World Resource Institute's Greenhouse gas protocol, supported by various organizations and data providers. Based on this protocol, GHG emissions are divided into three categories: direct emissions, i.e. produced by proprietary or controlled sources, are classified as scope 1; indirect emissions, deriving from the purchase and consumption of energy (electricity, steam, heating, and air conditioning) are classified as scope 2; all remaining indirect emissions (other than scope 2) along the value chain, downstream and upstream, are classified as scope 3. Consequently, the overall emissions of a product/service are given by the sum of scopes 1, 2, and 3 emissions. Typically, the scope 3 emissions of a single company make up the majority of its total emissions; however, they may overlap with the scope 1 emissions of another company, resulting in double counting.

[3] Estimating and using these emissions is anything but simple. The available studies indicate that this information, even when available, has serious quality issues. See for example Busch et al. (2020).

2. Which GHGs should we include in the calculation of emissions? CO_2 only or all gases, like those considered in the Kyoto protocol?[4]
3. How should we measure emissions, in absolute terms or normalized by company/country size (as emissions per employee, per unit of turnover, by value added, by enterprise value, per inhabitant, per unit of GDP, etc.)?

In addition to showing historical GHG emissions data, we: (1) simulate the emission profile relating to the future commitments of countries; (2) integrate the backward-looking emission patterns with the forward-looking ones obtained from the NGFS scenarios; and (3) combine information on emissions with a set of indicators for the energy system that identify which countries have greater room for manoeuvre to manage the transition.

Sections 2 and 3 present the indicators for the assessment of climate and environmental risks of public sector[5] and corporate sector issuers, respectively. Section 4 illustrates the methodology underlying the computation of exposure to climate and environmental risks of financial portfolios. Section 5 outlines the environmental sustainability profile of the Bank of Italy's euro-denominated investment portfolios and of foreign currency reserves. Section 6 concludes.

2 The Exposure of Government Bonds to Climate and Environmental Risks

The link between the climate risks of a country and those of its government bonds is examined in several studies (Volz et al. 2020; Battiston et al. 2019; Klusak et al. 2021; Zenios 2021; Cevik and Tovar Jalles 2020; Kling et al. 2018)[6] and research papers of financial institutions (FTSE Russel 2019; Bank of America 2021), based on the existence of different transmission channels for physical and transition risks.

[4] Global Warming Potential (GWP) is a measure of how much a given greenhouse gas (in addition to CO_2, CH_4, HFCs, NF_3, SF_6, N_2O, and PFCs) contributes to global warming, using CO_2 as a reference, and considering the combined effect of the residence time in the atmosphere and the ability to absorb the infrared radiation emitted by the earth (and therefore to retain heat). The overall unit of measurement of greenhouse gases (or GHG) is the CO_2 equivalent (CO_2e), whereby each greenhouse gas is converted into CO_2 by means of its GWP.

[5] A survey of the literature on how climate risks can affect the value of government bonds is beyond the objectives of this paper. Among the studies measuring the effects of climate risks, Volz et al. (2020) identify six transmission channels of climate risk to country risk: (1) fiscal effects of environmental disasters; (2) tax effects of adaptation and mitigation policies; (3) macroeconomic implications; (4) risks to the financial system; (5) effects on international trade and capital flows; (6) effects on political stability. Battiston and Monasterolo (2020) find that countries with a higher share of the less carbon-intensive sectors benefit from lower government bond yields. Cevik and Tovar Jalles (2020), examining 98 countries, also find that vulnerability and resilience to climate risks affect—negatively and positively, respectively—the cost of government funding.

[6] For a description of the macroeconomic impacts of climate factors on the developed countries, see also Burke et al. (2015).

Rating agencies as well consider the climate risk of government bonds and take the countries' carbon emissions as relevant risk indicators.[7]

To sum up, the transition towards a low-carbon economy—which entails the adoption of market-oriented and/or fiscal measures (e.g. carbon pricing with a cap-and-trade system or the introduction of a carbon tax), or new regulation modifying the relative prices of the energy sources to penalize fossil fuels—can cause reallocation effects among the economic agents, with consequences on economic growth and possibly on a country financial soundness. The technological breakthroughs in power generation and more energy-efficient production processes could impair the creditworthiness of the net fossil fuel exporting countries or affect the countries that depend on obsolete production processes, with implications on their competitiveness, and industrial policy. At the same time, the countries with a greater exposure to the physical risks of extreme climate events, such as floods, wildfires, and droughts, could be forced to face huge public and private expenses for adaptation initiatives (for example water resources management, dikes, and insurance) and mitigation projects (e.g. afforestation, substitution of internal combustion engine vehicles with electric ones, electric vehicle charging stations), or to bear expenses for fixing up the damages caused by climate change, with an impact on the financial solvency. The link between country risk and government bond risk is confirmed by Burns et al. (2016), Bank of America (2021), and Pinzòn et al. (2020), which find a correlation between the climate, environmental, and ESG profiles and the yield spread of government bonds.

2.1 *Backward-Looking Indicators: Emissions and the Energy System*

The carbon emissions of a country are the first indicator of the exposure to transition risks. An unexpected tightening of climate policies would imply new quantitative constraints to the emissions (for example a ban on the use of the most polluting energy sources like coal) or economic disincentives such as carbon pricing (for example by introducing a carbon tax or by making more stringent conditions for the EU ETS that allocates the emission permits in Europe). Both measures would make emissions more expensive. Such measures would exacerbate the costs for companies and households with negative spillovers on the domestic economy (in terms of reduced economic activity and worsening of the public finances). This would matter more in the countries that are strongly dependent on the fossil fuel industry (for instance the states of the Persian Gulf, Russia, Australia, Canada, and the USA). Being net exporters of energy sources, they would also face trade balance deterioration. For these countries the impact of an acceleration of the transition on the public finances is straightforward; the impact is less obvious for the energy-

[7] Angelova et al. (2021) criticize the methodologies employed by rating agencies for the integration of climate risks into the assessment of government bond risks.

importing countries (like Italy), whose higher transition costs would be compensated by the improvement of the trade balance (the energy bill of Italy in 2019 was 2.2 percent of GDP).

The country emissions originate from production and consumption of the resident entities.[8] This information for EU states is available in the *Air Emission Accounts* published by Eurostat with a sectoral breakdown.[9] According to this source, the 2019 emissions in Italy were equal to 431 million tons of GHGs, of which 111 million from households (due to heating, electricity consumption, and transportation) and 320 million from firms.

An alternative source is the official data transmitted to the United Nations Framework Convention on Climate Change (UNFCCC), which is also disseminated by Eurostat.[10] These statistics refer to the emissions produced by residents and foreign entities within the country's borders (in Italy they are provided by Ispra). For Italy, the two indicators are similar.[11]

The scope of the emissions. Total emissions encompass different GHGs. Besides carbon dioxide (CO_2), other greenhouse gases exist; they are measured in terms of CO_2 equivalent (CO_2e).[12]

Figure 1 shows CO_2 and CO_2e emissions in Italy. The former are due to fossil fuel combustion and are often the only information available at country level, in particular for extra-UE states. An analysis on these emissions only has shortcomings, such as the underestimation of the contribution of some sectors (producing mainly GHG different from CO_2) to total emissions. For example, in 2019 in Italy, the contribution of the agricultural sector to the CO_2 emissions was 3.6 per cent, while the share of the CO_2e attributed to the same sector was 12.2 per cent, mainly owing to methane emissions.

Emissions and carbon intensity. Among the largest European countries, Italy shows relatively low emission levels (Fig. 2a). Absolute emissions do not allow a comparison among countries of different size, in terms of population or GDP. For

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[8] The scope 3 emissions, which include all indirect emissions that occur in a company's value chain, are not considered. Even if they provide useful information (for example because the emissions reductions in the developed countries are partly due to relocation strategies increasing the imported goods from developing countries), a standard measure of this type of emissions does not exist; only some papers assess the carbon emissions attributed to net imports (see for example Peters et al. 2011).

[9] The data are provided by Eurostat based on the firms' location, including airline and shipping companies, and according to the Statistical Classification of Economic Activities in the European Community (NACE). The data refer to the emissions of the so-called Kyoto basket, that encompasses the following six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), the F-gases (hydrofluorocarbons and perfluorocarbons), and sulphur hexafluoride (SF_6).

[10] Eurostat provides UNFCCC data about National Inventories, where the emissions are assigned to the country where they are produced. Eurostat releases a link-table that accounts for the differences between the two systems.

[11] For example, in Italy the 2017 emissions were equal to 427.7 million of tons of CO_2 according to the UNFCC methodology, while the emission attributed to residents were 445.5 million.

[12] See footnote 4.

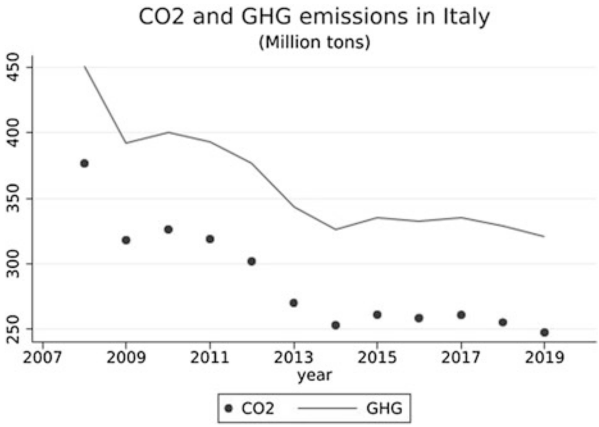


Fig. 1 CO_2 and GHG emissions in Italy (2007–2019; million tons). (Source: Own calculations on Eurostat data)

comparison purposes, the emissions should be normalized by means of a scale factor, yielding a **carbon intensity variable**.

Figure 2b shows the emissions per capita of a sample of European countries; Figure 2c illustrates the GHG emissions per unit of value added at constant 2010 prices. In both cases, Italy is well below the European average. In 2018, the quantity of CO_2e emissions per citizen was 5.4 tons in Italy, 1.5 tons below the EU average and 3.2 tons below Germany. Similar results are obtained for carbon intensity. The production of 1 euro of value added in Italy required 224 grams of CO_2e emissions, 50 grams less than both the EU average value and the German value.

