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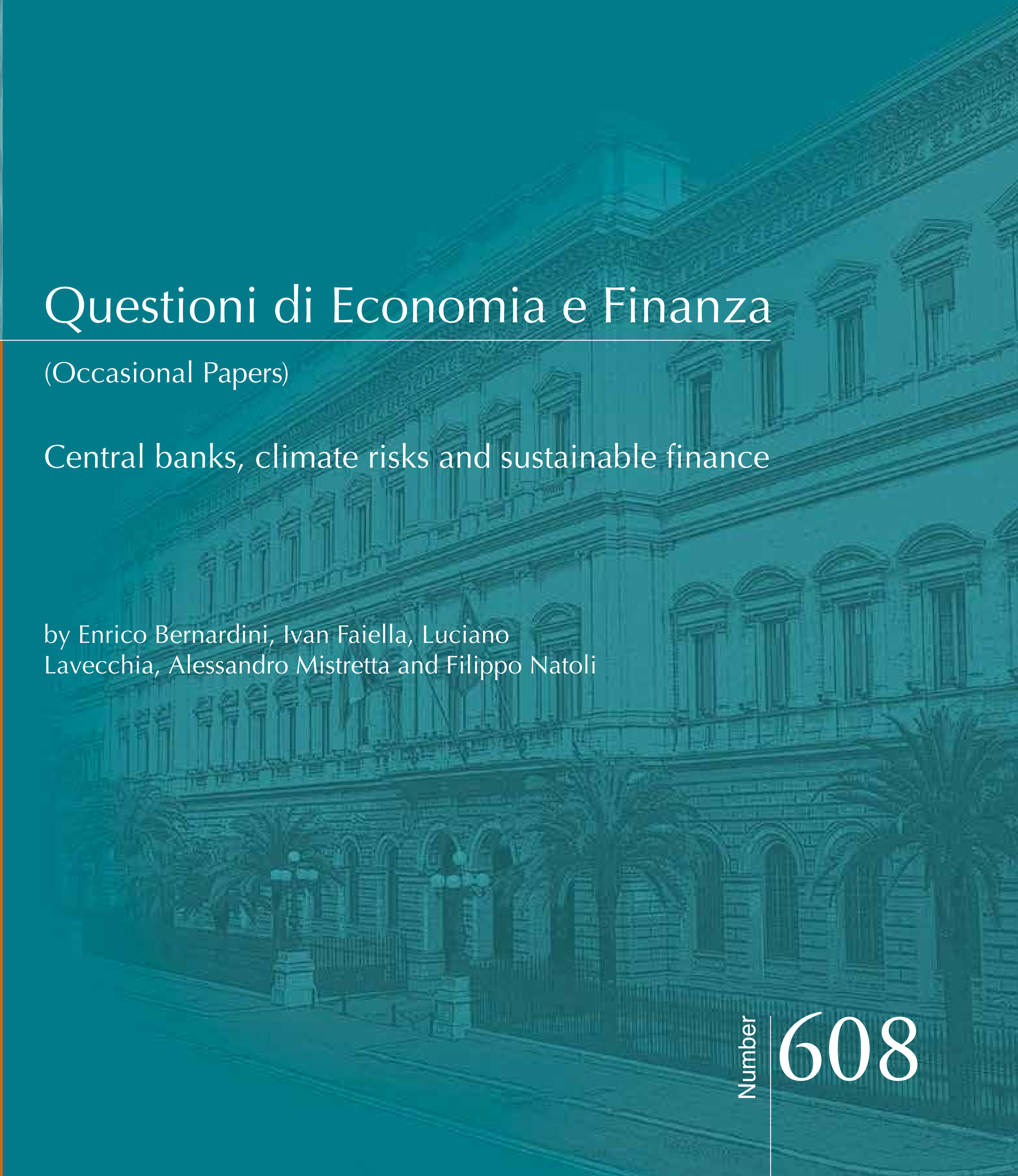

Questioni di Economia e Finanza

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CENTRAL BANKS, CLIMATE RISKS AND SUSTAINABLE FINANCE

by Enrico Bernardini°, Ivan Faiella*, Luciano Lavecchia*,
Alessandro Mistretta* and Filippo Natoli*

Abstract

In the last few years, the climate changes under way and the transition towards a sustainable economic development model have become of great importance for the financial system, involving central banks as well. The latter, whose interest is demonstrated by the work of the Network for Greening the Financial System (NFGS), are taking on the challenges posed by these events as part of their institutional and investment activities. By means of internal study projects and by taking part in the most important round tables at national and international level, the Bank of Italy is helping to analyse the risks that climate change creates for the economic and financial system. In addition, and in line with the recent developments in sustainable finance, it has also integrated sustainability criteria into its investment decisions. This paper aims to give an account of the evidence collected so far on the risks and opportunities linked to climate change and sustainable finance, highlighting what has already been done and what else can be done to put these issues on the agenda of central banks.

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° Banca d'Italia, Markets and Payment Systems

* Economics, Statistics and Research.

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1. Introduction *

The attention on the economic impact of climate change is now very high. The most up-to-date scenarios point to a further rise in global temperatures over the course of the 21st century, with effects on the frequency and intensity of extreme natural events and serious implications for human health and the ecosystems. The link between human activity and climate change highlights the need to recast global economic development to make it sustainable, starting from the gradual phasing out of fossil fuels, which have so far guaranteed unprecedented prosperity.

Economic activity is both a cause and a victim of climate change. It is a cause due to the use of energy generated from fossil fuels: energy combustion generates three quarters of greenhouse gas emissions, which contribute to the increasing trend in global temperatures. At the same time, climate change affects human activity: ever rising temperatures, with sharper fluctuations, are having a growing impact on all activities, starting from those – such as agriculture – most exposed to natural events; more frequent and intense hydrogeological events and heat waves can cause significant economic damage, and the gradual rise in sea levels endangers coastal communities all over the world.

The agreement reached at international level and enshrined in the Paris Agreement in 2015 calls for a rapid decarbonization process aimed at reducing human interference with natural processes and mitigating its consequences, limiting the temperature rise to 1.5-2°C compared with pre-industrial levels. The commitments made by the various countries in this respect appear largely insufficient and will be reviewed during the 26th UN Climate Change Conference of the Parties (COP26).[1]

Furthermore, the **process of reconverting the economic system to make it more sustainable is not immediate, also because of the global scale of the endeavor, and is exposed to several uncertainty factors.** Therefore, to understand what road to take, it is necessary to analyze the impact that climate change has on the economy and to quantify the risks that could emerge – including in the short term – in the event of a disorderly transition to a low-carbon economy. **Physical risks**, defined as those linked to future climate events, are compounded by the risks stemming from the transition itself for those sectors and those economies that will find it most difficult to adapt to the new paradigm based on the marginalization of fossil sources. The latter are known as **transition risks**, and will be greater the longer the transition is not managed properly and will result from untimely and uncoordinated decisions at international level.

In recent years, the international community has shown a growing commitment to dealing with climate change. This has provided a major boost to the analysis of the related economic risks, also eliciting great interest in the financial sector: environmental, social, and governance (ESG) scores, which for years have been computed by specialized providers for listed companies, have

* We are indebted for their useful comments: Matteo Alpino, Pietro Catte, Francesco Ciampi, Alessio De Vincenzo, Paolo Del Giovane, Antonio Di Cesare, Johnny Di Giampaolo, Marco Fanari, Patrizia Ferrauto, Eugenio Gaiotti, Gioia Guarini, Aviram Levy, Raffaele Loffredo, Pietro Maggio, Tommaso Perez and Roberta Zizza. Superb language assistance has been provided by Elizabeth Mary Bevan, Steven Fioco and Jennifer Ann Parkinson.

[1] The Conference of the Parties (COP) is an annual conference organized by the United Nations Framework Convention on Climate Change (UNFCCC), which was established following the Rio de Janeiro Earth Summit of 1992. The COP has convened every year since 1992 except 2020, owing to the pandemic. Among the most significant were the COP3 held in Kyoto in 1997 and the COP21 that took place in Paris in 2015.

started to be carefully considered by investors, together with the economic and financial characteristics of firms. In the last few years, sustainable finance has grown significantly, and is now a market trend in its own right. This stance, which is potentially beneficial also with a view to stimulating reconversion towards a green economy, is not without risks. The first is 'greenwashing', i.e. a situation in which investors fund activities that only appear to be sustainable on the surface. This risk is increased by the lack of a comprehensive and universally accepted taxonomy of sustainable activities.

The economic and financial aspects of climate change, and of sustainability in general, call for the involvement of central banks. Indeed, going forward, their ability to achieve their institutional goals could be more and more affected by the consequences of climate change for the economy.

Monetary policy is among the activities that could undergo change. By modifying the prices of energy products and their share in the goods' price basket, climate policies could impact the inflation rate, the main target variable of monetary policy. Moreover, more intense and frequent adverse weather events could affect the business cycle and, consequently, the conduct of monetary policy. In addition to this, by damaging firms and banks, these events could interfere with the transmission of monetary impulses to the economy, e.g. via the credit channel. In the longer term, a gradual rise in temperatures could affect productivity, thereby impacting potential output.

In several jurisdictions, including Italy, central banks also take on the role of the supervisory authority for credit institutions and for the financial system as a whole. Ever more intense adverse weather events, which can affect several geographical areas and numerous economic sectors, reduce the scope for financial intermediaries to diversify their risks and can propagate across the financial system, undermining its stability. Meanwhile, a disorderly transition could generate widespread losses among financial intermediaries through their exposure to carbon-intensive sectors, with possible systemic effects. Moreover, as the central bank is itself an investor, its portfolios could incur losses if the financial risks connected to climate change are not managed carefully.

The central banks of the major world economies have started to invest intellectual capacity and resources in the study of climate change and its manifold implications. The widespread interest in this topic led to the creation of the international Network for Greening the Financial System (NGFS), which coordinates analysis in this sphere based on common objectives and lines of action. Besides participating in the work of the NGFS, the Bank of Italy has taken on these challenges by integrating them into its many activities. By conducting internal studies and taking part in the main working tables at national and international level, the Bank actively contributes to the analysis of the risks that climate change implies for the economy and for the financial system. Furthermore, in line with the recent developments in sustainable finance, it has also begun to integrate sustainability criteria into its investment decisions.

The strong interest of central banks, together with their role and experience in analysis and in economic policy, has prompted a debate about whether they should be more closely involved in the fight against climate change. In particular, discussion is underway on the possibility of widening the scope of action to stimulate, via the policy instruments currently available, the transition towards a low-emissions economy. This would considerably alter the tasks of a central bank. On the one hand, a proactive approach on their part would contribute to reducing the climate change risks for the economy and, in turn, for their institutional activity. On the other hand, measures intended to counter climate change, such as purchases of specific categories of "green assets", could be outside their institutional goals. To assess these effects, in 2019, the ECB decided that one of the issues on which it would focus as part of its strategy review would be climate change. The possibility, as well as the need, to include the fight against climate change among the actions of a central bank, while at the same time preserving its traditional tasks, will remain a central question in the economic debate in the coming years.

Central banks have the possibility of playing a key role in countering the negative impact of climate change. Indeed, the study and quantification of these risks can benefit the community at large. As investors, central banks can serve as an example for other institutions and for the public by adopting investment policies that are consistent with the decarbonization objectives and by raising savers' awareness through financial education programmes that include sustainability issues.

2. The impact of climate change on the Italian economy

Climate change is already having an impact in Italy with a growing shift away from historical temperature and rainfall patterns. According to the available scenarios, which describe the various possible evolutions in the concentration of greenhouse gas emissions in the atmosphere, this trend will continue and be accompanied by the intensification of extreme weather-events such as floods and heat waves. The effects of climate change on the economy could be significant in the most exposed economic sectors and geographical areas over the next ten years. In aggregate terms, however, the effects are only significant in the event of extreme scenarios; it should be borne in mind, though, that the estimates available are subject to significant limitations in terms of the data and methods used.

Sustainable finance is currently focused on the effects of climate change on Italy's economic system. Nevertheless, it is not always clear how to react to these issues, as we are disoriented by information that is magnified by the media, which fluctuate between overemphasis (where every natural event is linked to climate change[2] or where life on earth will die out in a few years[3]) and a scepticism that undermines the scientific bases with specious arguments. This mechanism has obvious similarities with the current pandemic: 'only draconian measures can save us', or at the other extreme, 'the pandemic is an invention to make us stay at home'.

In order to understand what to reasonably expect from climate change in Italy, we can look at what is happening in the surrounding environment, both because of the worsening weather anomalies and of the greater frequency of extreme climate-related natural episodes, such as hydrogeological events and heat waves.

In the meantime, there is no doubt that the climate is changing in Italy, as it is in the rest of the world: the year 2019 was the third hottest year since records began (ISPRA, 2020), following the record years of 2015 and 2018. The latter was the hottest year in the entire historical series prepared by the Italian Institute for Environmental Protection and Research (ISPRA) since 1961 and, based on studies that reconstruct the history of climate in a more distant past, it was also the hottest year in at least the last two centuries.[4] The year 2017 was characterized by a worsening of climate conditions, with significant droughts in most of Italy and serious consequences for water resources.

What may seem paradoxical is that, despite the increase in temperatures and periods of drought, extreme rainfall is also rising. According to an indicator that measures anomalies in rainfall, 2019 was the eleventh rainiest year since 1961. There has been anomalous rainfall especially in the North, where the fifth highest amount of rainfall since 1961 was recorded in 2019 (ISPRA, 2020).

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[2] The attribution of extreme natural events to climate change is a complex science. A useful Carbon Brief map shows the extent of researchers' knowledge of this topic (https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world).

[3] The Guardian (2018), "We have 12 years to limit climate change catastrophe, warns UN". https://www.theguardian.com/environment/2018/oct/08/global-warming-must-not-exceed-15c-warns-landmark-un-report.

[4] ISPRA press release of 9 November 2018 (http://www.isprambiente.gov.it/files2018/area-stampa/comunicati-stampa/comunicato_stampa_clima_2018.pdf).

Aside from these chronic effects, it is likely that climate change is also at the root of other acute phenomena, such as floods and landslides. By influencing rainfall, climate change can lead to increased hydrogeological risk, to which Italy has long been exposed (ISPRA, 2018). On the other hand, when making these observations, not all phenomena should be seen as depending on climate change.[5]

The weather anomaly indicators can be projected into the future by means of climate scenarios; this allows us to evaluate what to expect under various hypotheses on rising temperatures. Climate scenarios are 'tales' that, based on some assumptions on socioeconomic development and its impact on energy use and greenhouse gas emissions, replicate possible futures in terms of climate (see Box 2.1). The assessments stating that it is necessary to reduce emissions to zero by the middle of this century to stop temperatures rising by more than 2°C, or that not reducing them will lead to a certain loss of GDP, are based on the results of these scenarios.

A key piece of information in these scenarios indicates a certain trajectory in terms of representative concentration pathways (RCPs) and therefore rising temperatures. The trajectory depends on the evolution of emissions: if they continue to increase at a swift pace, then the RCP8.5 scenario will become a reality; in contrast, if emissions reduce drastically, the RCP2.6 scenario is considered. There are two intermediate scenarios between these two extremes: RCP4.5 and RCP6.0.[6]

Box 2.1 Climate scenarios: what can happen from different perspectives

The effects of climate change are assessed by constructing 'tales' about how the climate could evolve in the future. The various tales are climate scenarios and are based on the combination of two elements. One element describes the possible alternative evolutions of a set of economic and social variables (Shared Socioeconomic Pathways - SSPs) that refer to the population, per capita GDP and its distribution, the extent of urbanization and the level of education. The other component assumes an evolution in energy demand and therefore in greenhouse gas emissions, which produces a Representative Concentration Pathway (RCP), with which a number is associated indicating the expected intensity of climate change ('radiative forcing'[1]), linked to human activity and estimated at the end of the century compared with the pre-industrial era.

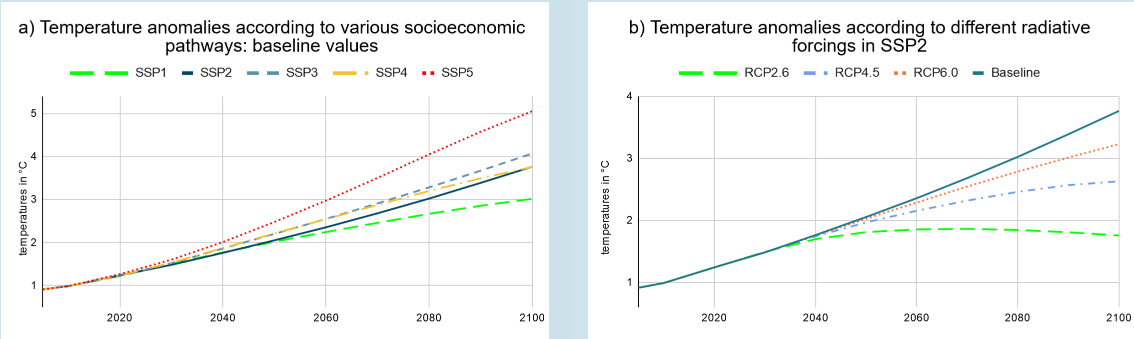
There are five SSPs (Rihani et al., 2017): SSP1, sustainability, taking the green road; SSP2, middle of the road; SSP3, regional rivalry, a rocky road SSP4, inequality, a road divided and SSP5, fossil-fuelled development, taking the highway, where only economic growth counts. The last IPCC Assessment Report (IPCC, 2014) used four RCPsS, numbered according to the change in radiative forcing expected at the end of the century compared with historical figures. RCP2.6, reduction in CO2 emissions; RCP4.5, emissions reach a plateau at the end of the century; RCP6.0, emissions rise slowly; and RCP8.5, emissions continue to increase at a fast pace. The concentration corresponds to a certain increase in temperatures via a ratio known as climate sensitivity.

The scenario is therefore a combination of various possible economic and social pathways (SSPs) and of the evolution of the emissions linked to potentialdevelopments in the energy system (RCPs).

[5] In some cases, this link is based on the misunderstanding that confuses the increase in events with their effects: sometimes the disastrous impact of events is not to be attributed to a higher intensity of natural events but rather to phenomena such as bad urban planning or excessive soil sealing, which magnify their impact.

[6] A higher number indicates a greater intensity in the effects of climate change; see Box 2.1.