Italy shows a good emission performance even in a broader comparison. For such a comparison, the available data is limited to the CO_2 emissions of the energy sector (about 80 per cent of total CO_2 emissions).[13] Figure 3a shows the CO_2 emissions per capita of Italy compared to non-European countries, such as Canada, Japan, Australia, China and USA; again Italy is the country with the lowest emissions. The same holds true for emissions per unit of GDP (in grams of CO_2 per 2011 PPP[14] in USD).

Beyond the emissions: efficiency and carbon intensity of the energy system. The decarbonization process requires a change in the traditional energy system by progressively phasing-out fossil fuels, which in 2018 accounted for about 80 per cent

[13] See Statistical Review of World Energy by BP for a complete, up-to-date and freely accessible database of the emissions.

[14] The official exchange rate does not provide an accurate assessment of the purchasing power of two currencies for those goods that are not involved in international trade (non-tradable goods). Therefore, to compare the standard of living between different countries, it is appropriate to take into account the general price level of each country. To this end, the exchange rate against the US dollar is adjusted for the different country price indices and GDP is expressed in PPP (Purchasing Power Parity) in USD terms.

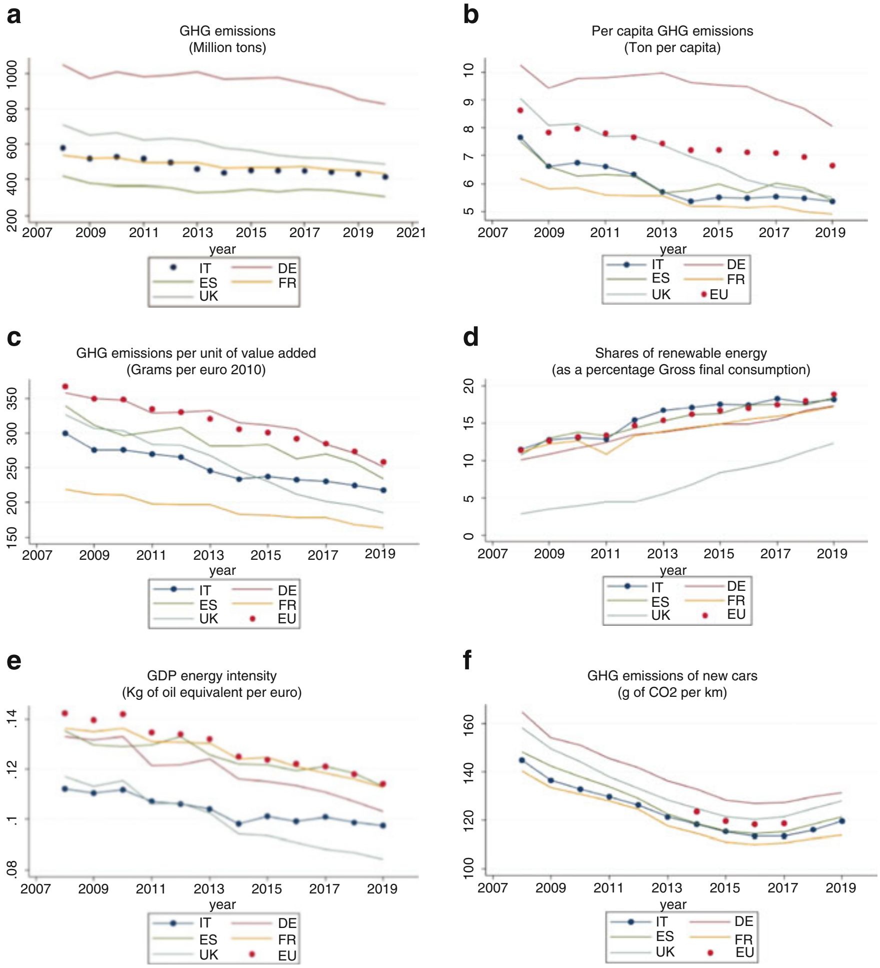


Fig. 2 Statistics on emissions and energy use: Italy vs European countries (Source: Own calculations on Eurostat data. EU = Data of the 28 UE countries as of 2019)

of the primary energy demand.[15] In particular, the decarbonization of the economy may occur through three channels: (1) limiting economic activity (Y); (2) reducing energy intensity (E/Y, the energy required per unit of product, that is the inverse of energy productivity); and (3) reducing the carbon intensity of energy uses (CO_2/E, the quantity of emissions per unit of employed energy).

[15] The primary energy demand equals the total energy demand of a country excluding losses during transformation in other types of energy and energy carriers used for non-energy purposes (for example used for the refining of the oil products).

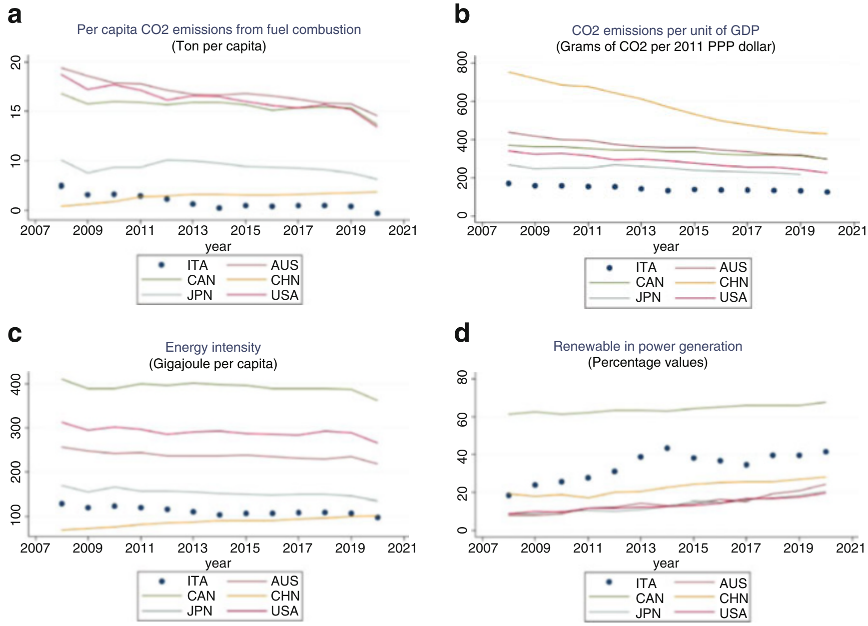


Fig. 3 Statistics on emissions and energy use: Italy vs extra-European countries (2008–2020). (Source: Own calculations on *BP Statistical review of world energy* and World Bank data)

In symbols, we can express the emission levels with the Kaya identity (Kaya and Keiichi 1997):

$$\overbrace{CO_2}^{\text{Emissions}} = \overbrace{Pop}^{\text{Population}} * \overbrace{\frac{Y}{Pop}}^{\text{Product}} * \overbrace{\frac{E}{Y}}^{\text{Energy}} * \frac{CO_2}{E},$$

which can be written in terms of variations, given the population, as follows:

$$\dot{CO}_2 \cong \underbrace{\dot{Y}}_{\text{Economic activity}} + \underbrace{\dot{E/Y}}_{\text{Energy intensity}} + \underbrace{\dot{CO_2/E}}_{\substack{\text{Carbon intensity}\\ \text{of energy uses}}}$$

The first channel, whereby the emissions decrease because of a slowdown in economic activity (or population), was at work in 2020 due to the containment measures introduced after the Covid-19 pandemic outbreak (this would be a manageable channel only in a Malthusian approach or in a degrowth setting). The second channel, related to the increase of energy productivity, involves policies that reduce the energy intensity of the economy (for example by reducing the specific consumption of buildings, cars and electric devices). The third channel is based on the diffusion of technologies that lower carbon intensity within energy usages and transformation, such as renewable resources for energy production for heating and electricity or the use of nuclear energy.

Figures 2e and 3c show how Italy uses energy compared with other countries, per unit of GDP and per capita. According to the latter indicator, in 2019 each Italian citizen consumed on average 105 Gj of energy; this quantity was slightly higher than that of a Chinese citizen, 30 per cent below that of a Japanese citizen and much lower than that consumed by a citizen of Australia, the USA, and Canada (41, 37 and 28 per cent, respectively; Fig. 3c). In addition to higher energy efficiency, Italy has a lower carbon intensity of energy usage, as revealed by the larger percentage of renewable sources compared to other European countries (Fig. 2d) and to extra-European countries (Fig. 3d).

2.2 *Forward-Looking Indicators: From Historical Emissions to Decarbonization Scenarios*

Backward-looking information gives a comforting picture of Italy's position so far, confirmed by the fact that Italy has achieved all the European targets by 2020.[16] Yet the transition process is in its initial stage and linked to the growth of renewable energies in the power sector. Furthermore, as already happened for the Lisbon 2020 objectives, the transition will be accompanied by a likely increase in energy expenditure for businesses and households (see Bernardini et al. 2021, and Chap. "The Eurosystem Collateral Framework and the Measures Introduced in Response to the Pandemic Emergency"). The trend in historical emissions is not sufficient to understand the capacity of a country to achieve the new European targets that envisage a sharp reduction in emissions in the next decade to achieve carbon neutrality by 2050: the new targets foresee that by 2030 EU emissions will decrease by 55 per cent compared to 1990 values.[17] The importance of monitoring the national commitments to decarbonization or to net-zero has been highlighted in the aftermath of the COP26 (UNEP 2021).

Historical emissions and future commitments. Figure 4a shows the time trend of Italian emissions (dark grey histogram) and the trend of emissions required to reach the new target by 2030. These values are calculated by setting the emissions of 2030 at 45 per cent of the 1990 value and interpolating the values for the

[16] Italy is one of the few EU countries that achieved all three of the Europe 2020 objectives, in terms of containing greenhouse gas emissions, reducing energy demand and increasing renewable energy deployment (EEA 2020).