Figure A - Temperature anomalies in the SSPs and in the various RCPs



Source: Based on SSP Public Database data (Version 2.0) https://tntcat.iiasa.ac.at/SspDb),

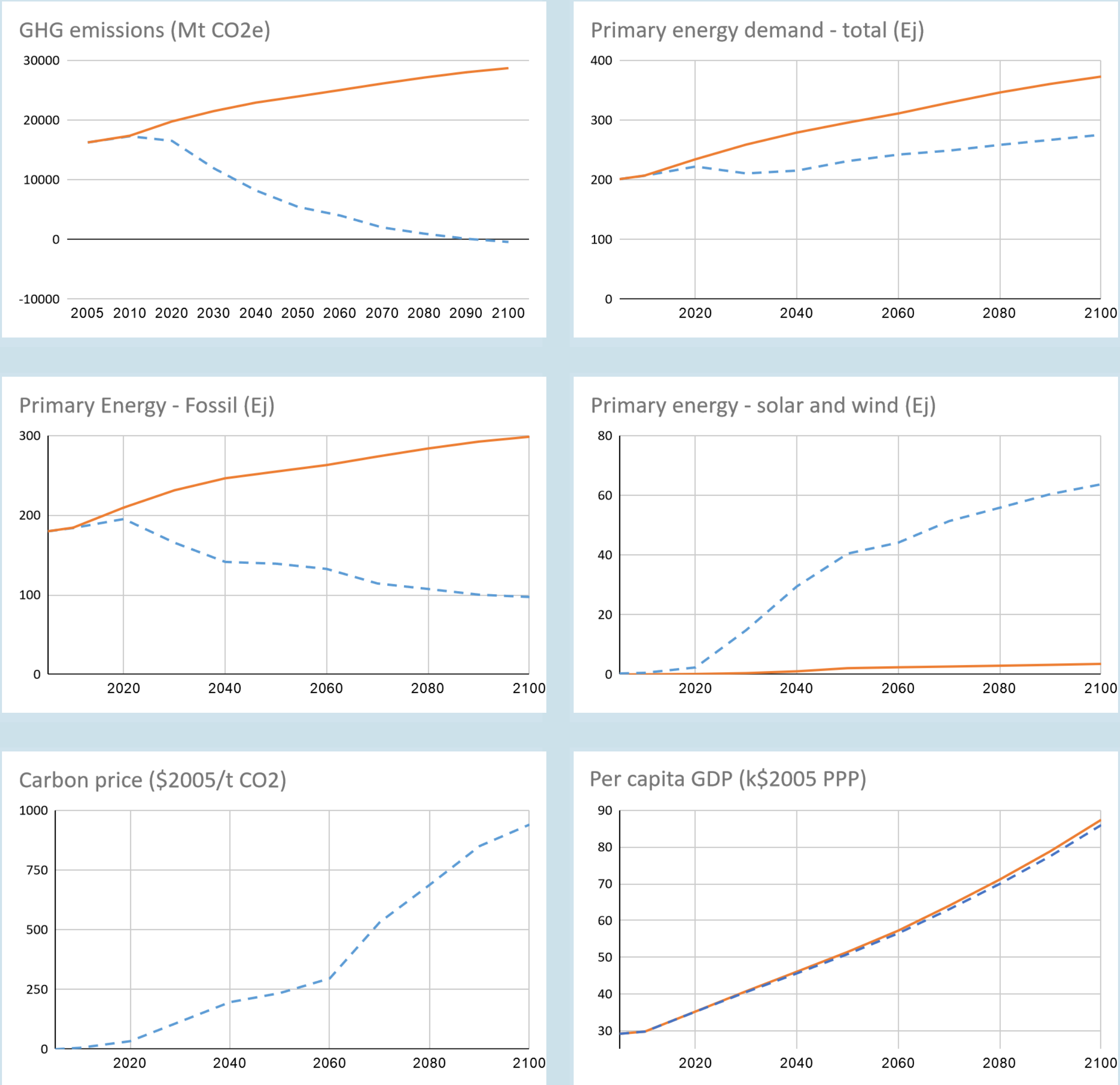
In panel (a) of Figure A, we can see how the various pathways lead to temperature increases that are different at the end of the century in scenarios with no interventions to reduce emissions (baseline scenarios); the shared socioeconomic pathway SSP1 would see the century end with a temperature growth of around 3°C, while SSP5, in which fossil fuels continue to dominate, would lead to an increase of over 5°C. Panel (b) of Figure A shows the expected increases assuming an intermediate pathway (SSP2) but with more or less intense interventions to limit greenhouse gas emissions that lead to four different levels of radiative forcing (and therefore of climate change intensity). The RCP2.6 scenario is the only one with a temperature increase of under 2°C in line with the Paris objective, while in the two intermediate scenarios it is between 2.6 and 3.2°C.

In order to understand how the energy system could change to achieve the Paris objective, it can be assumed that the world will evolve along the SSP2 pathway. There are no specific scenarios available for Italy, so the focus is on what would happen in higher-income countries (those belonging to the OECD area).

The panels in Figure B show what would happen with no interventions to limit climate change (the baseline scenario is represented by the solid orange line) and in a scenario in which mitigation reduces emissions, bringing them to zero before the end of the century (the RCP2.6 scenario is represented by the dotted blue line). This would lead to a reduction in the primary energy demand[7] and a contraction in the fossil fuel component, which would be reduced to one third of the total. The contribution of the renewable component linked to the production of wind and photovoltaic energy would increase at the same pace. This shift in the energy mix from fossil fuels to renewable sources (which assumes intense electrification) would only be possible thanks to policies that put a price on emissions, for example by taxing emissions or making the emissions trading systems stricter. By the end of the century, a price of just under $1,000 per ton of CO_2 would be needed (at 2005 prices), compared with the average current price of around $2 per ton (World Bank, 2020). The transition would result in a different profile for per capita GDP growth, which would be 1.5 per cent lower on average in the event of mitigation for the years 2050-2100.

[7] The primary energy demand measures a country's total energy demand; it is derived from the use of energy products available from natural sources, such as fossil sources before they are processed and renewable sources. Primary energy almost always has to be converted using energy conversion technology to become a fuel that is easier to use, such as the fuels produced by refining crude oil or electrical energy produced by thermoelectric power plants.

Figure B - The evolution of the main variables in the OECD area: a comparison of two scenarios*



*** The solid orange line indicates the baseline (current policies); the dotted blue line indicates a scenario in which emissions are reduced to zero before the end of the century (RCP2.6).**
Source: Our calculations based on SSP Public Database data (Version 2.0) https://tntcat.iiasa.ac.at/SspDb. Simulations of the AIM/CGE model referring to the OECD area. Ej=exajoule, equal to 10^{18} joules. 1. Ej is equal to 23.9 million tons of oil equivalent.

[1] Radiative forcing measures the change in the balance of incoming and outgoing energy in the atmosphere system and is an index of how important a certain factor can be in accelerating climate change. It is measured in Watts per square metre (W/m^2). For further details see https://www.ipcc.ch/site/assets/uploads/2018/03/ar5-wg1-spmitalian.pdf.

These scenarios are used to make projections for some indicators such as the extreme temperature and rainfall indices; the expectations for these indicators make it possible to represent climate and weather extremes and their variations over time (see Box 2.2).

A recent report by the *Centro Euro-Mediterraneo sui Cambiamenti Climatici* (CMCC) shows the possible evolution of some of these indicators in two scenarios, RCP4.5 and RCP8.5 (Spano et al., 2020). The climate models considered when using these two scenarios indicate a temperature increase of up to 2°C in the years 2021-2050 compared with the average for the years 1981-2010. In the RCP8.5 scenario, at the end of the century, summer temperatures in the Alps would be 5°C higher. Rainfall, whose expected effects are more uncertain (see Box 2.2), would decrease in the summer in the Centre and South but would increase in the North. Generally speaking, extreme rainfall would increase.

Box 2.2 The indicators that recount the impact, past and expected, of climate change

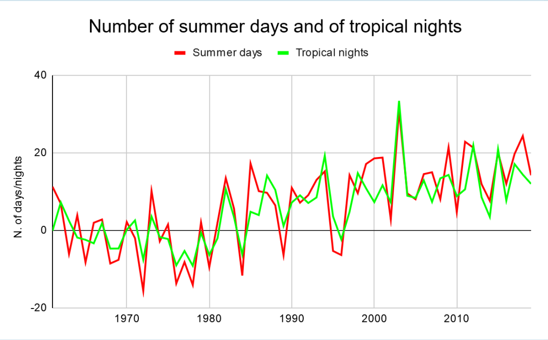
The scenarios outline what happens to the energy system and to some key variables of the economic system under a number of mitigation assumptions (namely policies for reducing emissions), and they can also provide useful information about what happens depending on the incisiveness of such policies. A certain level of greenhouse gas (which varies in the different scenarios) is associated with the frequency and intensity of extreme natural events, such as heat waves and periods of intense rainfall or drought, which have a significant impact on people's lives, health and activities.

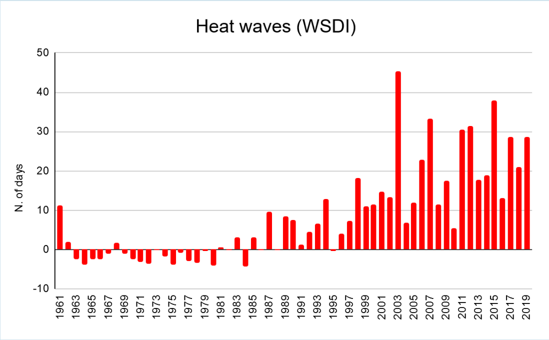
In order to measure weather and climate extremes and their changes over time, which is important information for defining a strategy for adapting to climate change, some indicators can be analysed, such as extreme temperature and rainfall indices. Since rainfall forecasts are more uncertain than those for temperatures, this box only focuses on the latter. Some extreme temperature indices are shown in the following table.

Name and symbol	Description
Tropical nights - TR20	Average number of days per year with a minimum temperature >20°C
Summer days - SU25	Average number of days per year with a maximum temperature >25°C
Warm spell duration index - WSDI	Number of days per year in which the maximum temperature is above the 90th percentile of the respective normal climatological distribution for at least six consecutive days.

In the meantime, we can see the historical trend in these indices for Italy. Figure A shows how, starting from this century, there has been constant growth in both the number of summer days and of tropical nights. The same is true for the indicator that measures heat waves (approximated by prolonged periods of hot weather) that, despite having reached a peak in 2003, has subsequently recorded high values (+29 days in 2019).

Figure A - Warming in Italy according to certain indicators.





Source: Our calculations based on ISPRA data, Yearbook of environmental data 2020.

By using the RCP scenarios, it is possible to evaluate how temperatures and rainfall might evolve if the scenario that keeps greenhouse gas emissions low at the end of the century occurs (RCP2.6), compared with a scenario in which they increase further (RCP4.5).

In Italy, the average increase in temperatures would stop at 1°C for the RCP2.6 scenario (Spano et al., 2020), while it would rise to 1.8 and 3.1°C in the RCP4.5 scenario (ISPRA, 2015). In the RCP4.5 scenario, heat waves continue to increase, as do tropical nights and summer days. For the reference

period 2061-2090, an average national increase in tropical nights (TR20) of between 14 and 35 days is forecast, in summer days (SU25) of between 19 and 35 days and in the WSDI of between 30 and 93 days (ISPRA, 2015).
The average increases in temperature and the greater frequency of heat waves may specially affect large city centres (forming heat islands) with negative effects on fire risks, on the quality and availability of water resources and on ecosystems. They may also impact air quality (increasing tropospheric ozone pollution), with repercussions for the health of the most fragile, and may increase the transmission of infectious diseases. In addition, they result in greater demand for energy for cooling purposes, at the same time reducing productivity in the use of various production factors, such as labour and cultivated land. However, they could also affect the energy supply: bearing in mind that hydroelectricity represents more than one fifth of installed electricity capacity, periods of low rainfall may significantly reduce the contribution of this resource, which supplies energy at very low cost.
Simulations of the future effects of climate change agree more on the upward trend in temperatures than on rainfall anomalies, as is clearly explained on the Carbon Brief website (https://www.carbonbrief.org/explainer-what-climate-models-tell-us-about-future-rainfall). More caution is therefore required for rainfall anomalies, to which the forecast of greater hydrogeological risk for Italy is linked.
Finally, when an economic value is given to these effects (for example in terms of the statistical value of a life in order to evaluate excess mortality), it is possible to construct a damage function that 'translates' the physical effects of climate change (measured by simulating indicators as seen previously) into monetary losses.

Changes in these indicators may in turn be associated with effects on the economic system, which could have a profound impact on economies and on people's wellbeing, especially in countries such as Italy, which are located in southern Europe.[8]

Weather anomalies can affect wellbeing in both direct and indirect ways. Among the former, there are those affecting labour productivity: the gradual rise in temperature translates into a reduction in labour productivity, and particularly affects sectors where people work outside, such as agriculture and construction. According to some studies, particularly hot days lead to a loss in productivity of more than 22 per cent because of the increase in heat stress (Deryugina and Hsiang, 2014).[9] Furthermore, a prolonged period of hot and humid days increases the number of accidents in the workplace and the likelihood of workers catching vector-borne diseases (Levi M., Kjellstrom and Baldasseroni, 2018).

Rising temperatures also influence individual consumption: the need to ensure a minimum level of comfort in homes during the summer will increase,[10] with a greater share of costs for

[8] The PESETA project, coordinated by the Joint Research Centre, provides a holistic assessment of the future physical and economic impacts of climate change in Europe in the 2071- 2100 period. See Ciscar et al., (2018) and Szewczyk et al. (2020).
[9] According to a recent ILO report (2019), this would lead to a global contraction of 2.2 per cent in working hours in 2030, with an impact on GDP of $2,400 billion.
[10] Under the RCP4.5 and RCP8.5 scenarios, the number of cooling degree days would increase significantly in Italy (CDD, an index associated with the consumption of energy for cooling purposes) (Spinoni et al., 2018). The number of CDDs increased by 33 per cent in Europe in the years 1950–1980 and 1981–2017 (https://www.eea.europa.eu/data-and-maps/indicators/heating-degree-days-2/assessment).

the most vulnerable households;[11] long periods of hot weather also negatively impact the amount of retail purchases made by households ('shopping productivity', Starr-McCluer, 2000).

Finally, the increase in temperatures could in itself lead to a worsening in people's health and an increase in mortality. The most recent assessments estimate that, in the absence of any mitigation policies, there could be 100,000 deaths by 2100 as a direct result of extreme weather events. These effects would be more concentrated in southern Europe, especially in Italy, Spain and France (Szewczyk et al. 2020).

As well as its direct effects on people and their activities, climate change also influences economic activity through the damage caused by extreme weather events occurring in the surrounding environment.

Over the last few years, there has been an increase in both the frequency and intensity of extreme rainfall, the effects of which are magnified by the excessive soil sealing linked to land use and the lack of drainage systems.

This type of acute risk hits horizontally across various economic activities (e.g. all those affected by damaged infrastructures) and is concentrated in a limited area. Looking ahead, these risks, especially hydrological and hydraulic ones, will be greater for northern Italy, where the number of rainy days has increased in recent years; geological risks, however, such as landslides and coastal erosion, are widespread throughout Italy.

Rising temperatures, together with irregular rainfall, influence the availability of water resources: on the one hand, higher temperatures make it easier for snow cover and glaciers to melt, increasing the short-term availability of water in winter; on the other hand, the increase in evapotranspiration could lead to water shortages in the long term, especially in southern Italy. Moreover, climate change will affect not only the quantity but also the quality of water bodies: the alternation of extreme events with long periods of drought encourages the growth of algae and reduces the presence of naturally occurring nutrients in water resources (Spano et al., 2020).

Once the main channels through which climate change influences economic activity have been analysed, if we want to quantify its effects we have to apply methodologies to give an economic value to the effects of such change that stems from the various climate scenarios considered.

One of the methodologies used here is linked to the damage function in which, by using microsector information, the various costs are valued on the assumption that the different weather scenarios considered become a reality. Another approach uses econometric techniques instead for an overall evaluation of the damage expected at macroeconomic level.

A recent study analyses the existing relationship between regional per capita GDP and the average temperature level recorded between 1990 and 2015 (Ronchi, 2019). By using a reduced form model, the authors find an inverted U-shape relationship between these two variables that

[11] See '2° Rapporto sullo stato della povertà energetica in Italia' by the Osservatorio italiano sulla povertà energetica (2nd report on the state of energy poverty in Italy)(OIPE, 2020).

indicates how, at extreme high or low temperatures, a lower per capita GDP level is associated that reaches a maximum at around 11.5 degrees centigrade (identified as an optimal temperature). Using the estimated coefficients, the authors estimate the effects on GDP until 2080 in the event of the RCP8.5 scenario becoming a reality. In this extreme scenario, GDP per capita would fall by 3.7 per cent in 2050 and by 8.5 per cent in 2080. The fall in GDP would be limited or equal to zero for northern Italy, while the South would record a loss of between 5 and 15 per cent of GDP in 2050 that could reach 25 per cent in 2080. Climate change could therefore further increase the regional disparities and inequalities.

There are two types of limits to this approach. The purely statistical nature of the analysis makes it impossible to qualify and quantify the channels that contribute to these results and does not consider possible progress in how technology adapts and changes. One element that suggests particular caution when interpreting the research is the fact that an extreme weather scenario is assumed that, despite being used the most in the economic literature, is recognized as being not very realistic (see Box 2.3). The effects estimated with a scenario compatible with RCP4.5 would be reduced by more than half, a result that is still higher on average than estimates found in other papers.