[17] The Integrated Climate-Energy Plan submitted to the Commission at the end of 2019 considers a strategy based on achieving by 2030 a 30 per cent share of renewables in gross final energy consumption, a reduction by 43 percent in energy use compared to the trend and a 40 per cent decrease in GHG emissions compared to 1990. The plan will be revised to integrate the new targets.

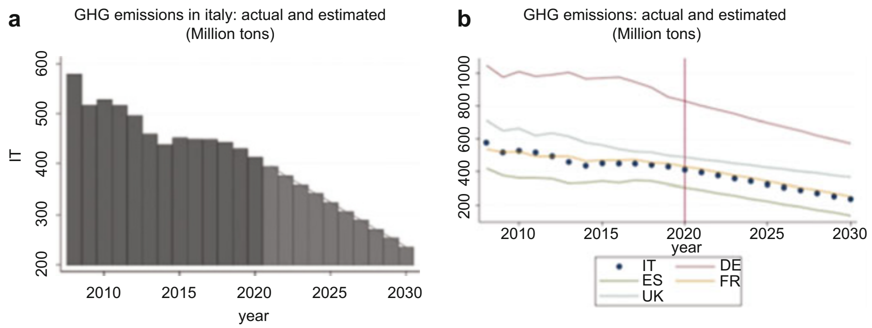


Fig. 4 Actual and projected emissions (2008–2030; million tons). Projected emissions are estimated assuming that emissions in 2030 are 45 percent of those in 1990 (based on IPCC inventories). The data between 2020 and 2030 are interpolated with a simple trend. (Source: Own calculations on Eurostat and EEA data)

Table 1 Yearly change in actual and projected emissions (percentage values)

CAGR	DE	ES	FR	IT	UK
2008–2019	−2.0	−2.6	−1.8	−2.9	−3.4
2019–2030	−3.9	−8.2	−5.6	−5.8	−3.0
Difference (in p.p.)	−1.9	−5.6	−3.8	−2.9	0.4

Source: Own calculations on Eurostat and EEA data

intermediate years.[18] The pace of emission reductions is expected to accelerate significantly; it requires halving the emissions over the next decade. Figure 4b shows a comparison with other European countries; the figure highlights the drastic decarbonization that should be implemented in Germany, involving in the next decade the elimination of a volume of emissions equal to the total annual emissions of Italy.

Table 1 shows the annual percentage change in emissions for the period 2008–2019 (observed) and those required to achieve the goal in the period 2019–2030 (estimated).

Except for the UK, all countries are expected to raise significantly their annual emission reduction rate. Italy and Germany should double it; France and Spain have to triple it. Even if the economic crisis caused by the pandemic will temporarily make these objectives less difficult to achieve, once GDP will grow again, the 'activity' channel of Kaya's identity will provide a positive contribution that needs to be compensated with structural reduction measures in energy and carbon intensity.

[18] In September 2020, as part of the European Green Deal, the Commission proposed raising the target and reducing greenhouse gas emissions by 2030 to 55 per cent. The Commission started the process for the detailed legislative proposals in July 2021.

Historical emissions and climatic scenarios. Historical emissions can also be compared with those of the scenarios published by the Network for Greening the Financial System (NGFS).[19]

Figure 6 shows the historical emissions profile of China, the United States, and Europe (overall the main contributors to GHG emissions) with the level consistent with each NGFS scenario. In the 'Current Policies' scenario, emissions continue to grow and there is no mitigation; only China reaches a plateau after 2080 (Fig. 6a). In the 'NDCs' scenario, which assumes that countries reduce emissions according to the commitments declared by signing the Paris Agreement, emissions are reduced but not enough to keep the temperature rise within 2 °C (temperatures at the end of the century would increase by 2.5 °C) (Fig. 6b). In the 'Delayed transition' scenario, a trend close to maintaining the 2 °C is assumed but with a disorderly transition, in which emissions increase before abruptly decreasing (they must become negative after 2060 in order not to affect the carbon budget[20]; Fig. 6e). In the two 'Orderly' scenarios (Net-zero 2050 and Below 2 °C), transition is instead orderly and emissions are reduced to keep the temperature rise within 2 and 1.5 °C, respectively (Fig. 6c, d).

NGFS Scenarios

Since 2020, central banks can rely on the climate scenarios published by the NGFS, which provide a common framework for forward-looking analysis. In June 2021, the NGFS baseline scenarios were updated to take into account more recent and granular information, which also includes the pandemic effects on GHG emissions (NGFS 2021c). In September 2022, the scenarios were updated with the latest economic and climate data, new model versions (for physical risk and more sectoral granularity for transition risk), new country-level policy commitments made at COP26 in November 2021, and the latest trends in renewable energy and mitigation technologies. However, the new data do not account for the war in Ukraine (NGFS 2022). The three groups of scenarios (a fourth group is not considered at this stage) are based on different profiles of future emissions (Fig. 5).

1. The first group assumes the adoption of immediate mitigation policies and a rapid transition towards climate neutrality (Orderly). The increase in global

(continued)

[19] The NGFS is a global network of central banks and supervisory authorities that promotes the sharing of experiences and best practices in the management of environmental risks (with specific attention to climate risks) in the financial sector.

[20] According to some estimates based on the assumptions of the United Nations Intergovernmental Panel on Climate Change (UN IPCC), to have half the probability of staying within a 2 °C increase by the end of the century, the carbon budget should be equal to 1200 billion tons (Gt) of emissions, compared to 2910 Gt of emissions embedded in the reserves of fossil fuels. Therefore 59 per cent of these reserves would be unburnable. The budget would be even more stringent (464 Gt) in the case of a global temperature target of 1.5 °C, making 80 per cent of the reserves unburnable.

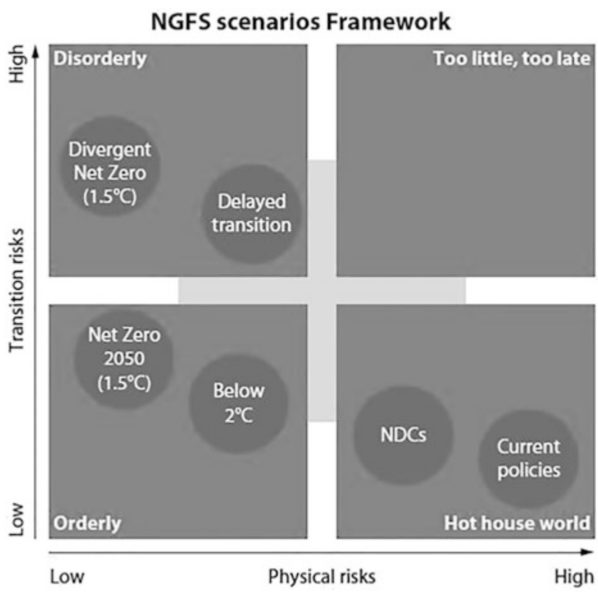
temperature remains below 2 °C, in line with the Paris Agreement. There are two scenarios in this group: Net-Zero 2050 and Below 2 °C.

2. In the second group, an uncoordinated and late action is assumed in which the transition is not implemented immediately and must accelerate later, without achieving the goal of containing the temperature increase within 2 °C (Disorderly). There are two scenarios in this group: Divergent Net-zero (1.5 °C) and Delayed transition.
3. In the third group, no new policies are adopted and emissions and their concentration increase towards values compatible with an increase in temperature that exceeds 3 °C compared to pre-industrial levels (Hot house world). There are two scenarios in this group: Current policies and NDCs.

Each scenario has different combinations of physical and transition risks. Physical risk is the highest in case of no policy or late and insufficient policy (scenarios on the right-hand side of Fig. 5). This risk is lower if transition policies are implemented, but transition risk increases. The latter risk is the highest when the transition is implemented in an unplanned way (scenario group in the upper left quadrant). Without climate policies, there is no transition risk.

The forecasted time series of variables of the NGFS scenarios, which derive from simulations of different climate models, can be downloaded from an archive hosted by the IIASA (https://data.ene.iiasa.ac.at/ngfs), an independent international research institute that regularly contributes to the IPCC climate reports.

Fig. 5 NGFS scenarios framework. (Source: NGFS (2022), 'Climate Scenarios for central banks and supervisors'



What are the underlying costs of these future emission trends? The value of the CO_2 price (in 2010 dollars per ton) required to reach the different decarbonization scenarios (which would be zero in the Current Policies scenario) hovers around USD 200 in the orderly transition scenario (represented by the line ‘Net Zero 2050’ in Fig. 6f); towards the end of the century, it temporarily exceeds USD 2000 per ton in the Delayed transition scenario.

The methods for integrating future emission paths in the evaluation of financial portfolios have been less explored than those employing historical emissions, owing

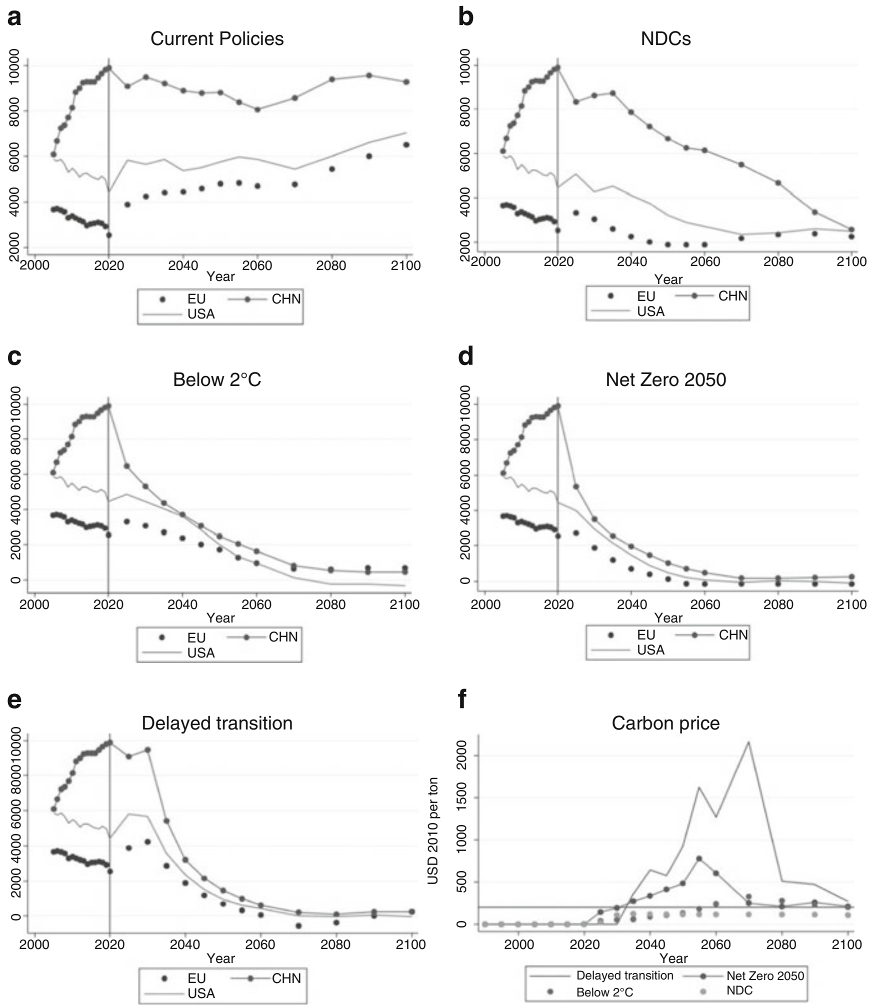


Fig. 6 Actual emissions and NGFS scenarios (million tons of CO_2 and USD 2010 per ton of CO_2). (Source: Own calculations on *BP Statistical review of world energy* and NGFS Scenario Explorer vers. 2.2.—model MESSAGEix—GLOBIOM 1.1 data)

to the greater complexity. However, if good quality data are available, the evaluation of the expected carbon footprint of the portfolio can be performed as well.

The financial community is thus gaining interest in a branch of 'Transition Finance' which employs new valuation methods (like stress tests and portfolio alignment tools) and financial instruments suited for investors that aim at the opportunities of the carbon transition (TCFD 2021; OECD 2021).

Qualitative assessment. In addition to the quantitative assessment reported above, a qualitative assessment can be performed. For the EU countries, the Commission assesses the climate and energy plans of individual countries. In particular, the Italian plan presented in 2019 received a positive assessment: 'Overall, the final NECP largely addresses most of the Commission recommendations' (EC 2020).

Another source for qualitative analysis is the IEA database on national policies on energy efficiency and renewable energy.[21] A further evaluation will be possible in the future once the European Union taxonomy of sustainable investments is finalized, for example by assessing how many sectors are aligned with the taxonomy and their relevance to GDP.

2.3 *Environmental Risk Exposure Indicators*

Climate change is the most urgent environmental issue also because it is directly linked to other negative effects on the environment (from water scarcity to biodiversity loss). The Human Development Index (HDI) of the United Nations Development Programme (UNDP) is a useful indicator. The UNDP has recently introduced a measure for the environmental footprint of the countries, the Planetary Pressures-adjusted Human Development Index (PHDI).[22] The new indicator has brought about an improvement of Italy's position in the ranking by 12 positions. After the adjustment, for example, Norway has moved down from the 1st to the 15th position; other countries that use and export natural resources have been downgraded as well (Australia, Canada, the United States, and other fossil fuel exporters). Besides Italy, other European countries (France, Spain, the United Kingdom, and Ireland) have improved their position thanks to the relatively low percentage of fossil fuels employed in their energy mix and to a lower use of raw material (Table 2).

[21] See www.iea.org/policies

[22] The environmental footprint of a product or policy is a multidimensional indicator that summarizes the environmental impact through specific indicators, such as greenhouse gas emissions, water consumption, and resource depletion.

Table 2 Planetary pressures-adjusted Human Development Index (PHDI)

Country	HDI	PHDI[a]	Position HDI	Position PHDI	Direction of the rank change
Australia	0.944	0.696	8	80	↓
Austria	0.922	0.771	18	29	↓
Belgium	0.931	0.800	14	10	↑
Canada	0.929	0.721	16	56	↓
China	0.761	0.671	85	101	↓
Germany	0.947	0.814	6	7	↓
Spain	0.904	0.795	25	14	↑
France	0.901	0.801	26	10	↑
United Kingdom	0.932	0.825	13	3	↑
Ireland	0.955	0.833	2	1	↑
Japan	0.919	0.781	19	17	↑
The Netherlands	0.944	0.794	8	14	↓
USA	0.926	0.718	17	62	↓
Italy	0.892	0.783	41	29	↑

Source: Own calculations on UNDP data as of 2019
[a]Planetary pressures-adjusted HDI

2.4 The Climate and Environmental Indicators for Some Countries

The previous sections presented a set of indicators for the assessment of the transition risk of government bonds. For most indicators, Italy shows a low carbon footprint and a limited climate/environmental risk in comparison with other countries, based on emission per capita and per unit of GDP. This is the result of the good performance of Italy both in terms of energy intensity and of carbon intensity of the energy system; in turn, this is partly due to the widespread use of renewable resources in the electric system (Table 3). These indicators are used to compare the climate risk exposure of the Bank's government bond portfolio with a market index (see Sect. 5.2).

3 Climate and Environmental Indicators for Corporate Sector Entities

ESG scores jointly measure the environmental, social, and governance factors of firms, states, supranational organizations, and collective investment undertakings. The relative importance of the climate and environmental variables, which are a

Table 3 Carbon intensity, energy intensity, and Italy's position in a sample of developed countries

	Carbon intensity		Energy intensity		Carbon intensity of the energy	
	Emissions per capita	Emissions per unit of GDP	Energy per capita	Energy per GDP	Emissions per unit of energy	Electricity from renewable sources
	Ton of CO_2 per capita	g of CO_2 per 2011 PPP USD	Gj per capita	Mj per 2011 PPP USD	Ton of CO_2 per TJ	Percentage values
Australia	17.0	338.7	254.3	5.1	66.8	20.9
Austria	7.2	129.7	167.5	3.0	43.1	73.9
Belgium	10.8	208.7	235.1	4.5	45.9	20.2
Canada	14.9	301.8	379.9	7.7	39.1	65.3
China	6.9	436.2	98.8	6.3	69.3	26.7
Germany	8.2	152.5	157.3	2.9	52.0	39.9
Spain	6.0	144.6	122.4	3.0	48.7	37.2
EU28	6.5	167.5	134.2	3.5	48.4	34.1
France	4.6	96.6	148.6	3.1	30.9	20.4
United Kingdom	5.7	124.1	116.1	2.5	49.4	36.9
Ireland	7.7	87.9	135.8	1.5	56.8	37.4
Japan	8.9	214.7	147.2	3.6	60.1	18.8
The Netherlands	11.2	194.6	205.4	3.6	54.7	18.5
USA	15.1	241.9	287.6	4.6	52.5	17.3
Italy	**5.4**	**127.0**	**105.3**	**2.5**	**51.0**	**39.7**
Italy position	**2**	**4**	**2**	**2**	**8**	**4**

Source: Based on data as of 2019 from the BP Statistical Review of world energy and World Bank

subset of those included in ESG scores, varies among industrial sectors. For instance, the relevance of climate and environmental factors is greater for firms belonging to the utility, energy, and basic materials sectors; the corporate governance and social indicators are more important in the financial and technology sectors. The link between ESG scores and climate and environmental factors is not direct. OECD (2020) shows that in some cases high ESG scores are associated with high carbon emissions.

The ESG scores take into account different aspects of the environmental and climate factors: the firm's exposure to these factors, its ability to manage the risks, and the capacity to exploit the opportunities. The scores are developed by providers who have built their own assessment methodologies and ancillary services. A consolidation process by the major ESG providers is ongoing in the global market. The largest providers often take over smaller firms specialized in specific fields and geographical areas. The importance of ESG scores for climate analysis is due to their large use in sustainable finance for the selection of financial assets, the definition of market indices, and reporting. The use of ESG scores should go together with the awareness of their current limits, in particular with regard to methodological heterogeneity and the completeness and quality of information.

Some studies highlight that the providers often assign quite different ESG scores to a firm. Overall, the ESG score correlation is mild and equal to 40–50 per cent. This phenomenon is largely explained by the absence of consolidated models, like those employed in the credit rating industry. The ESG score providers make a subjective choice of the sustainability factors (like the use of natural resources, waste management, workplace safety, consumer protection, board competence and composition) and of the indicators to be employed for the score calculation.[23] The ESG factors change according to the sector, the business model, and the materiality criterion. If one takes the viewpoint of the entrepreneur, then the factors that matter are those with financial consequences for the firm (financial materiality). If one takes the viewpoint of the other stakeholders, then the factors that matter are those with a significant impact on the environment and society (sustainability materiality). Furthermore, the factors evolve over time, because of technological progress, policy changes, and social phenomena (dynamic materiality).[24] For the selection of factors, providers do their own assessment and usually do not disclose the details to protect their intellectual property.

The main reason for the differences in the indicators is the heterogeneity of corporate reporting, in the absence of a regulation on the disclosure of non-financial information.[25] The lack of information induces the providers to replace missing data with model-based data or to resort to external sources.[26] In the near future, the review of the Directive 2014/95/EU on Non-Financial Reporting (NFRD) will bring about an improvement in the quality and breadth of information on corporate sustainability in the EU.[27] A further contribution to the homogeneity of ESG assessment will be provided by the European taxonomy of environmentally sustainable economic activities (Regulation EU 2020/852). Once the approval process of its technical screening criteria will be finalized, the Taxonomy will

[23] See Berg et al. (2019).

[24] See Rogers and Serafeim (2020).

[25] See Kotsantonis and Serafeim (2019).

[26] Specifically, it has been observed that the information is often qualitative, the time horizon of the analysis and the forecasts is short and medium term, and still few companies set quantitative sustainability targets. See 2 Degrees Investing Initiative (2017).