Box 2.3 An extreme scenario to be used with caution (RCP8.5)

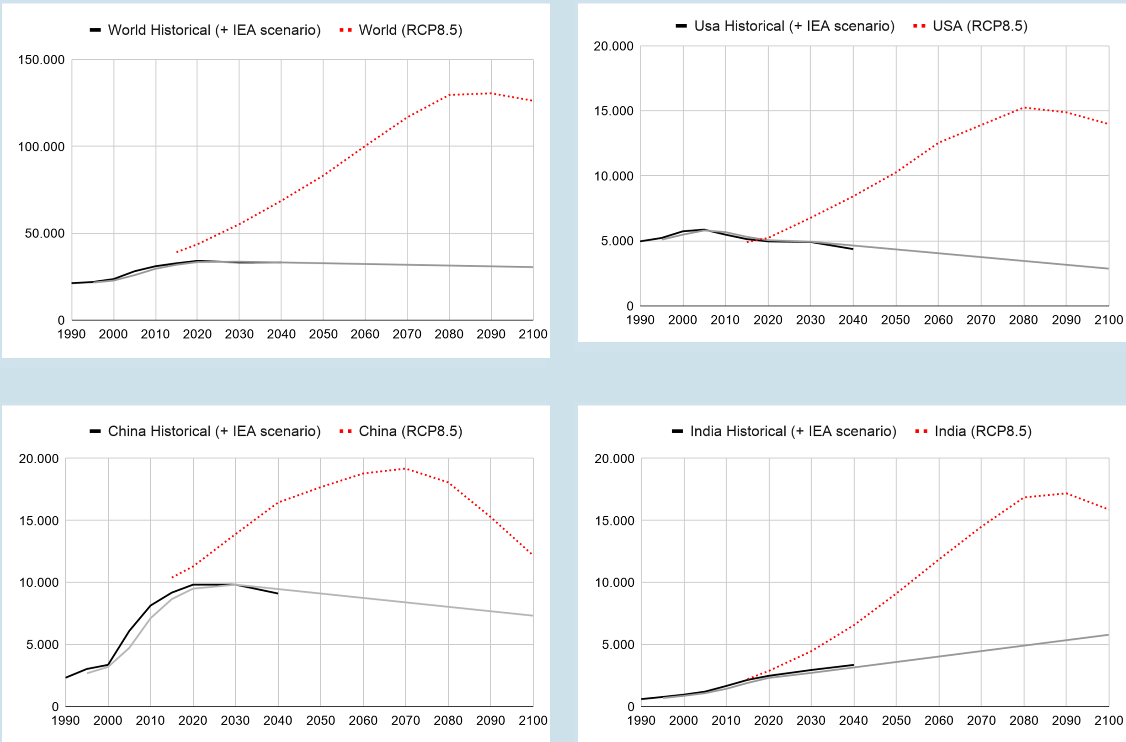
A considerable number of studies on the expected impact of climate change use the RCP8.5 scenario. This is often defined as the business as usual (BAU) scenario, suggesting that it would occur if no efforts were made to reduce greenhouse gas emissions, and it has been used in thousands of papers (Pielke and Ritchie, 2020). Some important papers that use it as a BAU scenario find that climate change at the end of the century:

1. between 5 and 43 per cent of countries, according to different growth assumptions, would have a lower per capita income in 2100 than today (Burke et al., 2015);
2. will shrink the income of the poorest third of US counties by between 2 and 20 per cent (Hsiang et al., 2017);
3. more banks will fail (+26/+248 per cent) with costs for bailing them out of between 5 and 15 per cent of GDP in the year that would lead to the debt-to-GDP ratio doubling (Lamperti et al., 2019).

However, the use of RCP8.5 as a BAU scenario is not what its creators suggest (Rihani et al., 2011), as they indicate that no probability or preference is assigned to the modelled scenarios. Furthermore, some recent studies underline how the assumptions underlying the RCP8.5 scenario are completely unrealistic (Hausfather and Peters, 2020) and suggest not using it even as the least favourable scenario. For these reasons, this scenario is not used by the sixth IPCC report, to be published in 2022, or by the scenarios of the Network for Greening the Financial System (see Box 6.1). The trend in emissions assumed in the RCP8.5 scenario is actually based on an unprecedented increase in the use of coal, which is even greater than its actual availability (Ritchie and Dowlatabadi, 2017).

The left-hand panel of Figure A overlaps the historical trend of global emissions with those predicted by the RCP8.5 scenario. Global emissions linked to energy use amounted to 34.2 billion tons of CO2 in 2019; bearing in mind the values of the baseline scenario of the International Energy Agency for 2030 and 2040, in which only current policies are applied (Stated policies scenario - IEA, 2020a), the extrapolated emissions would be just below this figure in 2100. In contrast, according to the RCP8.5 scenario, emissions would exceed 126 billion tons at the end of the century.

Figure A - Historical and projected emissions trends in the RCP8.5 scenario
(Million tons of CO2)



Sources: Our calculations based on data from the SSP Public Database (Version 2.0) https://tntcat.iiasa.ac.at/SspDb, the BP Statistical Review 2020 and IEA (2020). The values of the IEA's Stated policies scenario (2020) are added to the historical data (BP source) for 2030 and 2040. The RCP8.5 scenario uses the values of the REMIND-MAGPIE - SSP5-85.model.

The fragility of the assumptions in the RCP8.5 scenario is even more obvious if we look at the evolution in individual countries. In the United States (second panel of Figure A), in 2019, emissions totalled just under 5 billion tons, with a lower projected figure for the end of the century of around 3 billion tons, taking account of the IEA scenario. In the RCP8.5 scenario, the USA would reach a total of almost 14 billion tons of CO2 emissions (1.4 timesChina's emissions in 2019).
The last two panels of Figure A show the same evaluations for China and India: in this case too, the emissions trend in the RCP8.5 scenario is largely incongruous compared with the historical values and with the IEA's Stated policies scenario.

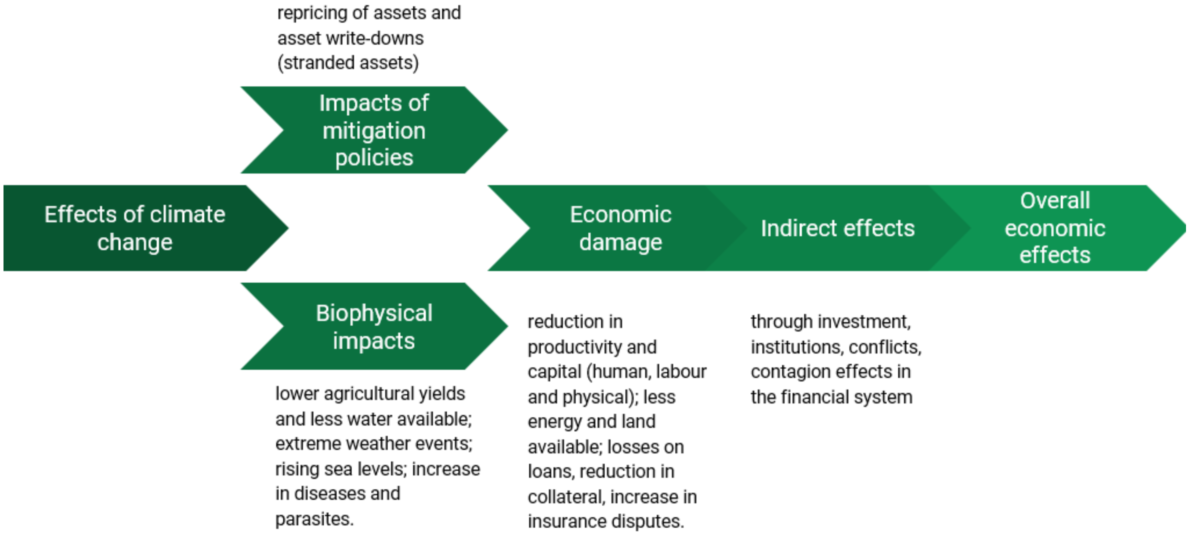
Other studies, which use general economic equilibrium models, propose a more modest estimate of the impact. Carraro et al. (2008) estimate a cumulative loss for Italy in 2050 of between 0.12 per cent, in the event of an increase in temperatures compatible with an RCP2.6 scenario, and 0.2 per cent of GDP, in the event of an RCP4.5 scenario (with a lower discount rate this would be 0.36 per cent).[12]

More recent estimates (Feyen et al., 2020), based on a model that considers various sectors and countries, indicate economic losses connected with global warming in southern European regions of less than 1 per cent of GDP in the event of an increase of 1.5°C by 2030. Losses would rise to just over 1 per cent and just under 3 per cent in the event of scenarios that

[12] Estimates based on the 'evaluation approach' underestimate the overall effects of climate change. They only partly take account of extreme events and do not capture catastrophic events. Furthermore, when its effects on GDP are considered, the effects on stock-related variables are not included (e.g. losses in the value of farmland).

envisage temperature increases of 2°C by 2050 and 3°C by 2070. This quantification would mainly be connected to the economic value of the excess mortality linked to climate change. These estimates, in mid-position compared with previous ones, nevertheless underline that the losses could be extremely significant for some sectors, such as agriculture, which could record a reduction in yields of up to around 5 per cent, and energy, which would experience an increase in costs of up to 1 per cent.

Figure 2.1 - The economic effects of climate change



In short, climate change will have a transversal impact on the entire economy in the future, becoming significant, given the production specificities, for some sectors that are characterized by a concentration of risks (Figure 2.1).

Box 2.4 The sectors hardest hit by climate change

One of the activities most affected by climate change is agriculture, which at the same time is one of the sectors responsible for greenhouse gas emissions, accounting for around one eighth of total net emissions. The increase in extreme weather events influences agricultural production, from both a quantitative and qualitative point of view, by destroying crops, encouraging the spread of fungi and parasites and modifying the length of the growing season (e.g. early crops). Agriculture is also exposed to the reduction in water resources caused by rising temperatures, a problem that would hit some specific sectors, such as maize, sunflowers and sugar beets. The European Environment Agency predicts an increase in heat waves and droughts, a reduction in rainfall and biodiversity, lower crop yields and greater risks for farm animals in the Mediterranean area (EEA, 2019). Italy's agriculture seems to be heavily exposed to the repercussions of climate change (Alpino and Lavecchia, 2020). The available empirical analyses estimate a general decline in the quantity and quality of food production and of farming in Italy, with a loss that appears to be high compared with other EU and Mediterranean countries, also in the event of moderate emission scenarios (Bozzola et al., 2018).
If we consider a high-emission scenario (RCP 8.5 - see Box 2.3), Italy would experience a drop in income from the agricultural sector (including farming) of about 10 or 40 per cent in 2050, depending on the presence (or absence) of the CO_2 fertilization effect, with significant variations at regional level (Perez Dominguez and Fellmann, 2018). Maize crop yields in Italy could fall by up to 25 per cent and fruit farming would record marked decreases, especially in the South (-50 per cent; Hristov et al. 2020). Climate change would also affect tree crops (such as olive groves, vineyards and so on), which would see a reduction in their life cycle and productivity. Specifically, there would be a decline in the yields of spring-summer cycle crops, such as maize, sunflowers and soya and a potentially positive effect on

crops such as wheat, rice and barley. A qualitative and quantitative reduction is expected for wine and olive oil in the South, with a shift to the North or to higher ground (CMCC, 2017). The effects would generally be more negative in the South, where an increase in temperatures would also be accompanied by droughts, with some crops possibly being moved to more northern areas of the country with a relatively fresher climate.

As in the case of agriculture, negative effects are expected for fishing and animal farming, where rising temperatures may affect animals' lives in terms of their growth, reproduction and being more likely to fall ill. The work of farmers in mitigating and adapting to climate change appears limited, while the benefits associated with rising temperatures would be limited to certain areas and crops, with the prevailing impact being largely negative, particularly in the South.

Another sector with a high concentration of risks is tourism. A recent study analysed the channels through which climate change may influence the different types of tourism in Italy (Mariani et al., 2020). Climate variations could make some beach destinations less attractive, above all because of the increase in erosion, leading to a loss of space and infrastructures; the rising temperatures and the greater frequency of heat waves could make this type of tourism less appealing, also because of the increased eutrophication of the Mediterranean. Mountain tourism would also be hit by the higher temperatures: the leading climate models predict a decline in the number of snow days, thereby reducing the amount of natural snow, which could see the present number of ski resorts fall to 75 per cent and, in the event of particularly adverse scenarios, to a third of those currently operating (Abegg et al, 2007). As regards summer Alpine tourism, climate change would of course have a less unfavourable impact. Lastly, there would also be negative effects on cultural tourism, since the conditions of Italy's cultural heritage could be put at risk. Rising temperatures could be magnified in the cities by the scarcity of vegetation, the abundance of reflective surfaces and the density of buildings (heat islands).

Lastly, the electricity sector will have to adapt to these effects, especially because of the growing use of air conditioning systems in the summer (Apadula et al., 2008; Gaudioso et al., 2009). This element, together with the increase in the frequency and intensity of heat waves, could lead to risks of blackouts owing to the system's inability to cope with peak loads (Apadula et al., 2012), which could also stem from the problems that climate change may entail for electricity generation. Thermoelectric plants could also be affected by acute events such as the chronic reduction in the availability of cooling water and specifically by the decreased water supplies that will necessarily have a negative effect on hydroelectric production capacity (about 12 per cent of total electricity production in 2019). However, the impact would be smaller for other renewable sources, such as wind, biomass and photovoltaic (Rademaekers et al., 2011).

3. Decarbonization in Italy

To mitigate ongoing climate change, the international community is committed to reducing the concentration of greenhouse gases in the atmosphere, by converting production processes to a low-emission model. Italy began the process of decarbonization many years ago and it shares, together with the other countries of the European Union, the goal of halving emissions by 2030 and eliminating them by 2050. As in the case of the Lisbon targets for 2020, this process implies higher spending on energy on the part of firms and households. Although Italy reached almost all the 2020 targets ahead of time, the transition process is still marginal and it is linked to the availability of renewable sources in the electricity and heating sectors. The pandemic caused an abrupt reduction in the use of fossil fuels, but this apparent transformation appears to be linked mostly to the temporary reduction in demand for electricity as a result of the contraction in economic activity.

Decarbonizing the economy calls for a reduction in both energy intensity (energy per unit of GDP) and emission intensity (greenhouse gas emissions per unit of energy). The first objective is linked to the increase in energy productivity and the need for policies to increase energy efficiency, while the second can be achieved by employing technologies that reduce our carbon footprint such as the use of renewable sources of energy.

Italy began this transformation together with the other countries of the European Union in 2007, when three different targets were set in the fields of energy and the environment. These were then incorporated into the Europe 2020 plan, i.e. to reduce greenhouse gas emissions by at least 20 per cent compared to 1990 levels; to increase the share of renewable energy sources in final energy consumption to at least 20 per cent; and to increase energy efficiency by 20 per cent (this was a non-binding objective).

The 2030 goals were agreed in the autumn of 2014, as part of the project for the Energy Union, raising the target for the reduction of greenhouse gases to 40 per cent and the share of renewables and the improvement in energy efficiency to 27 per cent. In February 2017 the European Commission approved its so-called 'Winter Package', which set the energy and climate goals for the following years, also taking account of the international targets contained in the Paris Agreement. The Winter Package states that each Member State shall submit a National Energy and Climate Plan (NECP) to monitor the objectives set, and the Commission may call for corrective measures to be taken should it consider that the plans are not in line with the European targets. Italy submitted the final version of its plan at the end of 2019.

To reach the goal of **climate neutrality** by 2050 (as described in the RCP2.6 scenario; see Box 2.1), the European Commission presented a series of proposals at the end of 2018 to define its long term goals:[13] 1) make full use of the benefits of energy efficiency; 2) increase the penetration of renewables in combination with the electrification of the energy system; 3) implement a sustainable smart mobility plan; 4) redirect the industrial sector towards the circular economy, with a strong preference for 'secondary raw materials';[14] 5) develop network infrastructure for digitalized intelligent energy use ('smart grids'); 6) increase the range of

[13] European Commission (2018), 'A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy'; COM(2018) 773.

[14] Secondary raw materials comprise primary raw material production waste or materials deriving from waste recovery and recycling.

instruments to absorb carbon (afforestation and use of the common agricultural policy to reduce increasing emissions in Europe's agricultural sector); 7) consolidate and extend the use of fossil fuels by carbon capture and storage in those cases where the technology does not yet enable the direct use of electricity (for those energy-intensive industries for which decarbonization is technologically more complex, such as the steel and cement industries and to address the question of residual emissions).[15]

These proposals were then finalized with the European Green Deal, which has the central aim of reaching zero emissions by 2050 and, as a result, the 2030 target for reducing greenhouse gas emissions was adjusted to 55 per cent (see Box 3.1).

Italy is one of the few EU countries to have achieved all three Europe 2020 targets, in terms of limiting greenhouse gas emissions by 2020, reducing the demand for energy, and extending the use of renewables (EEA, 2019). Italy's NECP was sent to the Commission at the end of 2019, presenting a strategy to make further progress by 2030, i.e. 30 per cent of renewables in final gross energy consumption, a reduction of 43 per cent in energy use compared with current trends and a 40 per cent contraction in greenhouse gas emissions compared with 1990.

According to the Plan, between 2020 and 2025 emissions should fall by 48 million tonnes and between 2025 and 2030 by a further 30 million tonnes, an average reduction of around 7 million tonnes per year. The decision to bring the emissions reduction to 55 per cent by 2030 could mean doubling the annual pace of emission reduction (from 7 million tonnes to 16 million tonnes). This pace of annual reduction had never been experienced in Italy prior to the pandemic - not even in the ten years that included the Great Recession, when the annual reduction in emissions was 13.5 million tonnes and the demand for primary energy fell to 1990 levels.

Box 3.1 European decarbonization commitments

The European Commission presented an ambitious plan with the aim of making Europe the first continent to remove all of its greenhouse gas emissions and reach a state of climate neutrality by 2050. The tool to reach this goal will be a European Green Deal, the contents of which will be included in the first European Climate Law.

To achieve climate neutrality, the Green Deal sets a series of intermediate objectives and identifies the tools needed to reach them. The main objective, which is functional to achieving zero emissions by 2050, is to increase the EU's climate ambitions in terms of reducing greenhouse gas emissions. For this reason, the objective of reducing emissions by 40 per cent by 2030 (measured against 1990) will be revised upward to 55 per cent (Parliament approved a 60 per cent reduction).

For this purpose, a series of instruments will be adopted: 1) The European Emission Trading System (ETS), which will also include emissions from the maritime sector and possibly from the construction sector as well. Furthermore, to strengthen the ETS price signal, emissions permits, which are issued free of charge to firms operating in the air transport sector (where emissions are increasing sharply) would be progressively eliminated; 2) a revision of the Energy Taxation Directive, with the aim of introducing a minimum tax threshold linked to the carbon content of the various types of fuel. Basically, a minimum

[15] Also known as CCS (Carbon Capture and Storage), this is a process involving the geological limitation of the carbon dioxide produced by large combustion plants, which is becoming part of the mix of strategies available to tackle the increasing concentration of CO2 in the atmosphere of anthropogenic origin.

European carbon tax would be set for sectors not covered by the ETS system, such as agriculture, waste, transport and heating; and 3) a Carbon Border Adjustment duty will be introduced to penalize the carbon content of imported products in order to ensure that European carbon pricing does not compromise European firms' productivity. This duty would be levied on countries without a carbon pricing policy equivalent to that in force in the EU and initially it would only apply to some products and would then be gradually extended to others.

Furthermore, to help contain any negative repercussions that climate policies could have on a country's economic and social fabric, various initiatives have been adopted: 1) the allocation of resources, through the Just Transition Fund, to support the population segments and areas hardest hit by the energy transition, such as workers in traditional fossil-fuel industries or people living in coal-mining districts. This fund would follow the same logic as the cohesion policy fund to support rural areas; 2) the setting up of the Sustainable Europe Investment Plan, which will act as a catalyst for resources from the private sector and promote green investment. This would be a way to mobilize €1 trillion worth of funds overall for the next decade (it is not clear how this is divided up between the public and private sectors); and 3) the European Investment Bank (EIB) is to become the EU's Climate Bank. By accelerating the adoption of the new policy for EIB loans, which is currently being approved, it is expected that projects involving the use of fossil fuels will no longer receive funding.[1]

[1] The European Green Deal includes other more general and secondary environment objectives, including a new Circular Economy Action Plan aimed at sectors making intensive use of natural and material resources, a strategy to protect biodiversity and another to protect rural areas and support agricultural communities by encouraging sustainable nutrition (Farm to Fork Strategy).

However, the pandemic crisis suddenly changed the situation. In the first nine months of 2020, final energy consumption in Italy contracted, which also led to a reduction of greenhouse gas emissions of about 33 million tonnes, 14 per cent less than in the same period in 2019 (ENEA, 2020). The reduction was due to petroleum products being less used in the transport sector and in industry – the sector hit hardest by the lockdown.

It is not, however, clear which parts of these trends are of a structural nature. To a large extent, the reduction in emissions can in fact be attributed to lower levels of economic activity and only in part to the increased share of renewable sources of energy. This is, moreover, the result of the shift in the mix of total consumption due to a reduction in transport and an increase in domestic consumption (electricity in particular), as a result of remote working and distance learning. It is not easy to predict if we will return to the pre-crisis trends once the pandemic emergency is over, or if some of these changes willprove permanent (see Box 3.2).

Box 3.2 What will change after the pandemic for the energy transition?

The COVID-19 pandemic and the economic measures taken to counter its effects are having a strong impact on the energy sector.[1] The fall in business activity and the reduction of transport and mobility to a minimum have generated a collapse in the global demand for energy. The International Energy Agency (IEA) estimates that the decline in energy consumption in 2020 will be the biggest ever recorded. Not only the quantity but also the prices of energy products have fallen. For example, the price of Brent crude oil collapsed during the first phase of the pandemic to about $40 a barrel from mid-June 2020, more than $20 below the 2019 average.

According to the estimates for 2020, the contraction in energy consumption implies a substantial reduction in greenhouse gas emissions worldwide. This variation will accelerate the emissions reduction process needed to achieve climate neutrality around 2050, the aim of the Paris Agreement. Yet the progressive reduction of atmospheric emissions cannot continue at the same pace once the pandemic and the measures taken to counter it come to an end. In general, the shock generated by COVID-19 could have implications for the energy sector and for carbon emissions that go beyond the immediate effects. In the medium term, the implications of the pandemic will influence energy demand and could have profound effects on the global transition towards a low-carbon economy.

Some factors linked to the outlook for the energy sector and investors' preferences could encourage the penetration of cleaner energy production technologies, decarbonizing the economy more quickly. The renewable energy sector has been particularly resilient to the pandemic shock, both in terms of new plant installations and of new project financing and market performance, as reported in the IEA's 'Renewables 2020' report published in September 2020. The trend observed for renewable energy companies could continue and strengthen in the medium term, lowering the price of energy produced from these sources. On the other hand, the world's oil companies have suffered heavy losses, with some defaults and the highest number of rating downgrades at sector level. According to Rystad 2020, investments in exploration for new fields in 2020 and 2021 are expected to be at their lowest levels since the recent financial crisis. Less investment in exploration could reduce production in the medium term, pushing up oil prices as soon as global demand recovers. Another reason why oil prices could increase in the short term is linked to the interests of the OPEC+ countries. According to Goldman Sachs (2020b), in the last five years, the oil companies in these countries have lost competitiveness compared with their counterparts in Europe and United States and the oil price threshold appears to have risen in order to maintain the fiscal breakeven point. If global demand for oil picks up sufficiently and OPEC is able to coordinate its actions, prices could remain high in the medium term.

While there are good reasons to think that the transition towards a low-emissions economy will gain strength, there are counter arguments that suggest that this process could slow down, with the risk of not achieving the 2050 objectives. Achieving net zero emissions, a necessary condition to contain temperature increases in line with the Paris Agreement, will require $50 trillion dollars of investments by 2050. The prolonged effects of the pandemic on economic growth could hinder this process. One study shows that economic recovery after a pandemic may be anything but immediate. In the aftermath of past pandemics, the economy's natural real interest rate declined until it hit bottom after 20 years, followed by a recovery in the next 20 years (Jordà et al., 2020) The COVID-19 shock has generated great uncertainty over future economic prospects, given its breadth (Ludvigson et al 2020). From the consumers' point of view, this uncertainty has already led to a sharp increase in saving in various countries, presumably in part for precautionary reasons. Firms for their part, hard hit by the pandemic, have focused on their own needs in the near term. If the outlook were to remain negative for long, they could consider that improving the ESG aspects of their business is no longer a priority. As suggested in a Goldman Sachs study (2020a) on the utilities sector, only those firms with greater financial resources have more potential for engaging in decarbonization efforts. Furthermore, if the trend towards remote working strengthens and companies reduce their global production chains (nearshoring), the demand for energy for transportation could be permanently reduced, keeping oil prices low and encouraging their exploitation on a larger scale again.

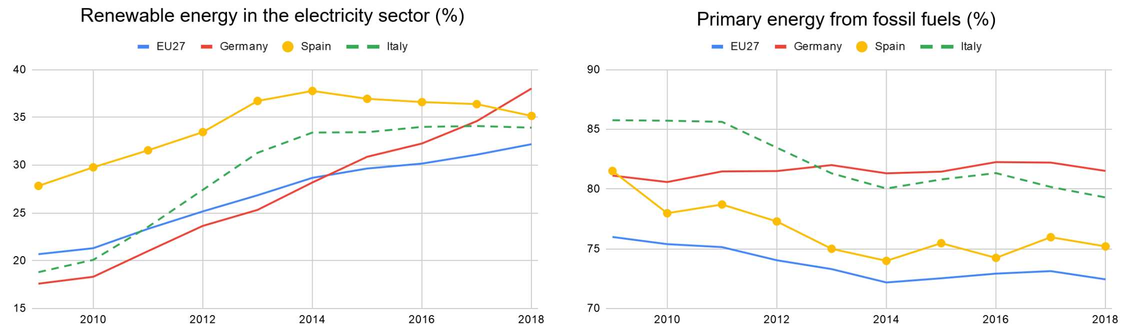
In the current context, in order to encourage the economy's green transition, it will be necessary to stimulate economic recovery with sustainability objectives that can be achieved over a longer period. As the transition could be uneven, favouring some sectors and technologies and penalizing others, it is important to design measures that, as far as possible, pursue both objectives at the same time. Involving government policy action in the decarbonization efforts would have the added advantage of providing a credible signal to investors that would strengthen (rather than depress) the entrepreneurial and financial drive towards sustainable development.

[1] This box is based on the work of Faiella and Natoli (2020).

It is not clear whether the ambitious European targets can be reached in such a short period of time. History has taught us that energy transitions are slow − coal took half a century to replace wood to then become the dominant source of energy, while oil took 60 years to parallel coal but it has not replaced it (Smil, 2016).

At international level the decarbonization process is more or less at a standstill. The energy system's carbon intensity (tonnes of CO2 per tonne of oil equivalent-TOE) was 2.39 in 1990 and 2.32 in 2018 (Di Giulio and Migliavacca, 2020).

Figure 3.1 - Limited progress in the transition process in the electricity sector



Source: Our calculations based on Eurostat data.

The situation in Europe and, in particular, in Italy is slightly better. The transformation underway has so far been concentrated in the electricity sector which, in Italy, accounts for 22 per cent of final energy consumption and 16 per cent of primary energy use. Looking at the contribution of fossil fuels to overall energy demand, in Italy as in other European countries, it can be seen that progress has been limited in the transition process. Figure 3.1 shows two ways of describing the transition. The left-hand graph shows the mini-revolution that has taken place in the electricity sector, where generation with renewable sources has, in just a few years, come to contribute over a third of total electricity generation. The right-hand graph shows, however, that overall energy demand, which includes all energy sources and final uses, the dominance of fossil sources appears barely to have been affected by the transition given that their contribution has fallen but still accounts for between 72 and 82 per cent of the total.

The policies needed to reach these objectives, such as those that adjust energy prices, will influence energy costs and affect the allocation of the factors of production within the economic system.[16] If this process is not accompanied by appropriate policies, it may undermine firms' competitiveness and households' wellbeing, in particular that of the most vulnerable ones (see Box 3.3). Moreover, it is expected that all those activities linked to the use of resources that are set to disappear from the energy system (oil products, gas and coal) will see their economic fundamentals worsen as the market for their products shrinks, with the risk that productive capital (the production plants, transport means, and distribution infrastructures) may lose its value because it can no longer be utilized (see Box 4.1). This is even more true for the extractive industries, given that their activities centre on the extraction and commercialization of fossil fuels.

[16] For example, incentives for producing energy from renewable sources or taxation of fossil fuel use linked to emissions.

Box 3.3 Decarbonization and transition costs

The transition process is based on two main pillars: 1) improved energy efficiency by using less energy to produce the same amount of goods and services; and 2) an adjustment to the energy mix, reducing the share of fossil fuels and increasing that of renewablesources in order to reduce carbon intensity.

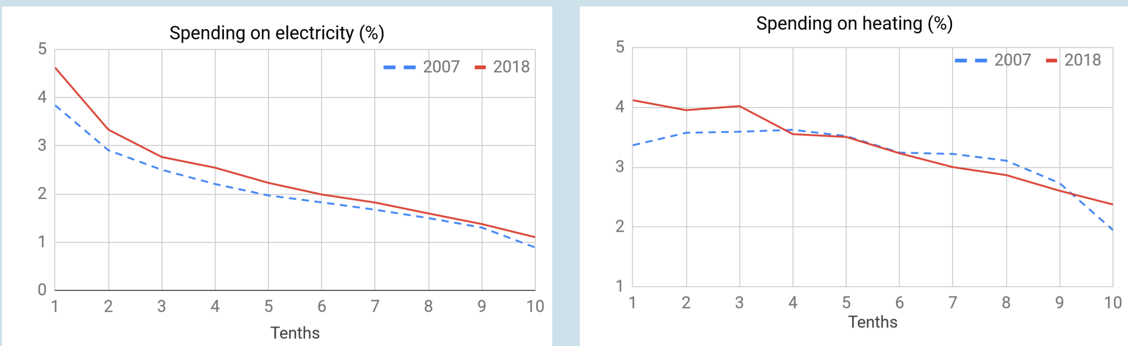
Both these elements call for profound changes in the infrastructures on which Italy's energy system is founded. On the one hand, this involves a partial or total loss of the use value of some capital goods: vehicles with internal combustion engines; coal and gas-fired thermoelectric power plants; and the infrastructure involved in transporting gas and oil products. On the other hand, it is necessary to build new infrastructures in order to support the electrification process in the transport and residential sectors. These processes will entail additional costs because they require resources, which can be found through general taxation, by increasing some of the costs we pay for our energy supplies, or by paying higher taxes on energy products (e.g. a carbon tax that increases the excise duties on fuels).

The increase in costs as a result of decarbonization has already been seen in Italy in the last few years both as regards support for renewable energy sources in the electricity sector (RES-Es) and to encourage energy efficiency. RES-Es are funded through an item on electricity bills that, up until 2020, represented about one fifth of the final price for a typical domestic consumer. Between 2010 and 2019, funding for RES-Es led to an increase in the national electricity bill of €108 billion (around 80 per cent borne by firms - ARERA, 2020), equal to about 0.7 per cent of GDP per year, and foresees a commitment of an additional €115 billion up to 2036. Since the first years, these incentives have led to the growth in the effective average price paid by non-domestic users for electricity (Faiella, 2014).

It follows that a serious effort to decarbonize will lead to a further increase in energy prices. According to many forecasters, electricity prices in the EU, amongst the highest in the world, will increase further in the decades to come because of the energy transition (IEA, 2017, European Commission, 2016).

The price increases have also been reflected in household spending. The share of resources that households allocate to electricity and heating costs increased by one percentage point between 2000 and 2018 (Figure A). This was largely driven by price developments, as it is difficult to cut down on energy uses. The increase in spending on energy was not uniform across all population groups but was more burdensome for less well-off households. In 2018, 10 per cent of households with the lowest consumption expenditure allocated more than 4 per cent of their budget to electricity, while 10 per cent of those with the highest consumption expenditure spent around 1 per cent of their budget on this item (Figure A, left-hand panel). Moreover, the increases over the last ten years, albeit generalized, seem to have accentuated these differences not only as regards spending on electricity but also that on heating. Further increases in electricity bills would exacerbate conditions for the most vulnerable households, a phenomenon known as energy poverty, affecting around 9 per cent of households in Italy (Faiella and Lavecchia, 2015; OIPE 2019).

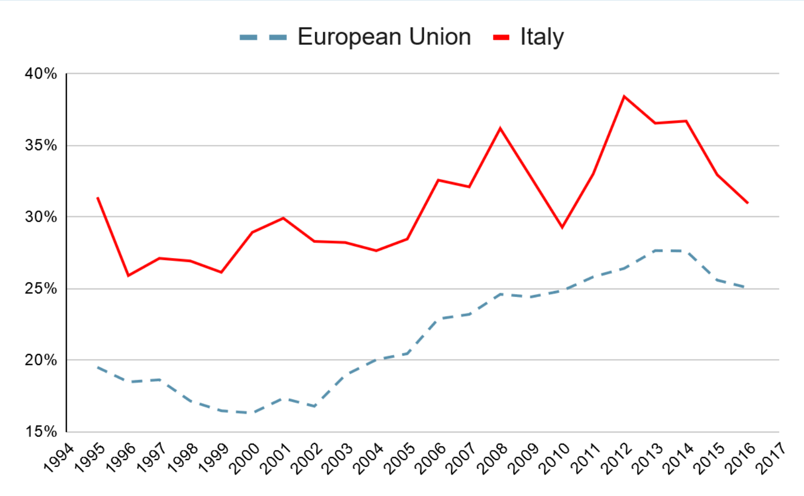
Figure A - Share of spending on energy by tenth of total spending



Source: Our calculations based on Istat data.

Firms have also recorded an increase in energy costs in recent years. A recent study evaluates the growing importance of the energy costs borne by manufacturing firms (Faiella and Mistretta, 2020). In the first ten years of this century, energy costs for the manufacturing industry in the EU amounted to about one seventh of the cost of labour; this share has increased further in more recent years, and now amounts to more than one quarter (Figure B).

Figure B - Ratio of energy to labour costs



Source: Our calculations based on the work of Faiella and Mistretta (2020).

Source: Our calculations based on Eurostat data.

The importance of energy costs is even greater for Italian companies: at the end of the 1990s, manufacturing companies' energy costs were just over one quarter of what they spent on labour; more recently, spending on energy has reached almost one third of that on labour. This trend seems to be the result of the growth in the prices paid by final users, driven by the tax and tax-related cost components linked to renewable energy incentives. By European standards, Faiella and Mistretta (2020) estimate that in the period 2000-2015, Italian manufacturing firms had a unit energy cost more than 14 per cent higher than the EU average. The growth in energy costs, largely due to the support mechanisms for RES-Es, seems to have created a competitive disadvantage, since individual states are unable to adjust their exchange rates.

4. The risks to the financial system

Climate change may be associated with increases in the intensity and frequency of extreme weather events, which in turn can affect economic activity (physical risk). At the same time, more ambitious climate policies, such as the European Union's objective of achieving net-zero greenhouse gas emissions by 2050, may lead to a significant reduction in the value of the tangible and financial assets connected with the use of fossil fuels (transition risk). Both risks are significant for the financial system since they can impair the ability of households and firms to meet their financial obligations, also following a decrease in the value of the assets pledged as collateral for loans.

The previous sections have shown that both the expected impact of climate change and the decarbonization process, especially if disorderly, could translate into losses for Italy's economic system. This section describes how these losses could be transmitted to the financial sector and outlines the characteristics of climate-related financial risks.

Two types of risk can be identified: the first is the risk associated with the lack of incisive actions to cut emissions (**climate-change mitigation policies**) or to limit their effects (i.e. no investment in **adapting to climate change**). Hence, this type of risk is linked to inertia in countering climate change and is classified as a physical risk, which we could define as the risk of inaction.

The physical risk is connected to the occurrence, in the short or long term, of the extreme natural events that science attributes to climate change. These events can be chronic, such as the progressive deviation of temperatures and rainfall from their historical trends, or acute, such as events that are unlikely to occur but when they do, they have a significant impact on the areas affected (e.g. flooding or heat waves).

While inertia entails risk, sudden action to counter climate risks can also be a source of risk for the economic and financial system, particularly if it is not well planned and contradictory. The previous chapter showed that policies that promote the transition modify the relative prices of energy inputs and may affect the value of assets relating to the exploitation of fossil fuels. Since these risks stem from a transition of the energy system from a model based on fossil sources to one with a lower carbon intensity, they are defined as **transition risks**.

The financial system is particularly exposed to these risks owing to the key part it plays in the economy. Its role as mediator for the savings and investments of households and firms makes it potentially capable of amplifying the negative impact of adverse events connected to climate change and to the green transition. For this reason, central banks are increasingly interested in understanding how climate risks translate into financial risks and how adverse climate events can propagate across the financial system, with possible risks to its stability (see Section 6).

Physical risks affect financial intermediaries both directly and indirectly. Extreme natural events linked to climate change (e.g. floods, landslides, hurricanes and so on) can, for example, cause direct damage to a bank's branches by making them inoperative. These direct risks are accompanied by indirect risks. In fact, those same natural events can damage a private home or firms' fixed capital (plant, industrial warehouses and machinery). Faced with a reduction in their production capacity or with unexpected expenses, the owners of the damaged assets may have difficulty honouring their financial obligations, implying possible losses in banks' balance sheets.

If those affected by natural disasters are insured, the damage resulting from extreme events may weigh on the financial situation of the insurance companies exposed. The magnitude of the damage can be significant if the events extend over a sizable area, such as Hurricane Katrina in the USA in 2006 or the fires in California in 2018 (**liability risk**). If the damaged assets are not insured, the effects of natural events may take away more resources from the people affected and lead to a significant reduction in the value of the collateral pledged to obtain credit. In turn, a reduction in the value of collateral, associated with a rise in the financial vulnerability of the households and firms affected, could increase both the probability of default and the amount of the losses that the bank must bear in the event of a borrower's default; if the affected area was large or the event particularly intense, these effects could propagate through a significant portion of the banking system.