[27] On 21 April 2021, the European Commission published a proposal for a directive on sustainability communication (*Corporate Sustainability Reporting Directive*—CSRD) to supplement and update the current directive on non-financial communication. Sustainability information will be reported according to the standards developed by the European Financial Reporting Advisory Group (EFRAG). According to the current forecasts on the approval process of the CSRD, large enterprises could be required to comply from 2024, while small- and medium-sized enterprises should start from 2027.

Table 4 Coverage of the main environmental and climate corporate factors (percentage values)

Environment	Coverage
Carbon emissions	
Scope 1 emissions	81
Scope 2 emissions	80
Scope 3 emissions	62
Energy	
Energy consumption	69
Renewable energy consumption	49
Water	
Water withdrawal	53
Water consumption	56
Water pollution	13
Waste	
Waste generation	69
Hazardous waste	50
Waste recycling	54

Source: Own calculations on ESG data provided by four leading suppliers on companies included in the MSCI EMU index, the FTSE Italy All-share index and two Bloomberg-MSCI euro area and USA corporate bond indexes

provide objective standards for the sustainability assessment of businesses.[28] The Regulation states that the companies themselves will communicate the share of their turnover from products and services associated with green activities, and the proportion of their capital expenditure and operating expenses relating to assets or processes associated with green activities.

The factors with a greater availability of information are those related to the carbon emissions, in particular the direct and indirect emissions (scope 1 e scope 2), while data on scope 3 emissions are scarcer. Some providers ensure a coverage close to 100 per cent with proprietary estimation models. The fields with the second largest coverage are waste generation and energy consumption (both 69 per cent), while coverage decreases for data on the use of renewable energy sources (Table 4).

We carried out a correlation analysis on the same list of indicators (Table 5), based on the data of four providers. We find a correlation above 90 per cent in the data on carbon emissions (especially scopes 1 and 3) among three providers. Similar results are observed for the indicators on energy consumption, waste generation, and recycling among the four providers. The correlation of these indicators suggests that they are highly reliable. Hence, some of them could be used directly in financial

[28] To be considered as environmentally sustainable under the European taxonomy, an activity must comply with three main conditions: (a) provide a substantial contribution to the achievement of at least one of six environmental objectives of the European Union; (b) do not cause significant damage to any of the other environmental objectives (so-called do not significant harm principle—DNSH); (c) ensure compliance with minimum ethical and social principles (so-called minimum safeguards), verified by the compliance with specific international standards and conventions.

Table 5 Correlation of the main environmental and climate indicators among providers

	Provider A/Provider B	Provider A/Provider C	Provider A/Provider D	Provider B/Provider C	Provider B/Provider D	Provider C/Provider D
Environment						
Scope 1 emissions	1.00	1.00	0.95	1.00	0.95	0.95
Scope 2 emissions	0.20	0.77	0.98	0.16	0.20	0.78
Scope 3 emissions	1.00	0.99	0.52	0.99	0.52	0.52
Energy consumption				0.89		
Water withdrawal				0.95		
Water consumption			0.93			
Waste generated				0.95	0.77	0.78
Hazardous waste				0.89		
Waste recycled				0.99	0.99	0.99

Source: Own calculations on ESG data provided by four leading suppliers on companies included in the MSCI EMU index, the FTSE Italy All-share index and two Bloomberg-MSCI euro area and USA corporate bond indexes models for sustainable investment, as it happens frequently for the carbon emission data.

The ESG scores may provide valuable information about the past and ongoing controversies, while they are less useful for the assessment of future sustainability and controversy risks. This is due to various reasons: corporate disclosure is mainly based on backward-looking indicators; corporate strategies and commitments are often generic; and risk analysis has a short- and medium-term nature.

Some providers have developed methodologies to estimate the 'climate value at risk', namely, the firm exposure to climate risks and the potential impact on its equity and debt through scenario analysis (Dietz et al. 2016).

4 The Carbon Footprint and Exposure of Financial Portfolios

As part of its sustainable investment activity, the Bank of Italy estimates the exposure to climate and environmental risks of its foreign reserves and euro-denominated investment portfolio, employing the indicators described in Sects. 2.1 and 2.4. Backward-looking indicators, such as portfolio GHG emissions, enable to: (a) track the carbon impact of investments over time; (b) obtain a measure of transition risk through the comparison between the portfolio and the benchmark index.

The carbon indicators for a portfolio of equities and bonds require a measure of each issuer's total value, i.e. the enterprise value including cash (EVIC), to allocate the company GHG emissions and revenues to either shareholders or lenders of the company, avoiding double counting. For government bonds, the country GHG emissions and public debt are weighted by the share of public debt held within the portfolio. Country GHG emissions include those from resident companies. As a consequence, it is not appropriate to calculate carbon variables for a portfolio of government securities and corporate securities to avoid double counting of GHG emissions. Therefore, we treat government and corporate securities separately.

For a portfolio containing *n* corporate securities (shares and/or corporate bonds) or *m* government bonds, the following carbon footprint and exposure indicators can be employed (TCFD 2021)[29]:

- **Portfolio emissions**: sum of GHG emissions, expressed in tons of CO_2 equivalent (tCO_2e), associated with each security using as weights: (a) for corporate

[29] The term *carbon footprint* is often referred to as the amount of GHG emissions produced by a good, a service or an organization; in this case, GHG emissions of companies and countries financed by the portfolio are measured in an absolute or normalized way. The TCFD of the Financial Stability Board has defined as carbon footprint of a financial portfolio a specific indicator (sometimes also referred to as *capital carbon footprint*); such indicator normalizes GHG emissions of the portfolio by its market value in a single currency.

securities, the ratio between the market value of the security and the enterprise value including cash (EVIC); (b) for government bonds, the ratio between the nominal value of the bond in the portfolio, and the nominal value of the country's public debt (PD);

$$\sum_{i=1}^{n}\left(\frac{\text{Market value}_i}{\text{EVIC}_i}\cdot \text{GHG emissions}_i\right) \text{ for shares and corporate bonds;}$$

$$\sum_{i=1}^{m}\left(\frac{\text{Nominal value}_i}{\text{PD}_i}\cdot \text{GHG emissions}_i\right) \text{ for government bonds;}$$

- **Carbon footprint**: portfolio emissions (expressed in grams of CO_2e) per EUR unit invested:

$$\frac{\text{Portfolio Emissions}}{\text{Portfolio Market Value}};$$

- **Carbon intensity** of the *i*th issuer: the ratio between GHG emissions and a) revenues for corporates, b) GDP for countries:

$$\text{CI}_i = \frac{\text{GHG Emissions}_i}{\text{Revenues}_i} \text{ for shares and corporate bonds;}$$

$$\text{CI}_i = \frac{\text{GHG Emissions}_i}{\text{GDP}_i} \text{ for government bonds;}$$

- **Portfolio carbon intensity:** ratio between total emissions and a) revenues associated to the portfolio for corporates (based on EVIC), b) GDP associated to portfolio for countries:

$$\frac{\text{Portfolio Emissions}}{\sum_{i=1}^{n}\left(\frac{\text{Market Value}_i}{\text{EVIC}_i}\cdot \text{Revenues}_i\right)} \text{ for shares and corporate bonds;}$$

$$\frac{\text{Portfolio Emissions}}{\sum_{i=1}^{m}\left(\frac{\text{Nominal Value}_i}{\text{PD}_i}\cdot \text{GDP}_i\right)} \text{ for government bonds;}$$

- **WACI** (*weighted average carbon intensity*): average of carbon intensity of the issuers weighted by the securities' weights in the portfolio (at market values):

$$\sum_{i=1}^{n}\left(\frac{\text{Market Value}_i}{\text{Portafolio Market Value}}\cdot \text{CI}_i\right) \text{ for shares and corporate bonds;}$$

$$\sum_{i=1}^{m}\left(\frac{\text{Market Value}_i}{\text{Portafolio Market Value}}\cdot \text{CI}_i\right) \text{ for government bonds.}$$

Some of the above indicators allow a comparison of the exposure to transition risk; other indicators employ the absolute size of the portfolio and may be of interest for their link with climate policies (see Sect. 2.1) or certain sustainability objectives.

The Kaya identity, shown in Sect. 2.1, shows that the (change in) emissions of a company or a state are due to the energy efficiency (revenue or GDP per unit of energy used) and the carbon intensity of energy uses (GHG emissions per unit of energy used) of the issuer. Therefore, emissions can be reduced by means of technologies that improve the energy efficiency and by means of the use of non-fossil energy sources. Carbon intensity is therefore useful for classifying companies (and sectors) or countries according to their energy-environmental efficiency.

The indicators that take into account the efficiency (carbon intensity and WACI) or that normalize emissions by the amounts invested (carbon footprint) enable to follow the climate impact of a portfolio over time, as well as to compare portfolios of different size.

As already noted, the carbon intensity of the portfolio is obtained as the emissions per unit of revenues (or GDP) in proportion to the share held in the assets of a company (or of the public debt of a country). This measure also provides an indication of the exposure to transition risk.[30]

Table 6 summarizes the main advantages and disadvantages of each indicator.

For companies, direct and indirect GHG emissions (scope 1 and scope 2) are usually considered.[31] These data are available from providers such as Refinitiv, Bloomberg, MSCI, Trucost, Sustainalytics, Vigeo Eiris, and ISS. Data on revenues

[30] The financial risk arising from the energy transition required to keep the global temperature rise below 2 °C can materialize through several channels, such as: (a) the imposition of taxes or restrictions on CO_2 emissions that would cause a significant increase in costs for less efficient organizations; (b) a sudden technological innovation that disrupts some sectors including, potentially, those related to fossil fuels (which have the highest intensity values); (c) more or less rapid changes in the expectations and/or preferences of economic agents. Transition risk could affect companies through all of these channels.

[31] See footnote 2.