The greater risks due to climate change could lead banks to tighten credit for borrowers located in higher-risk areas, with potential repercussions, among other things, on the transmission of monetary policy impulses. A study conducted on Italy shows that more than 20 percent of loans to the productive sector are granted to areas at high risk of flooding and that the flow of credit is negatively correlated with risk exposure, especially when the borrowers are small and medium-sized enterprises (Faiella and Natoli, 2018). Given that Italy is expected to be the country in Europe to suffer the greatest damage from increased river flooding (Ciscar et al. 2018), it is important to take account of this fact when assessing the possible future impact on the credit channel, both from the point of view of the stability of individual financial intermediaries and from a macroprudential perspective.

The losses relating to the credit granted or to the insurance policies taken out are compounded by other negative effects for the financial system. In the event of adverse events, the affected firms may face a depreciation of their stocks and bonds, leading to losses for the intermediaries that hold some of those firms' shares in their portfolios. Furthermore, the affected firms could be forced to shift some of their capital from investment in technology and innovation to reconstruction, thereby slowing their production and innovation processes and reducing their medium-term profitability.

Going forward, the rise in the frequency and intensity of extreme weather events might affect the financial position of an ever greater number of banks and insurance companies, creating risks to the stability of the financial system as a whole. Should the intermediaries exposed to the affected households and firms suddenly interrupt the provision of some services, or should the value of their own securities depreciate abruptly, the negative impact of climate change could propagate to the financial institutions that are so far unaffected, extending its negative repercussions to the credit and insurance markets (second-order effects). These phenomena would become even more significant if the frequency and severity of these events were underestimated and if the situation were to worsen over time, as the increase in the temporal and spatial correlation (clustering effects) would make the reinsurance process increasingly challenging.

Transition risk stems directly from the commitments made by the international community to stabilize the atmospheric concentration of greenhouse gases at a level that allows the rise in temperature to be kept below 2°C compared with pre-industrial levels. A disorderly transition towards a low-carbon economy could sharply reduce the value of energy reserves and of the infrastructures linked to the exploitation, processing and use of fossil fuels (coal, oil and gas). Unlike physical risk, transition risk is not persistent, but it could nevertheless disrupt the stability of the financial system. In fact, given the importance of the sectors involved and the pervasiveness of energy products, a sudden drop in the value of the reserves and of the related infrastructures could trigger a race to sell the securities of energy companies, with consequences that could affect the path to global economic growth (as happened with financial companies exposed to the subprime loan sector during the last great financial crisis that led to the Great Recession).[17] A recent study shows that even if the construction of energy infrastructures using fossil fuels had stopped in 2018, the cumulative greenhouse gas emissions due to the normal functioning of the existing plants would still not be compatible with the carbon budget necessary to keep the increase in temperature below 1.5°C (Tong et al., 2019). Therefore, if this objective became binding, many of these plants would not be able to function over their entire useful life, resulting in a depreciation of their value.

Moreover, the transition will likely lead to an increase in prices (see Box 3.3), as climate policies require the use of alternative energy sources that are at the moment more costly or the introduction of carbon pricing systems that internalize costs which are currently not borne by firms or by the public. This would affect prices and economic activity. For example, a carbon tax designed to increase over time is in line with the boldest emission reduction targets. Since the demand for energy is inelastic in the short term (Faiella and Lavecchia, 2020b), a sharp increase in energy prices would increase the financial vulnerability of firms and households owing to the higher expenditure they would face for the purchase of energy goods.[18]

In this context, it is useful to examine the evolution of the fundamentals of the firms most exposed to transition risk. By analysing the equity returns of European energy companies, Bernardini et al. (2019) find that companies with an energy mix tilted towards fossil fuels registered significant write-downs, which affected operating results by biting into equity and increasing leverage. By running a simulation exercise, they show that in the period 2012-16, adopting portfolio allocation strategies that took account of the carbon-intensity of generating electricity would have permitted a superior risk-return combination.

Box 4.1 Stranded assets and the 'carbon bubble'

The market value of equity and bonds is determined based on the current and forward-looking data available to investors that are deemed useful to estimate the future profitability and financial soundness prospects of the issuing firms. The pieces of information that the prices of financial instruments include today refer almost exclusively to economic and financial profiles, while those relating to sustainability aspects are more difficult to obtain (see Box 5.1). Moreover, it is difficult to assess the impact that could arise from public sector policies intended to mitigate climate risk and, more generally, deal with

[17] For this reason, some central bankers have referred to a possible climate-driven 'Minsky moment' (https://www.bankofengland.co.uk/news/2019/april/open-letter-on-climate-related-financial-risks).
[18] See Box 3.3. On the importance of the energy expenditure of firms, see Faiella and Mistretta (2015, 2020); on that of households, see Faiella and Lavecchia (2015, 2017) and OIPE (2019, 2020).

environmental risk, as well as that stemming from consumers' and investors' changed perception of environmental risk (Caldecott et al., 2016) and, finally, from the evolution of technology. According to Porter et al. (1995), environmental regulation can have positive effects on innovation and competitiveness, with benefits that in the long run could outweigh the short-term costs of the transition; however, there is still uncertainty regarding the break-even point between costs and benefits (Albrizio et al., 2014).

Should the market value of the financial instruments not take account of climate risk in full, investors would find themselves exposed to that same risk in their own investment portfolios (Battiston et al., 2018). Information about the impossibility of utilizing productive assets throughout their entire life cycle ('stranded assets') or about changes in the composition of firms' costs and revenues can cause significant revisions in the valuation of listed equity and bonds. For example, McGlade et al. (2015) estimated that, owing to the energy policies necessary to comply with the commitment to containing the temperature increase to less than 2°C, some 82 per cent of coal deposits, 49 per cent of gas reserves and 33 per cent of oil reserves would be unusable. According to a recent estimate (Financial Times, 2020), the write-downs of the major oil and gas companies would amount to $900 billion, or one third of their market value.[1]

The depreciation in the book value of firms since 2011 is ascribable above all to environmental risk factors (Carbon Tracker Initiative, 2011), which are attracting increasing attention. The write-downs of firms' investments that have become incompatible with the emission caps ('carbon budget') set by the climate targets (Carbon Tracker Initiative, 2013) mean that firms have to internalize the negative externalities of the most carbon-intensive sectors (Ansar et al., 2013).

The destruction of corporate value is not a new concept. Indeed, according to Schumpeterian theories (Perez, 1985), it is part of the innovation and change process that underpins economic growth. Past instances of depreciation of infrastructure, plant and machinery, and human capital[2] gave rise to new phases of progress and economic growth. Compared with the past, the difference is that the destruction does not take place owing to the entry of new emerging industries ('sunrise') but rather through the (induced) decline of pre-existing industries ('sunset'; Semieniuk et al. 2020).

In addition to the coal and hydrocarbons sector (where both the reserves and the entire production chain, – from exploration to refinement to the distribution networks – could be affected), the sectors most exposed to the risk of depreciation of multiannual investments) are those most focused on the production and consumption of energy (e.g. utilities, or the production of steel and cement) and those connected to transport systems (automotive) (Van der Ploeg et al., 2020). For these sectors, asset values could be affected by early economic obsolescence, and a change in the relative prices of the factors of production could impact the efficiency of the respective business models and call for changes – including radical ones – in the production systems, with profound consequences on the economic and financial equilibrium of the firms involved.[3] Estimating these effects is complex and subject to significant uncertainty regarding, among other things, the development path of public sector policies and of technology (Monasterolo, 2020). To make forecasts for aspects that are so complex and interconnected, it is useful to employ the assumed scenarios suggested by the NGFS (2019a), which published some benchmark scenarios in June 2020 (see Box 6.1).

The effects of the depreciation of the instruments most exposed to transition risk will be felt above all by those who invested the most in the instruments, among which are institutional investors (including pension funds) but also retail investors. These may be accompanied by second-order effects due to the interdependencies between the various players in the financial system (e.g. investment in banks or insurance companies that lend funds to or insure firms that are exposed to climate risks). Some estimates by Battiston et al. (2017) indicate that these second-order effects are significant and actually higher than the direct effects. Furthermore, any delays in the implementation of climate-related policies risk significantly increasing the final costs compared with an optimal scenario envisaging, where possible, a gradual reconversion of plants (Campiglio et al., 2020). The depreciation of assets can also stem from expectations regarding the impact of physical climate risks (e.g. flooding or sea level rise) that could generate destruction or loss of value for property and buildings. Moreover, the effects of climate change can negatively impact firms' factors of production, with repercussions on plants, infrastructure and workers as well as on the entire supply and distribution chain for firms' products and services. The impact on the supply chain may be especially significant for multinational firms and for those that operate in regions in which physical climate risks are more probable or more acute (Cicero, 2017).[4]

[1] According to some estimates based on the assumptions of the United Nations Intergovernmental Panel on Climate Change (UN IPCC), to achieve a 50 per cent probability of remaining within a 2°C temperature increase by the end of the century, the carbon budget would [have to] be equal to 1,200 billion tonnes (Gt) of emissions, against the 2,910 Gt of hydrocarbons and coal that are yet to be extracted. Therefore, 59 per cent of the reserves would be unusable. The budget would be even tighter (equal to 464 Gt) in the event of a global temperature target of 1.5°C, making 80 per cent of the reserves unusable.

[2] For example, the replacement of river transport networks with transport by rail during the industrial revolution, the replacement of typewriters and punch card readers with information and communication technology (ICT) tools and, finally, the decrease in the number of people employed in agriculture and the shift towards employment in the service sector stemming from the tertiarization of the economy.

[3] For example, at world level, the cost of producing electric power from renewable sources decreased in the last decade (2011-19), by 82 per cent for solar power and 40 per cent for wind power, making the use of coal for this purpose relatively less advantageous. Compared with using coal, producing 500 gigawatts using solar or wind power saves $23 billion per year in costs for the general system costs and enables additional investments of $940 billion, equal to 1 per cent of the world GDP, and prevents emissions equal to 5 per cent of those generated in 2019 (see Irena, 2019).

[4] Some examples of physical climate risks in the supply chains include exposure to the risk of flooding for suppliers of electronic components in Thailand or refineries on the US coast of the Gulf of Mexico, or exposure to heat waves or intense rainfall for, respectively, producers of agricultural commodities in Africa (Tanzania, Kenya and Ethiopia) and South America (Brazil, Colombia and Costa Rica).

5. The quantification of climate risks for the financial system

The quantification of climate risks for single intermediaries and for the financial system as a whole is a necessary element for drawing up policies for mitigating and adapting to climate change. This is unprecedented in recent history and is complicated by the need to use 'non-standard' data for economic analysis (such as estimates from the natural and climate-based sciences) and by the absence of detailed databases for measuring the exposure and vulnerability of single agents or activities.

To understand the range of climate risks to which the financial system as a whole is currently exposed, the number of financial instruments exposed to such risks has to be evaluated. Evaluation at individual intermediary level is a complex process, made even more difficult by the lack of detailed data on the exact geographical location or the carbon content of individual activities (see Box 5.1). In addition, aggregating the estimated risks for the financial system as a whole imposes assumptions as to how these risks are propagated among intermediaries and on any amplification mechanisms (between connected sectors or countries) or systemic mitigation. Lastly, the quantification of climate risks for the financial system takes place in essentially unexplored territory since, at least in recent history, there have been no climate or environmental patterns with implications comparable with those for the future that are marked by high uncertainty, knock-on effects (endogeneity) and non-linearity.

Before assessing these risks, it is important to define the logic on which to base the metrics analysed. The economic risk for an economic agent or activity linked to a climate shock (physical or transition risk) is commonly defined as the product of three components:

1. the expected probability (understood as happening at different levels of intensity) of the event in question (**Hazard**). In the case of physical risk, this is when an extreme natural event occurs (e.g. a heat wave or flood); transition risk could arise from the introduction of unexpected regulations that, for example, limit the use of a fossil fuel or of certain technology;
2. the value of the activities exposed to such events (**Exposure**);
3. the loss expected per exposed unit (**Vulnerability**).

Calculated in this way, the risk impacts the financial intermediary for the amount exposed towards a single firm or towards an entire economic sector. The estimate for the first component identifies the areas (or sectors) most at risk, for example because of the characteristics of the territory and the temperature scenarios at local level (see Box 2.2), the second superimposes information on elements at risk (population, infrastructures, firms, cultural heritage and so on) onto territorial areas/sectors, and the third requires an evaluation of the factors that make the units exposed more vulnerable (e.g. for floods, the lower floors of buildings).

This type of definition only refers to the risk of a single event, but it is commonly used to describe the overall risk generated by a sequence of possible weather events over a future time horizon. If it is used for this purpose with only Hazard being varied, it is implicitly assumed that the exposure and vulnerability - which also vary according to the capacity to cope - do not change during the period examined.

There are some estimates of the overall dimension of the global financial system's exposure to climate risks. Using a Value-At-Risk model, Dietz et al. (2016) estimate that, in the absence of mitigation measures in addition to those envisaged, global financial activities would be exposed to physical risks for an average total of \$2,500 billion and a potential tail risk of \$24,200 billion. Mercure et al. (2018) estimated instead that the potential losses for activities linked to fossil fuels extraction, use, processing and transportation would amount to between \$1,000 and \$4,000 billion. Battiston et al. (2017) estimate that, for European banks as a whole, the amount of loans exposed to transition risk - since they are granted to production sectors linked to the use of fossil fuels - is comparable with their overall capital.

Box 5.1 The limitations of the available data

In order to actively manage the risks stemming from climate change, financial intermediaries must be able to calculate the risk to which the assets being invested in are exposed. To do this, they need detailed information on the exposure to risk of households, firms, public institutions and on the other financial intermediaries to which they may potentially be exposed. The evidence from the surveys conducted on financial intermediaries, which indicate little consideration of climate risks in risk management (Faiella and Malvolti, 2020; SSM, 2020b), could also derive from the difficulties in measuring these risks owing to the lack of data. Some potentially useful information (for example on the environmental impact of large firms or the riskiness of the territory in terms of adverse natural events) is partially available publicly, but might not be directly usable for financial analyses or, since it has never been considered for this purpose, is not known to intermediaries. Since the latter are exposed to a worldwide network of customers, there should be a vast amount of information to consider. By limiting the field to national level, the lack of awareness of climate change isalso due to the lack of some important data.

As far as the management of physical risk is concerned, 'official' evaluations of the risk of extreme events linked to rising temperatures, such as floods, landslides and so on, are only available for Italy as a whole at provincial level.[1] It is assumed, however, that given the marked heterogeneity each province in terms of climate, topography, urban density, and the presence of waterways or coastal areas, the probability of extreme weather events also varies greatly. Assigning the same Hazard level to all the internal areas of a province (e.g. to a city and to the surrounding countryside) is a significant limitation for financial risk analysis. Even assuming that Hazard is known because the territorial detail is sufficient, it is not always easy to quantify Exposure. For example, for firms with premises (plants, offices, warehouses and so on) located in territories exposed to different risk levels, or even in different countries, the monetary value of the premises needs to be known in order to quantify the overall risk exposure.

For households applying for loans, an intermediary would need to know the value and location of all the assets owned by the applicant, such as buildings, land or any other property. Even if the probability of weather events and the value stated are known, Vulnerability, or rather the loss expected for every euro exposed, still has to be estimated. In this regard, the intermediary has no historical information to use for individual customers, and neither are there any detailed data on the impact on other households and firms of any natural disasters in previous decades; in addition, information on the funds provided by the State on such occasions is highly fragmented. Attributing the same vulnerability to every customer that lives in a high/low-impact province - according to the classification in the National Adaptation Plan - could make for an overgeneralized approximation.

If it is difficult for an intermediary to assess physical risk for individual clients, it is even more so, for example, for a central bank to make an aggregate evaluation of households, firms or intermediaries. In addition to these difficulties, there is the lack of public data on the location of households and their property, or on the existence of insurance policies for buildings or firms that cover them against extreme events. To assess the risk for each intermediary, there are no historical data on the impact of weather events on non-performing loans.

The transition risk is due to the sudden repricing or drop in value of the most carbon-intensive assets caused by changes in policy or in the preferences of investors/consumers. To better appreciate the exposure of individual firms: for activities that are *already funded*, information on the specific funding sources would be needed, together with the associated greenhouse gas emissions;[2] instead for those *to be funded*, prospective details on emissions would be necessary (including those avoided in the case of 'green' projects). In actual fact, this information is often unavailable except for dedicated bond issues (green bonds) that are fairly recent and still limited[3] or, in some countries, for firms that are almost always large and listed and that publish such information if required by law (such as non-financial reporting[4] in Italy) or by choice (for example because of reputational issues). However, no more than a few hundred firms publish this kind of information in Italy.[5]

Several independent providers supply detailed information on the green bonds, greenhouse gas emissions and ESG ratings of individual firms. The quality of this information often varies and is not always consistent at individual firm level among the providers; specifically, the reliability and consistency is greater for estimates of direct emissions (scope 1), followed by those of indirect emissions (Scope 2), especially if they are reported directly by firms. The limited number of firms that automatically provide these data forces data providers to estimate emissions with significant estimation error problems, which worsen as the amount of detail provided increases, especially in the case of Scope 3 emissions (Busch et al., 2020). This is probably the result in turn of the lack of precise and disaggregated information on firms' energy consumption, which is essential for estimating emissions.[6] Similarly, the ESG ratings for these same firms from various providers differ greatly (Lanza et al., 2020). In short, given the poor availability of granular data, it is currently possible to use highly detailed sectoral data on emissions.[7]

[1] By official evaluations, we mean the evaluations of risk at provincial level carried out by Mysiak et al. (2018) and used in the draft of the National Adaptation Plan of the Ministry for the Environment, Land and Sea Protection.

[2] The standard for classifying emissions is defined by the Greenhouse gas protocol of the World Resource Institute, supported by various organizations and data providers. Under this protocol, greenhouse gas emissions are subdivided into three categories: the emissions produced in the making of goods and services (direct emissions) are classified as 'Scope 1'; indirect emissions, which are the result of energy inputs used in production processes, are classified as 'Scope 2'; all the remaining indirect emissions (different from scope 2) along the value chain, both upstream and downstream, are classified as 'Scope 3'. Consequently, the overall emissions of a product/service are given by the sum of the Scope 1, 2 and 3 emissions.

[3] In 2019, green bond issues accounted for a total of $263 billion taken up on the market, a marked growth compared with 2009, when issues amounted to just under €1 billion. Nevertheless, total green bond issues in 2019 accounted for just under 3.5 per cent of global bond issues (Ehlers et al. 2020). Between 2007 and 2020, total issues came to over $1 trillion. Italy was in tenth place for emissions, with $18 billion (Climate Bond Initiative, 2020).

[4] Legislative Decree 254/2016, which transposes Directive (EU) 2014/95, introduced the obligation to publish a non-financial reporting(DNF) in Italy; this contains, among other things, greenhouse gas emissions and air pollutant emissions. Listed companies, banks and insurance companies with at least 500 employees and assets of over €20 million or net profits of more than €40 million are obliged to produce a DNF.

[5] Around 200 firms in Italy are obliged to produce a DNF. Just over 40 firms have voluntarily joined a scheme such as the Carbon Disclosure Project for publishing their emissions.

[6] There are no official data in Italy on the energy consumption of households and firms. Istat attempted to estimate energy demand in 2014, with its Survey on households' energy use, while a similar effort regarding firms, the survey on firms' final consumption of energy products (COEN) conducted in 2012, has never been published. The integrated information system (SII), managed by Acquirente Unico (GSE group) currently has precise data on gas and electricity consumption from meter readings, but these data are unavailable, even in aggregate form.

[7] In Italy, data on greenhouse gas emissions (Scopes 1 and 2) are published yearly by Istat as part of its Air Emissions Accounts (AEA, previously the NAMEA accounts) and refer to total national emissions for 2-digit

ATECO activities in the case of firms (with some sectors grouped together, for a total of 63 sectors) and for macro-categories of household consumption (transport, heating and other items).

The Bank of Italy recently assessed the exposure of the Italian banking system to these risks.[19] As regards exposure to physical risk, loans to households and firms have been classified using a provincial-level risk indicator (Abdullahi Hassan et al., 2020), produced by Mysiak et al. (2018) and used in the draft of the Piano Nazionale di Adattamento ai Cambiamenti Climatici (National Adaption Plan) of the Ministry for Environment, Land and Sea Protection.[20] The capacity of individual provinces to adapt to climate change was also considered for the time horizon of the analysis (2021-2050). In order to use both types of information, the credit risk analysis considers two indicators: the high-impact provinces (for which high impacts are expected whatever their capacity to adapt may be), and those at high risk, or rather those with an expected impact equal to or higher than the national average but with a limited capacity to adapt.[21] At the end of 2019, the total exposure of banks towards households and firms resident in high-impact provinces stood at 28 per cent for households and 29 per cent for firms of total loans. This latter figure appears slightly higher than in the findings of a previous study, which estimated that around one fifth of loans were disbursed to firms operating in areas at high risk of flooding (Faiella and Natoli, 2018). The share of loans to provinces at high risk amounted instead to 11 per cent for households and 5 per cent for firms.

As regards exposure transition risk, Faiella and Lavecchia (2020a) proposed a number of indicators for measuring the exposure to risk of Italian banks based on the composition of loans to firms by sector of economic activity. Higher greenhouse gas emissions are assigned to economic sectors that, owing to the technological characteristics of their activities, use more fossil fuel energy sources or produce large quantities of greenhouse gases. Since these sectors are considered to be more exposed to transition risks (e.g. because the introduction of a carbon tax would have a greater impact on their cost structures and profit margins), banks that have granted them loans are also exposed to such risks. The paper proposes two indicators to measure the share of outstanding loans exposed to transition risk. The first is based on the Loan Carbon Intensity (LCI), or rather on the quantity of emissions for every euro loaned; the second is constructed as the share of outstanding loans towards carbon-critical sectors (CCrSs), defined as those sectors that have the highest share of emissions and committed loans.[22] At the end of 2018, the share of loans to firms exposed to transition risks stood at between 38.5 and 52.4 per cent (between 7.5 and 10 per cent of total assets), for the indicators based on LCI or CCrSs respectively. These figures seem higher than the exposure of Spanish banks (estimated at

[19] See the box 'The banking system's exposure to climate-related financial risks' *Financial Stability Report,* 2, 2020, Banca d'Italia.

[20] In particular, the effects of the Representative Concentration Pathway 2021 (RCP 4.5) scenario are taken into account for the period 2021-50, when trends in growth of emissions could lead to the concentration of greenhouse gases stabilizing by 2100 (see Box 2.1). The effects on physical, social and natural capital are considered.

[21] For both indicators, provinces with indicator levels higher than the average of the respective distributions are considered.

[22] The first indicator (LCI) is constructed as the ratio between the greenhouse gas emissions of each sector and their total bank loans; sectors with an LCI index above the median of the distribution are considered to be facing transition risk. The second indicator is constructed as follows: economic sectors are ordered according to the share of loans per sector and to the share of emissions per sector, and the average position for each sector in the two rankings is calculated. Sectors are considered to be at risk if they are in the first quintile of the new distribution obtained.

around one quarter of total loans to non-financial companies; Delgado, 2019), but lower than what was found for the Netherlands (Vermeulen et al., 2019), where the banking sector is exposed for almost 13 per cent of its total assets.[23]

Table 5.1

Exposure to climate risks of loans to non-financial corporations in 2018

(per cent)

Climate risks	Transition risk (1)		Total
Physical risk (2)	NO	YES	
- NO	33.9	37.2	71.1
- YES	15.3	13.6	28.9
Total	**49.2**	**50.8**	**100**

Sources: Based on data from Eurostat and the Ministry for the Environment, Land and Sea Protection, and on supervisory reports. (1) Total loan to sectors most at risk in terms of emissions and credit, based on the relative contribution of each carbon-critical sector. – (2) Total loans disbursed in the provinces at high physical risk defined as those for which the climate impact indicator reports higher than average values.

For the credit exposure of firms alone,[24] a joint analysis of both risks can be carried out. The Bank of Italy's last Financial Stability Report[25] proposed an estimate of the exposure of loans to physical and transition risk for non-financial corporations. It considers the amount of outstanding loans disbursed based on the province of residence and on the sector of economic activity of the firms receiving the loans. Based on the classifications of physical and transition risk described above,[26] the amount of exposed loans is identified. At the end of 2018, some 37 per cent of loans were exposed to transition risk only, 15 per cent to physical risk only and 14 per cent to both types of risk (the remaining 34 per cent were exposed to neither; Table 5.1).

Of course, the estimates presented are based on numerous assumptions, such as the homogeneity of physical risk throughout the province and the proportionality of the risk of default, because of the transition, to total sector emissions. It should also be recalled that the numbers reported are not to be interpreted as a quantification of the climate risks for Italy's financial system, but rather as estimates on just one of its components (Exposure). The results obtained based on these assumptions suggest that two thirds of bank loans to Italian firms are exposed to at least one of the risks and one seventh of it is exposed to both.

These methods need to be refined by updating, based on the available data, the estimates of exposure with more granular data (at firm and household level), and by estimating the vulnerability of households, firms and intermediaries to climate shocks. Vulnerability also depends on how many agents have incorporated these risks ex ante into their budgets. The results obtained from surveys in Italy and abroad on the awareness of intermediaries of climate risk are not comforting (see Box 5.2).

[23] These comparisons ought to be considered with caution owing to the different methodologies used to identify the sectors most exposed to transition risk.
[24] The transition risk for households is significantly restricted to mitigation policies, currently not present in Italy, which can alter the price of property (e.g. the minimum energy standards required for rental properties in the UK www.gov.uk/guidance/domestic-private-rented-property-minimum-energy-efficiency-standard-landlord-guidance).
[25] See the box 'The banking system's exposure to climate-related financial risks', *Financial Stability Report*, 2, 2020, Banca d'Italia.
[26] Since the estimate of exposure to transition risk does not consider the capacity to cope, the impact indicator is used for physical risk. For transition risk, the definition of a carbon-critical sector is used.

Box 5.2 Awareness of climate risks

To evaluate the intermediaries' exposure it is first necessary to understand the extent of their awareness of such risks. The evidence available paints a very mixed picture. Some surveys conducted on large financial intermediaries show how they have integrated risks stemming from climate change into the management of their portfolios. In the years 2017-18, Krueger et al. (2020) interviewed 439 institutional investors, mainly large banks and pension funds in North America and Europe. On average, those interviewed said they believed the risks to be significant and declared they had already taken steps to mitigate them. Other studies show how large international banks have begun to actively consider climate risks in their credit policies as well: Delis et al. (2020) demonstrate how, following the Paris Agreement, multinational firms exposed to the risk of more stringent climate regulations obtained syndicated loans at higher rates than less exposed firms. On the other hand, evidence for more varied groups of financial intermediaries seems to show a different situation: a survey conducted in 2016 on a broad and representative range of investors (43 per cent of assets under management at global level) observed that only 15 per cent of respondents considered firms' ESG scores in their portfolio allocation (Amel-Zadeh and Serafeim, 2018). A lack of ex-ante assessments of climate risks could lead to abrupt modifications in investment strategies following significant weather events. Cortés and Strahan (2017), taking account of the main natural disasters occurring in the United States between 2001 and 2010, show how the smallest banks, faced with an increase in credit demand in the areas hardest hit, reduced credit supply in the areas not affected by around 50 cents for every dollar of additional loans in the areas that were affected. Looking ahead, with climate policies increasingly in evidence and extreme natural events ever more intense and frequent, underestimating risks ex ante may put the availability of capital for some economic sectors and some geographical areas at risk. Other surveys have been conducted by central banks on supervised intermediaries in order to assess the extent to which exposure to climate risk is disclosed in the regular reports published by the respondents. The ECB conducted a survey at the leading European banks in 2019 (SSM, 2020b); the sample consisted of 107 significant institutions supervised by the SSM and 18 less significant institutions and the survey used the methodology for assessing climate-related risks proposed by the Task Force on Climate-related Financial Disclosures (TCFD). The results show that, although most of these institutions mention climate risks in their annual reports and underline the involvement of their boards in assessing them, only a few of them quantify such risks. For transition risk, which is mainly considered in comparison to physical risk, one third of the institutions report evaluation metrics and objectives for their portfolios, but only a few of them disclose their carbon intensity, making it difficult for a supervisor to make an off-site assessment with respect to their set targets. As far as risk management practices are concerned, only a minority of them say that they use climate scenarios or carry out climate-related stress tests on their portfolios. These results, relating to the most important banking groups at European level, suggest they generally tend to show their focus on and involvement in analysing climate risks, but they do very little in terms of actively managing such risks. Generally speaking, climate risk assessment is still at an early stage, at least in some jurisdictions. A questionnaire used as part of the work of the Italian Observatory on Sustainable Finance had provided similar evidence for the Italian financial system to that obtained by the ECB (Faiella and Malvolti, 2020).

6. Central banks' initiatives

Climate risks can influence the soundness of individual banks and the stability of the financial system. They can also interfere with monetary policy transmission channels and price stability. Central bank action to counter these risks is complicated by the specific characteristics of such risks. Analysing them requires new elements to be added to the tools normally used, such as the stress tests that assess the stability of financial systems or the models used to conduct monetary policy. Looking ahead, central bank action cannot ignore climate change and its implications for the economy. Greater involvement on the part of central banks in countering climate change is the subject of ongoing debate. One aspect of the debate is tied to the principle of market neutrality.

The effects of climate change clearly constitute a possible threat to economic activity and the stability of the financial system. Central banks must therefore safeguard against such risks (Faiella, 2019), but managing them is complicated by some specific aspects: the profound uncertainty about the extent of the effects of climate change and of climate policies, possible actions to adapt, and risks transmission channels. However, first and foremost, assessing the effects of climate change requires a longer time-horizon than is usual for central bank policymaking.[27]

In 2015, the then Governor of the Bank of England, Mark Carney, highlighted this aspect, referring to it metaphorically as 'the tragedy of the horizons' in what was the first and most influential speech by a central banker on this subject.[28] Also in 2015, and again on the initiative of Mark Carney, the Task Force on Climate-related Financial Disclosure (TFCD) was created under the auspices of the Financial Stability Board, to study the financial risks linked to climate change and to increase awareness and transparency on the part of financial firms as regards the financial risks connected with the climate.[29] In 2016, the G20 launched the Green Finance Study Group to examine strategies for encouraging private investors to increase green investment, but its activities ceased after 2018, when the name of the group was changed to the Sustainable Finance Study Group. In 2021, under the Italian presidency of the G20, the group is being revived to explore the role of the financial system in facilitating the energy transition.

The growing attention being paid by the central banks is witnessed by the creation of the Network for Greening the Financial System (NGFS) at the end of 2017, a global network of central banks and supervisory authorities that promotes the sharing of experiences and best practices concerning the management of environmental risks in the financial sector, focusing specifically on climate risks. The NGFS, of which the Bank of Italy is also a member, has published two reports (NGFS, 2019a and NGFS, 2020a), and a series of other studies including a guide for the supervisory authorities (NGFS, 2020b) and two guides for sustainable

[27] The typical horizon of monetary policy is 2-3 years, while that of financial stability is just under ten years, following the credit cycle, but the horizon for climate change can be measured in decades.

[28] Mark Carney, 'Breaking the Tragedy of the Horizon – climate change and financial stability', September 2015, https://www.bankofengland.co.uk/-/media/boe/files/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability.pdf.

[29] In June 2017, the TCFD published its final report, in which it recommended considering both the risks and the opportunities arising from climate change. All reporting entities, regardless of the sector in which they operate, should disclose information about Climate-related Financial Risks in four areas (Governance, Strategy, Risk Management, and Metrics and Targets) and should use a scenario analysis, including a scenario for limiting temperature rises to 2°C (reference goal of the Paris Agreement), https://www.fsb-tcfd.org/publications/final-recommendations-report.

investment (NGFS, 2019b and NGFS, 2020e). Above all, the NGFS has produced a first set of standard climate scenarios (NGFS, 2020d), to help central banks and supervisory authorities define climate stress tests that are homogeneous and comparable (see Box 6.1).

Interest in this subject on the part of central bankers worldwide is also shown by the numerous speeches by members of the governing boards of the European Central Bank,[30] the Federal Reserve System,[31] the Australian Reserve Bank,[32] the Bank of Canada[33] and the Bank of Japan.[34] The Bank of Italy has also been following the question for some years now,[35] with increasing interest.[36]

The academic world has recently investigated how central banks and regulators should take climate risks into consideration (among others see Batten et al., 2016; Battiston et al., 2017; McKibbin et al., 2017; UN Environment, 2017; Campiglio et al., 2018; Dikau and Voltz, 2018; and Schoenmaker, 2019). A central bank may include climate risk management in its activities with varying degrees of intensity (Dikau and Volz, 2018), starting with projects to raise awareness on these issues, for example by drafting guidelines or by means of other initiatives to inform and raise awareness among bankers, investors and the other stakeholders (including savers). Moreover, a central bank can help the financial market to develop by establishing information requirements (for example, by asking for the TCFD transparency criteria to be applied) or by encouraging the issuance and trading in climate-friendly securities (such as green bonds, see Box 7.4). As a supervisory authority, it can also state what it expects from financial intermediaries in terms of the management and disclosure of climate risks (NGFS, 2020b). For example, the Single Supervisory Mechanism (SSM) has published a list of its non-binding expectations for directly supervised banking groups (SSM, 2020a).[37] The recommendations for climate risk management include their inclusion in credit rating assessment processes, the

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30 Christine Lagarde: 'Climate change and the financial sector', speech by Christine Lagarde, President of the European Central Bank, at the launch of the COP 26 Private Finance Agenda, London, 27 February 2020. See https://www.bis.org/review/r200302c.htm; 'When markets fail - the need for collective action in tackling climate change', speech by Isabel Schnabel, Member of the Executive Board of the European Central Bank, at the European Sustainable Finance Summit, Frankfurt am Main, 28 September 2020. https://www.bis.org/review/r200929e.htm

31 Glenn D. Rudebusch, 'Climate Change and the Federal Reserve', 25 March 2019, https://www.frbsf.org/economic-research/publications/economic-letter/2019/march/climate-change-and-federal-reserve. Governor Lael Brainard, 'Why Climate Change Matters for Monetary Policy and Financial Stability', 8 November 2019, https://www.federalreserve.gov/newsevents/speech/brainard20191108a.htm

32 Guy Debelle, 'Climate Change and the Economy', 12 March 2019, https://www.rba.gov.au/speeches/2019/sp-dg-2019-03-12.html

33 Tiff Macklem, 'From COVID to climate - the importance of risk management', remarks (delivered virtually) by Tiff Macklem, Governor of the Bank of Canada, at The Global Risk Institute, 8 October 2020. https://www.bis.org/review/r201009c.htm

34 Haruhiko Kuroda, 'COVID-19 and the global economy - impact and challenges from Asia's perspective', speech (via webcast) by Haruhiko Kuroda, Governor of the Bank of Japan, at the 62nd Annual Meeting of the National Association for Business Economics, 7 October 2020. https://www.bis.org/review/r201007d.htm.

35 Luigi Federico Signorini, 'The Financial system, environment and climate: a regulator's perspective', 6 February 2017, https://www.bancaditalia.it/pubblicazioni/interventi-direttorio/int-dir-2017/Signorini_06.02.2017.pdf.

36 Ignazio Visco, 'Sustainable development and climate risks: the role of central banks', 21 May 2019, https://www.bancaditalia.it/pubblicazioni/interventi-governatore/integov2019/en_visco_21052019.pdf?language_id=1

37 The SSM directly supervises the significant institutions (SIs) in euro-area countries and, since October 2020, Bulgaria and Croatia. At the end of 2020, 113 SIs were directly supervised by the SSM, representing 82 per cent of the banking assets of the countries involved.

establishment of appropriate climate risk governance (for example, by creating special committees to support top management), the choice of specific metrics and indicators and the use of scenario analysis (see Box 2.1) and climate stress tests (see Box 6.2). Furthermore, the SSM Guide recommends that the largest banks ('significant institutions') should follow the guidelines of the TFCD directive.[38] The SSM Guide also suggests that the national supervisory authorities should extend these recommendations to the other banks ('less significant institutions'). The recommendations of the Guide arose from a consideration by the SSM itself about the gap between a generalized awareness of climate risks and the adoption of appropriate safeguards and measures for their management (see Box 5.2).[39] The European Banking Authority (EBA) reiterated in its 2019 Action Plan that as part of the three mandates relating to climate change, it will proceed with the introduction of risks into the Supervisory Review and Evaluation Process and increase disclosure by June 2021. The EBA reserved the right to make an assessment in relation to micro-prudential interventions by June 2025.

Central banks can not only assess the stability of an individual institution but also that of the entire financial system, by means of tools such as 'climate' stress tests (see Box 6.2) to identify the major risk factors and the transmission channels through which the risks can be propagated. As regards climate-related stress tests, several central banks have conducted or are developing specific tests, often following scenarios outlined by the NGFS. For example, in 2017, the Central Bank of the Netherlands completed a test on its own financial system, including banks, insurance companies and pension funds (DNB, 2017), while France's Autorité de contrôle prudentiel et de résolution (ACPR, 2020) and the Bank of England (2019) are conducting an exercise which will be completed in the next few years. This information can be used to evaluate the use of prudential risk mitigation policies, for example by acting on capital requirements (with 'green supporting factors'[40] or 'brown penalties'[41]).