Table 6 Climate risk indicators of a portfolio in terms of GHG emissions

Indicators	Pro	Cons
Total portfolio emissions (tCO2e)	It can be used to monitor the performance of a portfolio of constant size over time	It cannot be used to compare portfolios with different size
Carbon footprint (gCO2e/EUR invested)	It allows a comparison between portfolios	It does not consider energy and carbon efficiency
Carbon intensity (gCO2e/EUR of revenues or GDP)	It takes into account the energy and carbon efficiency of a portfolio	It is more complex to calculate
WACI (gCO2e/EUR of revenues or GDP)	It is easier to calculate, independent of the economic value/size of the company	It is highly dependent on the exposure to carbon-intensive sectors

and EVIC can be obtained from financial data providers including MSCI, Refinitiv, and Bloomberg.

Country carbon emissions are available from the Emissions Database for Global Atmospheric Research (EDGAR), maintained by the European Commission Joint Research Centre (JRC) with international statistics and the IPCC methodology. The database provides the national emissions of GHG by resident entities (businesses and households). At the time of writing, emission data for 2021 were not available. Estimates from other sources indicate an increase in national carbon emissions after the remarkable reduction caused by the Covid-19 pandemic between 2019 and 2020.[32] In addition, data of the Air Emission Accounts provided by Eurostat can be used for the public debt and GDP of EU countries.[33] For non-EU countries, data on emissions can be retrieved from the British Petroleum (BP) database (British Petroleum 2020),[34] although these data are not harmonized with the Eurostat database. In our analysis, GDP and public debt data were obtained from the World Bank's database and normalized using the US dollar as the base currency.

The calculation of the carbon footprint of a bond portfolio does not differ according to the type of bond; therefore, this indicator is not directly affected by the presence of green bonds. However green bonds may make an important contribution to environmental sustainability, by financing projects in water and waste treatment, pollution prevention and control initiatives, transport infrastructures

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[32] Based on the data for 2020, in February 2021 the Italian EPA (ISPRA) estimated a reduction in Italy's GHG emissions by 9.8 per cent; this value is greater than the drop in GDP (−8.9 per cent). This is due to a set of pandemic-related facts: (a) the reduction of emissions from power generation (−12.6 per cent) for lower energy demand; (b) the reduction of energy consumption in other sectors, such as manufacturing (−9.9 per cent) and transport (−16.8 per cent), due to the reduction of private transport in urban areas, and of heating (−5.8 per cent) for the partial or total closure of public buildings and commercial activities.

[33] In the following, we consider consolidated gross public debt and real GDP in euro at constant 2008 prices.

[34] These data cover the annual CO_2 emissions of individual countries and not those of all greenhouse gases, as with Eurostat data.

including railways, systems for energy efficiency, and energy production from renewable sources. To take into account the positive contribution of green bonds to the environment, it is useful to calculate their percentage in the portfolio.

5 The Climate and Environmental Risk Exposure of the Bank of Italy's Investments

In this section, we apply the climate and environmental risk exposure indicators to the Bank's investments and analyze the results.

The integration of sustainability criteria into the investment policy aims at improving the financial risk management and signalling the Bank's commitment to sustainable development, mindful of society, and the environment. In 2019, the ESG investment policy was applied to the equity portfolio, with a focus on the European stock market, for which the availability of ESG data is wider (NGFS 2019b). In 2020, the ESG strategy was extended to the US and Japanese equity investments held via ETFs and to corporate bonds. Purchases of green bonds issued by supranational entities started in the same year.

5.1 The Bank of Italy's Foreign Reserves and Investment Portfolio: Objectives and Composition

In addition to the monetary policy portfolios, the Bank of Italy manages the foreign reserves and the investment portfolio in euro-denominated assets.

Foreign reserves can be used for foreign exchange market interventions to preserve currency stability. The Bank of Italy also uses the national reserves to service the foreign currency-denominated debt on behalf of the Treasury and to fulfil its obligations towards international organizations such as the International Monetary Fund. Lastly, national reserves, being part of the reserves of the Eurosystem, play an important role in building up and maintaining the ESCB's credibility.

The management of reserves, which contributes to the Bank's annual net income, is primarily aimed at preserving their value and liquidity. Besides, their management pursues the prudent maximization of returns within some risk limits. The portfolio is diversified across the major global currencies (US dollar, Japanese yen, British pound, Canadian dollar, Australian dollar, and Chinese renminbi). In the remainder of this section, we consider only the foreign reserves invested in government securities, which amounted to EUR 35.8 billion at the end of 2021 (Table 7).

The investment portfolio serves two purposes: it helps to cover business costs and it maintains the Bank's capital strength against the risks involved in carrying out institutional activities. Approximately 10 per cent of the portfolio is invested in equities (see Chap. "The Strategic Allocation and Sustainability of Central Bank

Table 7 The Bank of Italy's investments considered in the sustainability analysis (market values in billions of euro; percentage values)

	31.12.2020	31.12.2021	% chg
Investment portfolio			
Equities[a]	12.1	16.1	33.2
Corporate bonds	0.8	0.8	−1.2
Government bonds[b]	147.1	139.8	−5.0
Total	160.0	156.7	−2.1
FX reserves			
Government bonds[b]	31.4	35.8	16.1

Source: Own calculations
[a]US and Japanese stocks are excluded from the sustainability analysis
[b]This item includes supranational bonds

Table 8 Carbon indicators of EUR government bond investments

	Portfolio[a] 31.12.2020	Portfolio[a] 31.12.2021	chg. %	Benchmark[a, b] 31.12.2021
Emissions *(thousand tCO_2e)*	29,087	27,141	*−6.7*	40,529
Carbon footprint *(gCO_2e per EUR invested)*	210	207	*−1.6*	309
Carbon intensity *(gCO2e per EUR of GDP)*	255	240	*−5.9*	253
WACI *(gCO2e per EUR of GDP)*	255	240	*−6.0*	250

Source: based on Edgar, World Bank, ICE
[a]National GHG emissions and GDP (PPP) based on 2020 levels
[b]Index ICE BofAML All Maturity Euro Government Index considering only euro area countries with an average rating equal to or greater than BBB

Investments"). The remainder of the investment portfolio consists of corporate and government bonds. Overall, the financial portfolio amounted to EUR 156.7 billion at the end of 2021 (Table 7).

The next two sections show the carbon and climate indicators for the government bonds and corporate securities, respectively.

5.2 *Government Bonds*

The investment portfolio has a large share in government bonds, mainly issued by the Italian Government. It also includes government bonds issued by other euro area countries and supranational issuers, comparable to governmental entities.

The indicators presented in Sect. 4 are calculated for this portfolio with reference to the end of 2020 and 2021, using the carbon intensity of the individual countries at the end of 2020 to disentangle the effect of the change in the size and composition of the portfolio between the 2 years (Table 8).

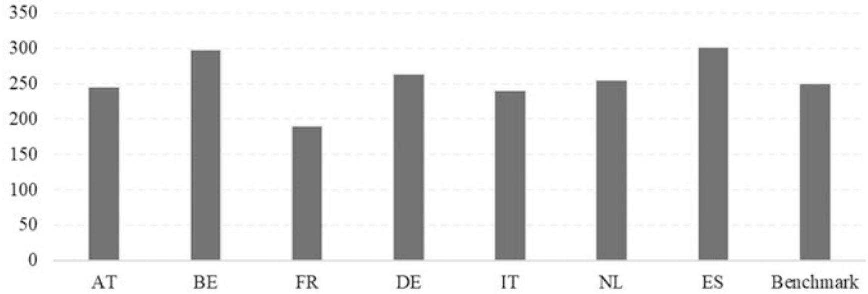

Fig. 7 Carbon intensity of the main euro government bonds (grams of CO_2e per EUR of GDP based on 2020 GHG emission levels). (Source: based on Edgar)

For comparison, a benchmark index is estimated from the *ICE BofA All Maturity All Euro Government Index*, considering the 16 countries of the euro area with a rating equal to or higher than that of Italy.[35]

The euro-denominated government bond portfolio decreased by 5 per cent in 2021 (Table 7), largely due to the market value depreciation of the portfolio caused by the interest rate rise. The reduction of portfolio GHG emissions was more than proportional (−6.7 per cent, Table 8); consequently, the carbon footprint decreased as well in the period (−1.6 per cent). The carbon intensity and the WACI declined too (−5.9 and −6 per cent, respectively). The WACI is in line with the carbon intensity of Italy (240.8 gCO2e per euro of GDP), as Italian government bonds account by far for the largest share of the portfolio.

The benchmark index shows emission indicators in line with the portfolio, as a result of a combination of some countries with higher values (e.g. Germany has a carbon intensity of 263 gCO_2e per EUR of GDP) and other countries with lower values (France's carbon intensity is 190 gCO_2e per EUR of GDP; Fig. 7).

At the end of 2021, the sovereign green bond holdings were 2.5 per cent of the total. Among the supranational securities, green bonds were worth approximately 20 per cent.

The foreign exchange (FX) reserve portfolio was composed mainly of US Treasuries and to a lesser extent of Japanese, British, Australian, Canadian, and Chinese bonds. The reference index used for comparison is obtained using the *ICE All Maturity* indices for the government bonds of the six countries in which the Bank invested.

The carbon indicators of the FX reserve portfolio are calculated on the basis of the holdings at the end of 2020 and 2021, with the GHG emissions as at the end of 2020, similarly to the EUR portfolio. Although currently the Bank of Italy does not have in place an investment strategy based on sustainability criteria for the FX portfolio, its indicators outperform the benchmark (Table 9).

[35] Austria, Belgium, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Slovakia, Slovenia and Spain.