As investors, central banks can also decide to lead by example by: 1) integrating the consideration of environmental factors into their portfolio management strategy (as the Bank of Italy has decided to do - see Chapter 8), and the Central Bank of the Netherlands and the Monetary Authority of Singapore; and 2) publishing their own exposures and climate risk management strategies based on the TFCD guidelines, as in the case of the Bank of England (2020) or the Banque de France (2018).

[38] The details of the TCFD's recommendations are given in Faiella and Malvolti (2020).

[39] The EBA was also explicitly mandated to study how to incorporate ESG principles into the three pillars of microprudential rules and outlined its own action plan for sustainable finance (https://eba.europa.eu/financial-innovation-and-fintech/sustainable-finance).

[40] 'To incentivize lending, we are looking positively at the European Parliament's proposal to amend capital charges for banks to boost green investments and loans by introducing a so-called green supporting factor. This could be done in the first stage by lowering capital requirements for certain climate-friendly investments, such as energy-efficient mortgages or electric cars. We could model it on existing capital requirement adjustments for investments in SMEs or high-quality infrastructure projects.' Valdis Dombrovskis, 'Greening finance for sustainable business', 12 September 2017, http://europa.eu/rapid/press-release_SPEECH-17-5235_en.htm.

[41] As an alternative to granting a 'discount' on capital requirements to banks that invest their resources in green projects, the brown penalty imposes an increase in capital requirements for institutions that have excessive exposure to carbon-intensive sectors. A comparison between the two approaches is given by the 2 Degrees Investing Initiative (2018).

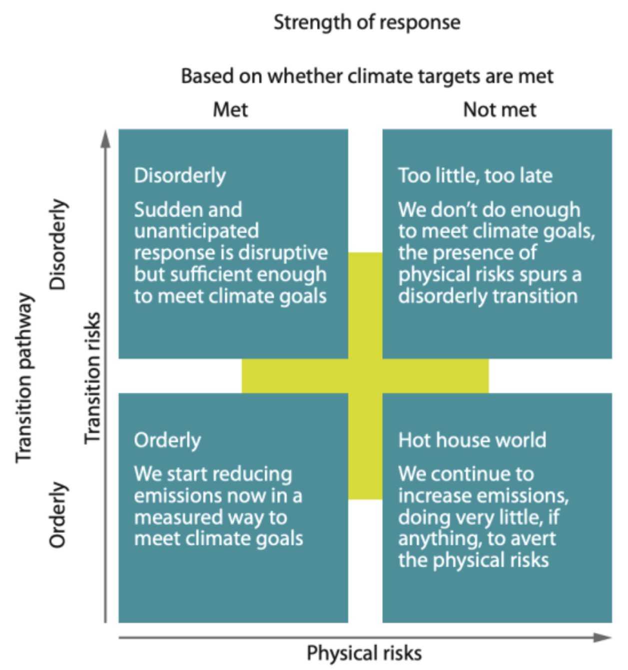
Box 6.1 NGFS scenarios

As a common frame of reference, central banks can rely on the climate scenarios published in June 2020 by the Network for Greening the Financial System (NGFS, 2020d). The three scenarios considered assume that the economic and social variables will follow Shared Socioeconomic Pathway 2 (see Box 2.1) and they combine this trajectory with three different levels of mitigation (see Figure A).

1. The first scenario (Orderly) assumes the adoption of immediate mitigation policies and a rapid transition towards climate neutrality. The increase in global temperature remains below 2° C, in line with the Paris Agreement.
2. The second scenario (Disorderly) evaluates unplanned and late action that then has to be accelerated to reach the objective of keeping the temperature increase below 2° C.
3. Under the third scenario (Hot house world), no new policy is adopted and emissions and their concentrations increase to approach values compatible with a temperature increase of more than 3.5° C compared with pre-industrial levels.

These scenarios aim to represent different combinations of physical and transition risk. The first is the worst-case scenario where no policy has been adopted or, in any case, is too little and too late (the scenarios on the right of the red bar in Figure A. The risk is reduced in the event that the transition process has begun (scenarios on the left of the red bar), but in this case there may be an increase in transition risk, which is at its highest when the transition begins in an unplanned way. Of course, in the absence of any climate policies, there is no transition risk (Hot house world scenario).

Figure A - NGFS scenarios



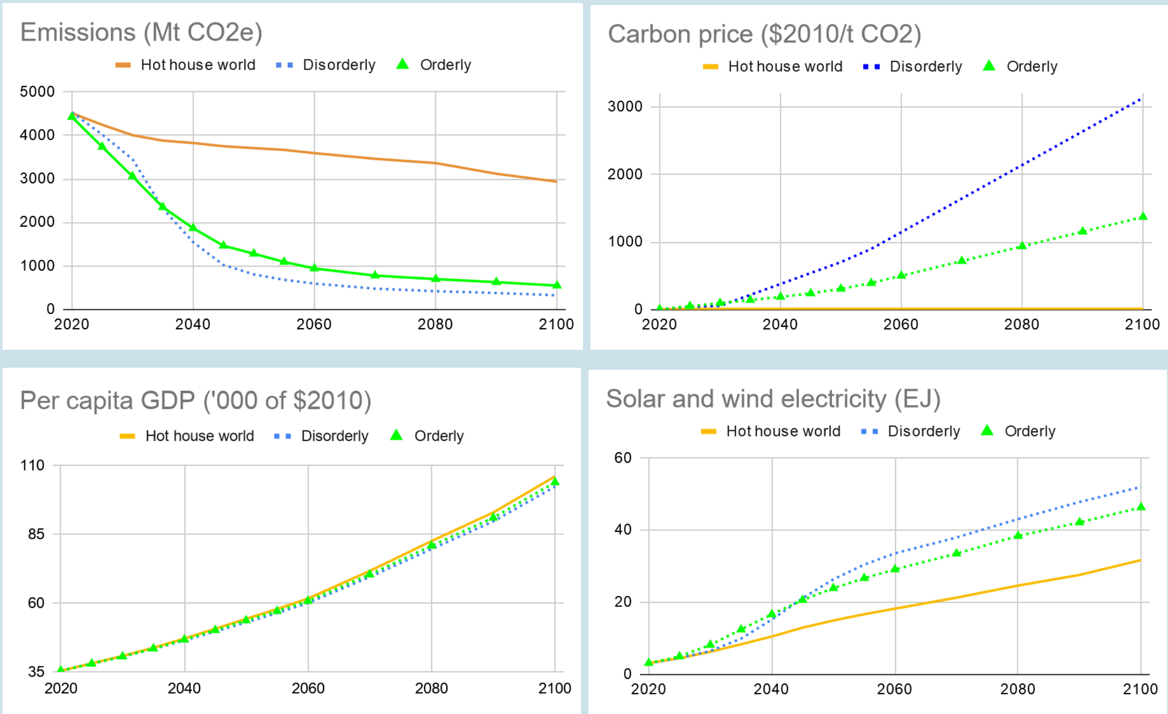
The results of the NGFS scenarios, which emerge from simulations of the various climate model, can be consulted online at (https://data.ene.iiasa.ac.at/ngfs), a site hosted by the IIASA, an independent international research institute that regularly contributes to the IPCC's climate reports.

To understand how these scenarios could be used, we can try to construct a narrative similar to the one presented in Box 2.1, but this time focusing on the impacts for the European Union (Figure B).

In the Hot house world scenario, the EU-28 fails to reach climate neutrality and, at the end of the century, its greenhouse gas emissions still stand at 3 billion tonnes. In the scenario where the transition is planned (Orderly), the price of emissions needed to achieve neutrality is $500 per tonne in 2050 but over $1,000 at the end of the century. If, on the other hand, the transition is sudden and unplanned, the price signal is markedly higher, already exceeding $1,000 per tonne by the middle of the century.

Transition scenarios see an important role for electricity, particularly from solar energy, which by the end of the century is expected to be between 15 and 17 times higher than 2020 figure. Per capita GDP is highest in the Hot house world scenario and lowest in the Disorderly scenario. The Orderly scenario is a compromise between the other two in that there is lower GDP growth. This information, particularly on carbon pricing, can be used for the climate stress test exercises (See Box 6.2).

Figure B - Evolution of selected variables in Europe according to NGFS scenarios



Source: Our calculations based on NGFS Scenario explorer data, https://data.ene.iiasa.ac.at/ngfs. Simulations of the REMIND-MAgPIE 1.7-3.0 model are in reference to the EU-28 area. Ej=exajoule, equal to 10^{18} joules. One Ej is equal to 23.9 million tonnes of oil equivalent.

Box 6.2 Climate stress tests

Conducting climate stress tests over a medium- and long-term horizon can help central banks and supervisory authorities to better understand the implications of climate change for financial stability. In fact, some central banks are integrating climate scenarios and risks into pre-existing stress test templates.[1]

As a first step, when designing a climate stress test, the authorities must define the climate scenarios (Box 2.1 and Box 6.1). To date, the authorities have followed two main approaches. The first, adopted by the Autorité de contrôle prudentiel et de résolution (ACPR, 2020), employs scenarios based on the Integrated Assessment Models (IAM) that are already available. The second, instead, uses ad hoc scenarios, such as those in the stress test conducted by De Nederlandsche Bank (Vermeulen et al., 2018). Both methods utilize several alternative scenarios that reflect different assumptions regarding, for example, the policies deployed to mitigate climate change.

However, unlike the macroeconomic scenarios adopted in standard stress tests, the climate scenarios do not assume extreme shocks ('tail events'), but rather describe trends in economic and climate variables based on plausible hypotheses regarding greenhouse gas emissions, environmental policies, consumer preferences or technological innovation. Consequently, climate stress tests generally tend to raise the environmental risk awareness of financial intermediaries (and of the central banks themselves); they do not, instead, have the goal of setting additional capital requirements.

Moreover, given the uncertainty about climate change and the policies to mitigate it, a broad set of scenarios relating to physical and transition risks is usually considered. The scenarios used are based on different economic and climate models (IAM) and on alternative hypotheses relating to the occurrence of environmental events (chronic or acute, see Chapter 3), to the policies adopted (e.g. the introduction of a carbon tax), to technological innovations in the production of energy (e.g. the storage of electric power generated using renewable sources), and to the behaviour of economic agents (e.g. with respect to preferences and their energy and environmental implications). The climate stress tests conducted so far include both top-down models looking at the short-to-medium term (up to five years) and using data that are aggregated at sectoral level (such as the model used by De Nederlandsche Bank) and bottom-up models considering a longer time horizon (up to 30 years) and employing granular data (such as the stress test to be conducted by the Bank of England in 2021). Given the current state of the art in terms of data, methodologies and tools, special care should be taken when interpreting the results of these exercises. As highlighted by Pindyck (2013, 2017), the results of these models come with several limitations: in the definition of the damage function that determines the share of GDP lost owing to the effects of climate change; in the choice of the intertemporal discount rate to apply (which also indicates the value attributed to welfare provided to future generations); and in terms of climate sensitivity, i.e. the uncertainty about the expectations on what will happen to the temperature if the concentration of greenhouse gases in the atmosphere doubles.[2] These choices imply a value judgment on society's priorities, e.g. on whether to give more weight to one sector or another when choosing the damage function, or more weight to future generations in decisions regarding the discount rate.

[1] This box is partly based on Angelico (2020).

[2] Climate sensitivity represents the range of temperature rises corresponding to a doubling of CO2 concentration compared with pre-industrial levels (280 ppm; in November 2020, a concentration of 413 ppm was recorded in Mauna Loa). The estimates calculated in the 1970s indicated that a doubling of the concentration would lead to a rise of between 1.5°C and 4.5°C. This interval was confirmed, among others, by the latest assessment report of the IPCC (AR5). Some models (CMIP6) report a wider range [1.8°C - 5.5°C], while Sherwood et al. (2020) estimate a narrower interval that reduces the upper bound in particular [2.6°C - 4.1°C].

Lastly, some studies suggest redefining the monetary policy framework to incorporate the effects that climate change on the macroeconomic framework (Batten et al., 2020). Another study (McKibbin et al., 2017) suggests that when central banks define their targets, they should take into account the price effects of climate policies (such as a carbon tax or more extensive use of emission permits); a simple inflation target could mean overly restrictive policies. The adoption of these strategies is further complicated by the high uncertainty surrounding the effects of climate change on potential output.

Box 6.3 Climate change and monetary policy

Monetary policy, together with fiscal policy, is one of the instruments used to pursue economic policy objectives. In Europe monetary policy is conducted by the European Central Bank (ECB) within the Eurosystem. The primary objective of the ECB in conducting monetary policy is maintaining price stability; however, the European Treaties also entrust the ECB with the secondary objective of supporting the European Union's general policies, including those for the protection of the environment. The issues connected with climate change have become increasingly important in the monetary policy debate as well. More recently, debate on these issues has also gained momentum in the Federal Reserve System, which joined the Network for Greening the Financial System (NGFS) in December 2020. The importance that these issues now have as part of European monetary policy debate is also demonstrated by the creation of a dedicated workstream as part of the monetary strategy review, tasked with revising and redrafting the Eurosystem's monetary policy strategy for the next few years. The relationship between monetary policy and climate change can be analysed using both a regulatory and a positive approach. The former considers climate change and the relative effects on the economy as part of the models currently used by central banks to support monetary policy decisions; an example of this is the inclusion of climatic variables in forecasting models to improve their performance. The latter approach focuses instead on the actions that central banks can undertake to facilitate the mitigation policies for climate change adopted by the fiscal authorities. Central banks have a set of tools at their disposal for carrying out monetary policy, expanded since the global financial crisis, e.g. asset purchase programmes and refinancing operations with particular characteristics, that could be adapted both to improve their effectiveness (also with a view to pursuing the secondary objectives described previously) and to guarantee greater protection for their balance sheets (in terms of exposure to climate risks). As a protection against the risks connected with monetary policy operations, the Eurosystem has drawn up criteria for the requirements for both counterparties and for the pledged collateral (in terms of credit ratings, duration and haircuts). The sphere of risk management includes the debate on how central banks might consider climate risks, either proactively or protectively. In the first case, the operations for refinancing the banking system and the asset purchase programmes could be recalibrated to foster the climate-related transition both by banks and by the firms. In the second case (protective mode), central banks could confine themselves to reducing the climate risks to which they are exposed through their financing measures and portfolios of purchased securities. In both cases, it is vital to identify the sources of climate risk and measure their dimensions in order to be able to manage them by adjusting the tools.

Matikainen et al. (2017) suggest that the current set-up not only does not protect the budget of euro-area central banks, but also tends to create unfavourable conditions for the climate-related transition of financial institutions and firms. Most of the guarantees and securities of private issuers held by central banks relate to firms in the hydrocarbon, automotive and transport sectors, which have high levels of carbon emissions and high capital intensity (Doda, 2016), which actually lowers the cost of capital by giving a signal to the markets that discourages the transition (Schoenmaker, 2019).

It should be borne in mind that the principle of market neutrality, generally adopted by central banks in their actions, is a significant constraint (see Box 6.4). This principle is designed to prevent distorsions and to ensure the smooth functioning of the market in which they operate. If the tools are revised, it is therefore important to produce a set-up that does not jeopardize the functioning of the market, and that at the same time creates favourable conditions for the climate-related transition.

Some studies (Matikainen et al., 2017; Dafermos et al., 2018) observe that central banks' purchases of private sector securities for unconventional monetary policy operations tend to be directed predominantly towards companies with a high carbon footprint, as a consequence of the principle of market neutrality, aimed at containing any potential distorting effects of central bank action on market prices and volumes (see Box 6.4). The fact that the bonds issued by carbon-intensive companies constitute a significant share of the debt market means that central bank purchases are biased towards the sectors in which they already operate. In this way, monetary policy operations would help lower the cost of capital by encouraging these sectors to fund further investment (Schoenmaker, 2019). On the contrary, this would penalize companies operating in the renewable energy sector, which, instead, tend to raise funds mainly through equity (Monnin, 2018).

According to this interpretation, we should move beyond the principle of market neutrality for two reasons: first, because it runs counter to the decarbonization targets (see Chapter 3); moreover, if the prices of debt instruments do not adequately reflect climate risks, the central bank is potentially exposed to sudden adjustments in the values of financial assets, induced by the transition process (see Box 4.1). For this reason, it is proposed that, for monetary policy operations, preferential treatment be given to instruments issued by entities operating in sectors resilient to climate change (Matikainen et al., 2017).

In order to reconcile the different aims of the central bank, it is, however, necessary to identify an equilibrium point that balances climate neutrality and market neutrality, which is an important condition for the orderly functioning of the markets. In this context, we will also have to discuss whether to go beyond the concept of market neutrality (see Box 6.4).

Box 6.4 Market neutrality and climate risks

Market neutrality is a principle that central banks follow in carrying out their institutional activities to ensure that they do nothing to distort the functioning of the markets where they operate or to interfere with the correct pricing of assets (Wuermeling, 2018; Bindseil et al., 2017). This principle generally translates into maintaining a composition corresponding to that of the market in their interventions.

Taking account of climate risks, the current market composition poses a dilemma for central banks because of the significant divergence between market neutrality and carbon neutrality. Firms with high greenhouse gas emissions are currently among the biggest issuers of shares and bonds, such as those in the automotive, basic materials, transport and utility sectors, for which transition risk is higher. Firms in these sectors are typically larger and more capital intensive, and their fixed assets have longer-term investment horizons than other sectors. As a result, they resort more often to capital markets for funding. In addition, the increasingly common practice among investors of replicating market composition ('passive investing'; Silver, 2018) creates a comparative advantage in terms of the cost of equity (Nagel, 2016) for firms more present in the markets, encouraging a status quo incompatible with the emission reduction targets.

The increasing interest in climate risks and in their effects on prices and on the stability of financial markets has led central banks to wonder whether the current market mechanisms are sufficient to include such risks in the valuations of financial assets. If climate risk were appropriately priced, the most exposed activities/firms would bear the cost of this risk, while greener firms would not; in this case, market neutrality would coincide with carbon neutrality. In a situation like this, central banks could pursue market neutrality without shifting the economic system away from carbon neutrality.[1] A number of factors suggest that this has not happened, although the empirical evidence is still scarce and inconclusive; this issue will therefore require further analysis.

The factors to be considered include the mismatch between the typically short time horizons of financial management, and the much longer ones of climate change, making it complicated to integrate climate risk into the outlines of modern finance theory (Thoma et al., 2017). A second element is the above mentioned lack of data in terms of time frames (the time series data on climate risk are not very significant with respect to the expected impacts, while the time series on financial impacts are too short), and also in terms of asset classes (e.g. government securities have the biggest data gaps; Hong et al., 2018). Lastly, risk management practices that include climate risk are still not common among financial and banking intermediaries at national and global level,[2] in part because of the lack of shared methodologies (NGFS 2020c; Andersson et al., 2016).