Table 9 Carbon indicators of FX reserves' government bond investments

	Portfolio[a] 31.12.2020	Portfolio[a] 31.12.2021	chg. %	Benchmark[a, b] 31.12.2021
Portfolio emissions *(thousand tCO_2e)*	13,579	14,449	*6.4*	20,146
Carbon footprint *(gCO_2e per USD invested)*	484	464	*−4.2*	647
Carbon intensity *(gCO2e per USD of GDP)*	372	360	*−3.4*	408
WACI *(gCO2e per USD of GDP)*	326	315	*−3.5*	305

Source: based on Edgar, World Bank, ICE
[a]National GHG emissions and GDP (PPP) based on 2020 levels
[b]Index ICE BofAML All Maturity indices

For a better comparison of the environmental sustainability of the government bond portfolios (investment portfolio and FX reserves) vis-à-vis their benchmarks, the analysis has been extended to further environmental indicators:

- energy per unit of GDP (Megajoule, Mj per USD 2011): energy consumed (Mj) divided by 2017 PPP USD GDP;
- Sovereign Warming Potential in the business as usual (BAU) scenario and in the nationally determined contributions (NDCs) (in degrees Celsius): it assesses a country's alignment to a global stabilization goal, based on the country's commitments to reduce its emission profile with current policies (BAS) and considering the NDCs to reduce national emissions, declared by each country as part of the Paris Agreement;
- Environmental Vulnerability Index (EVI): it reflects the extent to which the natural environment of a country is prone to damage and degradation. This index contains indicators on weather and climate, geology, geography, ecosystem resources and services, high winds, dry periods, endemics, frequency of earthquakes, tsunamis, volcanic eruptions, etc.[36] Score thresholds are: below 215 (resilient), above 215 (at risk), above 265 (vulnerable), above 315 (highly vulnerable), and above 365 (extremely vulnerable).

As of 2021, the FX government portfolio shows better indicators than the benchmark (Table 9) as regards total emissions, the carbon footprint and carbon intensity. The latter result is mainly due to the lower exposure to China, one of the most carbon-intensive countries in the world.

The euro government portfolio achieves better results than the benchmark also in other environmental indicators, thanks to the larger exposure to Italy, which is one of the best-performing countries in environmental and energy indicators, except for the EVI.[37] As concerns EVI, both the portfolio and the benchmark are 'extremely vulnerable' (Fig. 8).

[36]This variable is provided by MSCI ESG Research LLC.

[37]This variable includes seismic risk, which, though very significant for Italy, is not related to climate change.

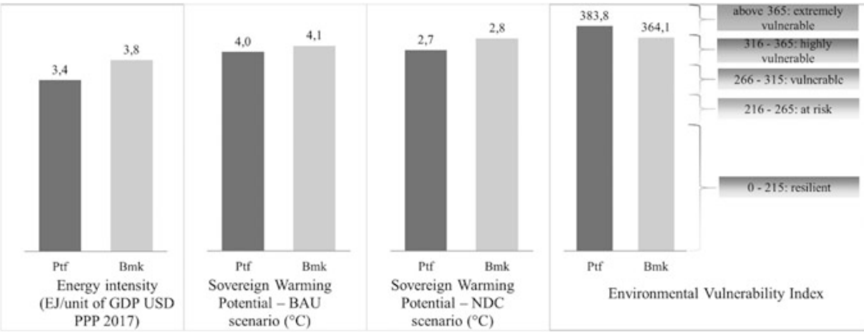

Fig. 8 Environmental and energy sustainability of the Bank of Italy euro government bond portfolio (portfolio data as of 31.12.2021). (Source: based on ICE, BP, MSCI ESG Research LLC and World Bank as of 2021)

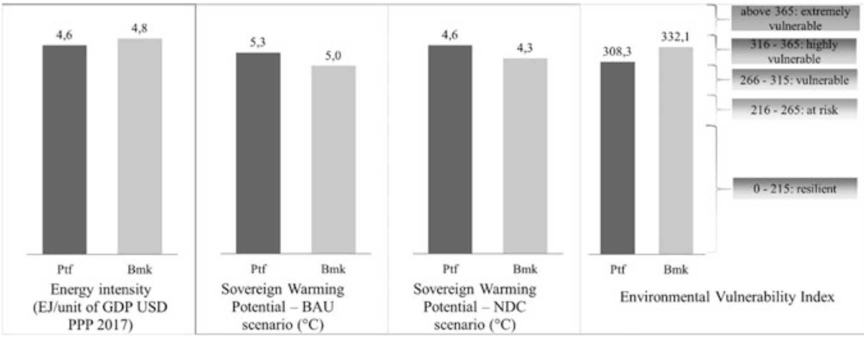

Fig. 9 Environmental and energy sustainability of the Bank of Italy FX government bond portfolio (portfolio data as of 31.12.2021). (Source: based on ICE, BP, MSCI ESG Research LLC and World Bank as of 2021)

The FX portfolio underperforms the benchmark in terms of sovereign warming potential (Fig. 9). This result is explained by the higher exposure of the portfolio to the USA, a country that has a worse indicator in a global comparison. As concerns EVI, the portfolio qualifies as 'vulnerable', while the benchmark is 'highly vulnerable'

To obtain a forward-looking indicator for the government bond portfolios, we carried out a comparative analysis of the energy mix employed for the total energy supply in the nations whose government bonds are held by the Bank (in euro and in foreign currencies, separately), weighted by their share in the portfolio. Specifically, we compare the current total energy supply mix with the one compatible with a temperature increase within two degrees, according to the International Energy Agency scenarios for 2030 and 2040 (IEA 2020). The difference between the euro government portfolio and the IEA projections is primarily due to the high percentage of natural gas in the portfolio (Fig. 10). This is a consequence of the large exposure

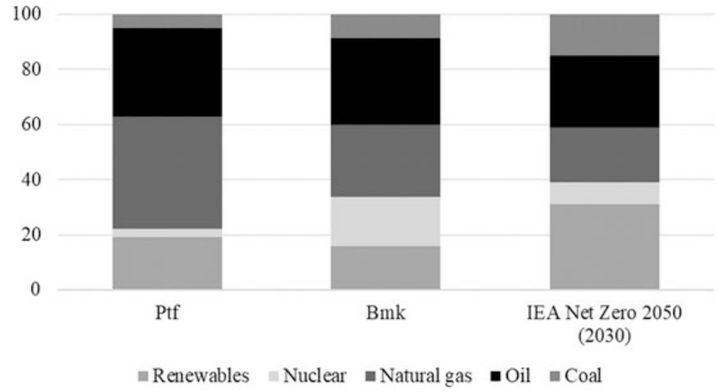

Fig. 10 Share of sources for energy supply: euro government bond portfolio vs IEA projections (portfolio data as of 31.12.2021; percentage values). (Source: based on IEA as of 2021)

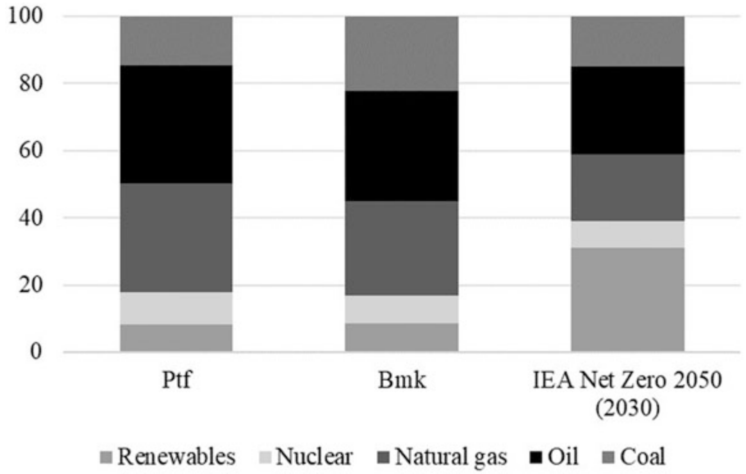

Fig. 11 Share of sources for energy supply: FX government bond portfolio vs IEA projections (portfolio data as of 31.12.2021; percentage values). (Source: based on IEA as of 2021)

to Italy, which makes a large use of gas power plants. These are more efficient in terms of units of energy produced than other fossil fuels; in turn, this explains the relatively high efficiency of the Italian energy system. Finally, Italy is also one of the countries with the largest share of renewable energy sources employed in the total energy supply mix.

The FX government portfolio has a lower share of high carbon-intensive fossil fuels, such as coal, thanks to a lower weight of Chinese and Japanese bonds; the higher share of natural gas is due to a larger government bond exposure to the USA and Canada (Fig. 11).

5.3 Corporate Sector Securities

Corporate sector securities in the investment portfolio, excluding US and Japanese stocks, had a value of EUR 16.9 billion at the end of 2021. We computed carbon and climate indicators for all corporate sector securities (Table 10) and then separately for equities (Table 11) and for bonds (Table 12).

The indicators are based on the previous year's carbon emissions, revenues and EVIC, in line with the best practices of data providers.

At the end of 2020, the sustainable investment criteria were extended to corporate bonds. The further progress on decarbonization caused a decline of the portfolio GHG emissions in 2021 (−11.2 per cent; Table 10). This change, coupled with the

Table 10 Carbon indicators of corporate securities, investment portfolio

	2020	2021	% chg.
Portfolio emissions *(thousand tCO_2e)*	1717	1525	−11.2
Carbon footprint *(gCO_2e per EUR invested)*	134	91	−32.1
WACI *(gCO_2e per EUR of revenue)*	243	196	−19.3

Source: Based on data from MSCI ESG Research LLC and Bloomberg Finance L.P.

Table 11 Carbon indicators of equity investments

	Portfolio 2020	Portfolio 2021	Benchmark 2021	Δ% Port 2021—Bench	Δ% Port 2021–2020
Portfolio emissions *(thousand tCO_2e)*	1664	1471	2346	−37.3	−11,6
Carbon footprint *(gCO_2e per EUR invested)*	137	92	146	−37.0	−32.8
WACI *(gCO_2e per EUR of revenue)*	251	199	261	−23.8	−20.7

Source: Based on data from MSCI ESG Research LLC

Table 12 Carbon indicators of EUR corporate bond investments

	Portfolio 2020	Portfolio 2021	Benchmark 2021[a]	Δ% Port 2021—Bench	Δ% Port 2021–2020
Portfolio emissions *(thousand tCO_2e)*	52	54	53	2	4
Carbon footprint *(gCO_2e per EUR invested)*	70	79	83	−5	13
WACI *(gCO_2e per EUR of revenue)*	118	138	162	−15	17

Source: Based on data from MSCI ESG Research LLC
[a]ICE BofA AAA-A Euro non-financial

size increase of the equity portfolio (+33.2 per cent, Table 7), mainly due to market value appreciation, led the carbon footprint to decrease further (−32.1 percent) to a very low level. WACI also decreased (−19.3 per cent), showing a progressive shift of the portfolio towards carbon-efficient companies.

To analyze the drivers of the improvements, we broke down the results by asset class. The reduction of the carbon footprint and WACI was larger for corporate bonds, for which 2020 was the first year of adoption of sustainability criteria, 1 year after the equity portfolio. Furthermore, the carbon emission indicators are better for the bonds than for equities; this is partly explained by the lower exposure of the former to carbon-intensive sectors.

The Bank's **direct equity investments**, i.e. those managed internally without making use of collective investment instruments, consist of two portfolios, one of Italian stocks and one of stocks of other euro area countries (see Chap. "The Strategic Allocation and Sustainability of Central Bank Investments"). In 2021, the equity investments overall showed a significant improvement in the carbon emission indicators; these were also much better than those for the benchmark indices (Table 11).

In 2021, the absolute GHG emissions of the equity portfolios were 37.3 per cent lower than the benchmark. Compared with the 2020 portfolio, absolute emissions decreased by 11.6 mainly as a result of divestments from companies with high GHG emissions and the general decrease of the companies' absolute emissions. WACI also decreased compared to both the benchmark (−23.8 per cent) and the 2020 portfolio (−20.7 per cent) owing to the investment strategy aimed at favouring companies with lower carbon intensity.

The direct investments in **corporate bonds** of the Bank are managed internally and consist in the portfolio of EUR bonds. The portfolio management aims at the replication of bond indices; these are adapted to exclude, as for equities, bond issuers from the financial sector and the Italian media. Since 2020, the management of corporate bonds has been integrated with ESG criteria; as for the equity investments, the companies dealing with controversial activities are excluded and the companies with the best ESG profile are preferred.

In 2021, bond investments show overall an environmental sustainability profile, measured with the indicators listed in Sect. 4, better than the market index (except for portfolio emissions) and worse than the 2020 portfolio (Table 12).

The comparison with a market index and not with the one actually used—which already integrates ESG criteria—enables us to analyze the differences in transitioning from a traditional management to one that considers ESG profiles.

To identify the drivers of the increase in the carbon footprint, the sectoral distributions of carbon indicators at the end of 2020 and 2021 for the portfolio are compared with the respective market benchmark (Fig. 12). While there is a significant difference for the Utilities sector, which has a very low weight in the 2021 portfolio, the increase in the portfolio's carbon footprint in 2021 mainly depends on the sharp rise of the indicator for the Energy sector, in which the portfolio is overweighted.

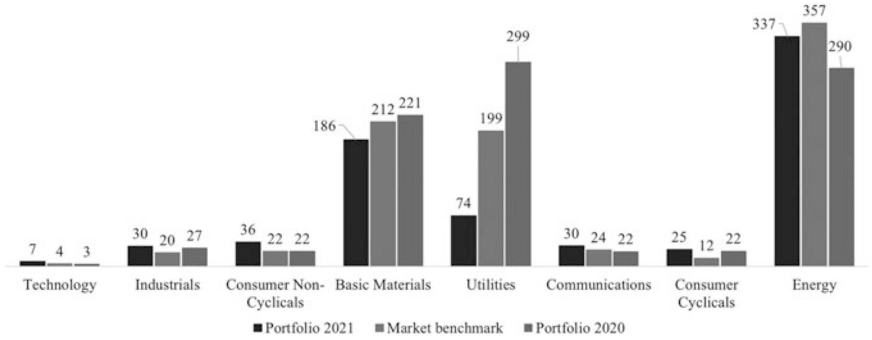

Fig. 12 Sectorial carbon footprint of corporate bonds (grams of CO_2e per EUR invested). (Source: Based on data from MSCI ESG Research LLC)

6 Conclusions

This chapter contributes to the ongoing debate on the selection and use of indicators for the measurement of climate risk exposure, offering a review of the indicators available for different categories of financial assets (equities, corporate bonds, and government bonds). Although the array of comparable indicators is still limited, the chapter shows how investors can measure and manage climate risks using public information that is little explored yet, although it is systematically used by private data providers in their sustainability assessments.

Public sources are very useful for government bond valuation and can be complemented by additional data from specialized providers. For a forward-looking analysis of countries' climate risks, we emphasize the usefulness of combining historical data with the government commitments and the scenarios developed by the NGFS. Due to the limitations in the data for climate-related physical risk assessment, the analysis only marginally investigates this topic (through the environmental vulnerability index).

For private sector companies, we find quite a wide coverage and correlation among the carbon emission data of the leading providers; this evidence supports the idea that such data can be integrated into financial models. The divergence in the data for other environmental indicators (e.g. the use of energy and water, waste management) across different providers remains significant. The joint use of data from different providers can thus contribute to achieving a broad coverage of the investment universe and to identifying potential data anomalies.

The chapter also addresses the methodological issues for measuring the indicators at portfolio level and shows a practical application to the Bank of Italy's financial investments in euros and in foreign exchange reserves. The analysis shows a significant reduction of the exposure to the climate and environmental risks of the Bank's investments, obtained by means of the integration of ESG principles into the strategies adopted for the management of financial portfolios not related to monetary policy. After the integration of ESG criteria into the equity portfolio in 2019, the scope of sustainable investment criteria was further extended in 2020 to equity investments carried out through collective instruments in the United States and Japan and to bond portfolios, which include green bonds issued by private sector companies, supranational bodies, and agencies to finance projects with environmental sustainability features.

In February 2021, the Eurosystem agreed on a common stance for the disclosure by central banks, starting from 2023, of risk measures for investment portfolios not related to monetary policy. In addition, the Eurosystem is currently carrying out an analysis on the implications of climate-related risks as part of the review of its monetary policy strategy; the first results were published last September.

In July 2021, the Bank of Italy published its Responsible Investment Charter to set out its vision of sustainable finance, to communicate the core principles inspiring the management of financial investments and to draw the lines of action to improve its own sustainable investments, thus leading by example the financial system.

In March 2023, the Bank published the second annual Report on sustainable investments and climate-related risks.

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Glossary and Abbreviations

ABS	Asset-Backed Security
ABSPP	Asset-Backed Securities Purchase Programme
AH	After Haircuts
APP	Asset Purchase Programme
BH	Before Haircuts
BV	Book Value
Carbon footprint/intensity	It is the ratio of the greenhouse gas emissions caused by a product, service, organization, event, or individual, generally expressed in tons of CO_2 equivalent (i.e. taking as a reference for all greenhouse gases the effect associated with CO_2, assumed equal to unity) and the value of the related investments (value of the company, including the equity and debt capital). When GHGs are divided by turnover, the ratio is referred to as carbon intensity
CBI	Climate Bond Initiative
CBPP	Covered Bond Purchase Programme
CDS	Credit Default Swap
CDS-I-EDF	CDS-Implied-EDF
CISS	Composite Indicator of Systemic Stress
CO_2	Carbon dioxide
CQS	Credit Quality Step
CSDB	Centralized Securities Data Base of the European Central Bank
CSPP	Corporate Sector Purchase Programme
CSRD	Corporate Sustainability Reporting Directive
EAD	Exposure-at-Default
ECAF	Eurosystem Credit Assessment Framework
ECB	European Central Bank
EDF	Expected Default Frequency

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ES99	Expected Shortfall at 99 per cent confidence level
ESG	Acronym of the *environmental, social and governance* dimensions of corporate practices not closely related to economic and financial practices
ESG score	It is the summary judgment expressed on a scale of letters or numbers by an independent party on the environmental, social and governance profiles of an issuer, a financial instrument or an investment fund. The assessment, in its broadest sense, takes into account exposure to ESG risks and the ability of the assessed entity to manage them and seize any opportunities. It differs from the traditional rating, which assesses the creditworthiness of a company based on its economic and financial variables
EU	European Union
EUREP	Eurosystem repo facility for non-euro area central banks
FSB	Financial Stability Board
FV	Face Value
GC	Governing Council of the European Central Bank
GHGs	Acronym of *greenhouse gases*, i.e. gases considered in the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the so-called F-gases (hydrofluorocarbons and perfluorocarbons) and sulphur hexafluoride (SF_6). These gases are able to retain the heat produced by solar radiation on the earth's surface and prevent it from being dispersed into the atmosphere, resulting in an increase in the average temperature of the earth's surface
ICAS	In-House Credit Assessment System
IMF	International Monetary Fund
IRB	Internal Rating Based (models)
KMV	Moody's proprietary model, originally developed by Kealhofer, McQuown, and Vasicek
LGD	Loss Given Default
ML	Machine Learning
NCB	National Central Bank (member of the Eurosystem)
NCR	National Credit Register
NGFS	Network for Greening the Financial System
NMPP	Non-Monetary Policy Portfolio
OMO	Open Market Operation
OMT	Outright Monetary Transactions
PD	Probability of Default
PELTRO	Pandemic Emergency Longer-Term Refinancing Operations
PEPP	Pandemic Emergency Purchase Programme
PIT	Point-In-Time
ELA	Emergency Liquidity Assistance

PSPP	Public Sector Purchase Programme
RR	Recovery Rate
SIO	Scorecard-Indicated Outcome (an intermediate rating provided by Moody's)
SMP	Securities Market Programme
SAA	Strategic Asset Allocation
TCFD	Task force on climate-related financial disclosures, promoted by the Financial Stability Board and established in 2015 by the private sector to develop a broad and flexible framework for the disclosure by companies and investors of information on exposure to sources of climate-related financial risks. In 2017, the TCFD developed recommendations for the disclosure of information covering four areas of interest: corporate governance, strategy, risk management, and indicators/targets related to climate risks
TLTRO	Targeted Longer-Term Refinancing Operations
TTC	Through-The-Cycle
UNPRI	United Nations Principles of Responsible Investments
UP	Unconventional Policies
VLTRO	Very Long-Term Refinancing Operations
WACI	The *weighted average carbon intensity* is a portfolio indicator computed as the average carbon intensity of the issuers weighted by the security weights in the portfolio, at market values