In the event that current prices do not reflect climate risks, the role of central banks as guardians of financial and price stability may require them to intervene so that the energy transition can take place gradually, with no sharp fluctuations. In this case, the intervention of central banks to encourage the integration of climate risks into market prices would not constitute interference with the functioning of the market but would instead serve to make it function correctly.

On the other hand, a central bank stance that only respects the principle of market neutrality could slow down the transition of financial markets towards climate neutrality. Looking ahead, favoring investment in financial assets issued by firms with lower carbon emissions, increasing their market share, could be usefully supported by a proactive attitude on the part of central banks.

[1] Carbon neutrality means essentially reducing emissions to zero. Net carbon neutrality means achieving a balance between greenhouse gas emissions and their removal (emissions are equal to removals). The term climate neutrality is also used sometimes.

[2] Italian Observatory on Sustainable Finance (2019), the Climate Risk for Finance in Italy, Report of Working Group 3.

7. From climate risk to sustainable finance

The significant resources necessary to fund projects advancing the transition towards a low-emissions economy, coupled with investors' increasing focus on environmental issues and the risks stemming from climate change, have contributed to the rapid growth of green finance. The development of the market for sustainable financial instruments depends crucially on the quality and reliability of the data backing investment decisions, and it is not devoid of risk, both for investors and for the environment itself. Only a system of shared data, methodologies and principles that enables the assessment of the various dimensions of sustainability can reroute private capital towards the desired objectives.

In the last five years, green finance has grown significantly, and nowadays represents a market trend in its own right. According to a report by the Global Sustainable Investment Alliance, in 2018 at least $30.7 trillion (of which $14 trillion in Europe and $12 trillion in the United States) were used for sustainable or green investments, up by 34 per cent compared with 2016. Overall, these investments accounted for one third of global managed assets, a share rising to more than half in some jurisdictions.

Green finance comprises sustainable investments carried out through several kinds of financial instruments built using sustainability metrics that have become popular among operators. One of these metrics is ESG scores. Based on information obtained from publicly available documents, questionnaires, data or news archives and other sources, some private-sector data providers have developed scores of firms relating to three areas not strictly connected to their core business, i.e. environmental, social and governance aspects. By aggregating these scores (weighted according to different criteria to obtain the final score), investors are provided with two types of information: 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 by consumers or of penalties for illegal conduct, reputational risks and so on) and 2) its ability to seize new opportunities (i.e. in terms of innovation and efficiency in its processes and of competitiveness of its products) through sound practices (e.g. contributing to internalizing negative environmental externalities by generating low levels of waste, or having a high percentage share of women in managerial positions).

ESG scores are attributed to a broad range of financial instruments: equity, corporate bonds, investment funds and market indices. According to a report by the Global Sustainable Investment Alliance, making purchases or sales on the basis of ESG scores is one of the most popular sustainable investment strategies, and the market crisis due to the pandemic has not changed this consumer preference (see Box 7.5).

Notwithstanding its widespread use, this metric has several problems. First of all, the way in which the individual factors are evaluated and then aggregated into the overall scores remains opaque for the most part, making it hard to judge the actual environmental, social and governance quality of the asset in question, regardless of the overall score.[42] The arbitrary choice of the metrics to include in the processing and aggregation leads to significant

[42] For example, it is not clear how much a satisfactory performance of the individual E, S and G components is determined by current performance (e.g. low atmospheric emissions recorded in the latest data) and how much is determined by the will and capacity to achieve future goals (e.g. the existence of an emissions reduction target).

inconsistencies in the scores obtained by different providers, highlighting the limitations of applying ESG scores to investment decisions (see Box 7.1). The fragility of these indicators increases the risk of 'greenwashing', i.e. the improper use of the label 'green' to mislead potential clients and investors. Indeed, the fact that there is no obligation to oversee firms' non-financial communication and the prevalence of non-standardized indicators and qualitative data in this field leave room for altering the true sustainability performance of the firms being evaluated in order to attract capital to the markets.

Box 7.1 ESG scores: limits and possibilities

Good-quality information is essential both for assessing the sustainability of investments and for redirecting the financial resources needed for transition. To this end, ESG scores are often used to summarise the assessment of environmental, social and governance sustainability of issuers such as firms, States, supranational organizations and collective investment schemes (UCITs and ETFs). The scores are provided by specialized companies that have developed their own assessment methodologies, which they offer on the market together with ancillary services such as instruments for screening the sustainability of issuers, for reporting and monitoring ESG disputes. There is an ongoing process of global consolidation on the market around the biggest ESG ratings providers, with the acquisition of smaller providers that are often highly specialized in terms of assessment and geographical focus. Credit rating agencies are also taking part in the process, since in the last few years they have begun to integrate ESG profiles into their credit assessment.[1] ESG scores are widely used in the field of sustainable finance for selecting financial instruments, building investment portfolios, creating market indices and reporting. Nevertheless, it is important that their use be accompanied by an awareness of the current limits of such instruments, especially in terms of the varied nature of the methodologies and of the completeness and quality of the information provided. Various studies have shown that the providers often give very different scores to the same issuer, which translates into a low correlation for the scores given, on average close to 40-50 per cent. The reason is the lack of consolidated benchmark models such as those for financial evaluations or credit ratings, which has led the providers to create very different assessment methodologies on which they have built their competitive advantage. The methodological differences mainly concern the identification of the sustainability factors considered when calculating the scores (such as the use of natural resources, waste management, safety in the workplaces and for consumers, and the composition and skills of management) and the metrics used to measure these factors (Berg et al. 2019). The ESG factors considered by the providers to be important vary according to the sector of activity and the firm's business model. In addition, they vary depending on whether the investor's point of view is considered, who is only interested in factors that may have a financial impact on the firm (financial materiality) or the point of view of external stakeholders, who are interested in all factors that may have a significant impact on the environment and on the society (sustainability materiality). Furthermore, the factors' relevance vary over time in relation to the progress in technology and changes in public policies and social phenomena (dynamic materiality) (Rogers et al. 2020). To identify the factors, the providers use their own specific quali-quantitative analyses; little of their information is disclosed to the outside world in order to protect their intellectual property. As regards the differences in the indicators used to assess ESG factors, the main cause is the quality of corporate disclosure, which is the main source of data. The lack of uniform regulations for non-financial communication as regards standardized definitions and reporting formats implies neither a categorical interpretation nor a homogeneous evaluation of the data is possible. This results in a marked heterogeneity in the quantity, quality and types of indicator provided (Kotsantonis et al. 2019), with differences by geographical area, sector of activity and firm size, which pushes providers to make up for the missing or non-comparable data by using estimated data or alternative data sources to corporate ones.[2]

With regard to the completeness and quality of the information incorporated into the ESG scores, it has often been observed that they mainly provide indications on past situations and current controversies, but that there is very little information useful for predicting the evolution of sustainability performance or the risks of future controversies. This limitation essentially depends on three circumstances: corporate disclosure is mainly based on backward-looking indicators; the strategies and commitments for firms' sustainability are often very general and not accompanied by quantitative objectives; and risk analysis often refers to the short and medium term (EFRAG, 2020).

Lastly, when using ESG scores, it should be remembered that they express an assessment that synthesizes various sustainability factors and therefore do not represent solely the environmental profile, or more specifically, the issuer's exposure to climate risk. These aspects only combine to formulate an ESG score if they are held to be relevant for assessing the issuer, and their capacity to influence the score depends on the relative materiality assigned to them compared with other factors considered, so there is no direct relationship. This also emerges from some studies that find a negative relationship between ESG scores and firms' greenhouse gas emissions. The data on the three profiles - environmental, social and governance - are also differentiated by their quantitative or qualitative nature, the level of coverage and the uniformity of definitions; these differences make the processing of information complex (OECD, 2020a).

In the European context, the initiatives in the Action Plan on Sustainable Finance will considerably increase the availability of information and the harmonization of the definitions for assessing sustainability profiles. Specifically, the EU directive on non-financial reporting currently only obliges firms with more than 500 employees to do so and does not establish any uniform formats for disclosing information. The revision of the directive under way aims to increase its scope and make the information required more comparable.

[1] Nevertheless, there is still not a sufficient level of transparency for all agencies as to how sustainability factors influence credit risk assessment; this aspect may raise doubts among investors and others that use the ratings, and looking ahead, more information will be needed on the methodologies used by ratings agencies. Subcommittee on Climate-Related Market Risk of the Market Risk Advisory Committee (2020). Managing Climate Risk in the US Financial System: Report of the Climate-Related Market Risk Subcommittee, Market Risk Advisory Committee of the U.S. Commodity Futures Trading Commission.

[2] As regards the limitations of disclosure, it has been found that the information is often qualitative, the time horizon of the analyses and forecasts favours the short and medium term and only a few firms set quantitative sustainability targets (The 2nd Investing Initiative, 2017).

The difficulty of obtaining reliable and consistent ESG scores is due to the fact that, for the three aspects considered, there are no shared reference guidelines or taxonomies that can be used as benchmarks. Several national and supranational institutions are promoting the development of taxonomies that can serve as a benchmark for the markets. Between 2018 and 2020, a group of experts brought together by the European Commission put forward an EU taxonomy for sustainable activities, which has identified objective criteria – currently only for the part relating to climate change – to define a firm's activity as environmentally sustainable (see Box 7.2). Only with the adoption of detailed and internationally recognized taxonomies will it be possible to enable sustainability-conscious investors to invest their capital according to sustainability criteria.

Box 7.2 Taxonomy: an attempt at a harmonized classification of green activities

With the 2018 Action Plan for financing sustainable growth,[1] the European Commission deemed it necessary to involve the private sector in financing the decarbonization of the European economy. The additional investment needed to reach these objectives ranges between €127 and 270 billion per year (Alessi et al., 2019a), which is too big to be covered by the available public resources. Moreover, the Commission recently made the targets for 2030 even more challenging (-55 per cent), with a subsequent increase in the resources to be raised (see Box 3.1). Creating a harmonized system for classifying sustainable assets, i.e. the Taxonomy, is the first fundamental step towards redirecting private capital flows towards sustainable economic assets, at the same time avoiding 'greenwashing'. To this end, a Technical Expert Group (TEG) on Sustainable Finance has been working since July 2018 on providing the Commission's offices with some discussion points. The TEG published its final report in March 2020, and a few months later, the Commission published the Regulation (EU) 2020/852, which came into force on 12 July 2020 and established disclosure obligations for large firms and financial market players operating on EU territory. Specifically, since 2022, large firms subject to non-financial disclosure obligations (see Box 5.1) will have to publish the share of turnover and investment connected with sustainable assets (with reference to the financial year 2021), as set out by the Taxonomy and with reference to the first two environmental objectives: climate change mitigation and adaptation. Similarly, any firm wishing to sell a financial product defined as sustainable in the European Union is obliged to prove its adequacy with respect to the criteria of the Taxonomy (by 31 December 2021 for products that already exist).

The Regulation states that an activity is defined as sustainable if it meets the following requirements: 1) it contributes substantially to at least one of the six environmental objectives;[2] 2) it does not significantly harm any of the other environmental objectives (DNSH); 3) it is in compliance with the minimum safeguards; and 4) it complies with technical screening criteria (TSC). The latter are an essential element for making the classification operational. There are some particular activities, defined as 'enabling', which enable other activities to make a substantial contribution to the environmental objectives, at the same time without being a source of significant damage (for example the manufacturing of components for using renewable sources to generate electricity).

The Taxonomy Regulation delegated the definition of the technical screening criteria to the delegated acts (secondary legislation) issued by the European Commission: a draft for the first two environmental objectives (climate change mitigation and adaptation), inspired by the TEG's previous work, was submitted for public consultation on 20 November 2020. For the subsequent delegated acts, to be published by 2022, the Commission will instead rely on a committee of experts (Platform on Sustainable Finance).

The Taxonomy has already become a point of reference for other jurisdictions as well, such as the United Kingdom, which recently announced the adoption of a Taxonomy that will draw inspiration from the European one.[3] However, the decision to exclude some technologies, such as nuclear or natural gas (the latter because it exceeds the threshold of 100g of CO2e/kWh) has caused considerable problems because it could make it impossible to use bridge technologies and that could make the decarbonization process more gradual.

[1] Action plan for sustainable finance, COM(2018) 97 final, Brussels, 8.3.2018.

[2] The six objectives are: climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources; transition to a circular economy; pollution prevention and control; and protection and restoration of biodiversity and ecosystems.

[3] The Chancellor sets out ambition for future of UK financial services, 9 November 2020 (link).

With a view to reducing the financial risks stemming from climate change, investors use specific investment strategies that factor in climate risks in the risk-return evaluation of the assets in their portfolios (see Box 7.3).

Box 7.3 Sustainability profiles and investment strategies

The bulk of the evidence according to which sustainable factors have a positive influence on the corporate financial performance (Clark et al. 2015, Friede et al. 2015), and particularly the greater consideration of climate risks, has prompted investors to integrate ESG information into their investment decisions. In their broadest sense, sustainable and responsible investment strategies are long-term investment methods that integrate ESG factors into the research, analysis and selection of securities and into the financial management of portfolios. These methods combine the fundamental analysis of firms with an assessment of ESG profiles to achieve benefits both for investors in terms of yield and for society by influencing its behaviour.[1] Based on a widely adopted classification, drawn up by Eurosif and using the United Nations' Principles for Responsible Investment (UN PRI),[2] sustainable investment strategies can be divided into five types: 1) exclusion or screening of some securities or sectors, based on national rules or international treaties (e.g. referring to weapons and tobacco); 2) best in class, focusing on a positive selection of firms with the best ESG characteristics compared with other comparable firms, with reference to the economic sector or in general; 3) ESG integration, which consists of the explicit and systematic inclusion of the most important ESG factors in traditional financial analysis; 4) theme-based or positive impact investment, designed to generate a positive, voluntary and quantifiable impact in certain areas, including environmental ones (e.g. energy, water and waste) together with financial returns; and 5) shareholder voting and engagement with firms, as a tool for maximizing risk-adjusted returns, improving corporate conduct and contributing to sustainable development; in some cases (e.g. for pension funds), this activity is seen as a fiduciary duty t. These strategies are not mutually exclusive, but they can be combined and can also be tailored to specific climate-based criteria and objectives or to broader ESG criteria. According to the latest survey conducted by Eurosif (2018) on professional European asset managers, at the end of 2017, exclusion strategies were the most used, followed by shareholder voting and engagement, with a marked growth in ESG integration in the two years 2016-2017.

[1] The survey involved 263 professional investors with €20,000 billion of assets under management, equal to a market coverage of 79 per cent (Eurosif, 2018).

[2] This initiative was launched in 2005 by the United Nations with the involvement of a network of investors that drew up six principles and guidelines for making responsible investments.

Besides the different strategies, sustainable investments cover a broader range of financial instruments compared with that for which ESG scores are available. To fund individual projects with specific sustainability features, firms turn to debt as well, both in the form of loans and of bond issues. Among the latter, the most common are 'green bonds'. Green bonds are bonds whose proceeds are used to finance investment projects connected with the environment (see Box 7.4). There are some issues with green bonds too. First of all, while criteria have been established for ensuring that the proceeds are used for pre-set green goals, it is not always possible for investors to have access to that information or to monitor the development of a project, exposing them to the risk of greenwashing. Second, green bonds are not intended to reduce the overall environmental impact of the issuer: firms that issue green bonds to finance specific projects might increase their environmental impact in other domains, or carry out activities that entail a rise in their atmospheric emissions. In this respect, a green bond does not identify the issuer as environmentally virtuous, nor does it guarantee a low level of climate risk for the issuing firm or for the project itself. Investors choosing green bonds must be aware of both these aspects.

Moreover, a green bond may be issued with the additional objective of mitigating climate change or adapting to it, or to pursue related goals. Besides green bonds, several instruments specifically designed to combine climate and sustainability objectives are becoming more widespread. Examples include sustainability-linked bonds, climate-aligned bonds and transition bonds. However, these bonds still have a limited presence in the markets.

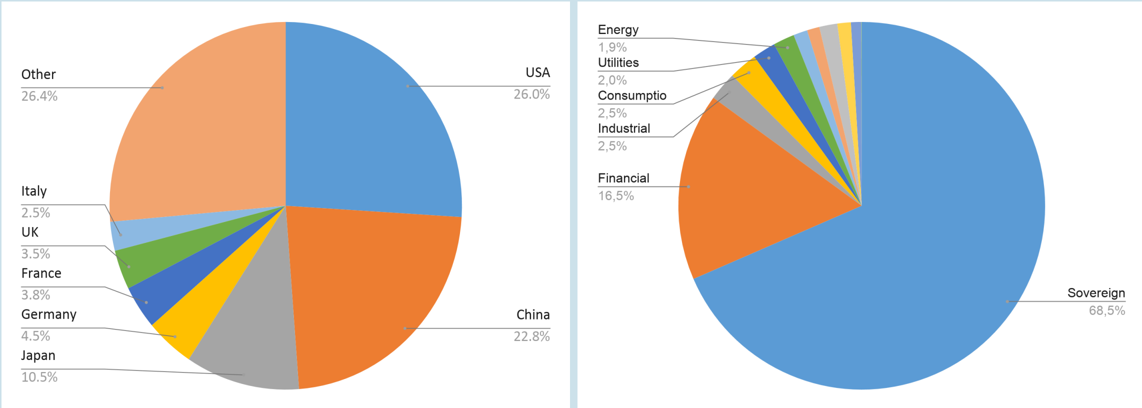
Box 7.4 The development of green bonds

Green bonds are instruments designed to raise resources for financing or refinancing projects designed to tackle environmental problems, including climate-related ones. In channelling resources towards environmental objectives, green bonds are an example of how finance can contribute to the transition to more sustainable systems. These instruments adopt a similar structure to that of other bonds but have a specific constraint on the use of proceeds, for which an annual report is required to inform investors about its actual use. Projects eligible for financing cover a wide range of initiatives: energy efficiency, renewable energy, transport networks, natural resources management, and so on.[1] A green bond label is only assigned to instruments that meet the exact conditions laid down by international guidelines, including the International Capital Market Association (ICMA) principles, the Climate Bond Initiative's standards and those recently approved by the European Union. Verification of the requirements set by the standards, adopted by issuers on a voluntary basis, is carried out in most cases by means of independent verification. Since the introduction in 2007-08 of the first green bonds by the European Investment Bank and the World Bank,[2] the market for these instruments has grown considerably both in terms of amounts, exceeding $1,000 billion at the end of 2020,[3] and of their level of sophistication. Issues of bonds by supranational institutions and by development banks have been joined by those of firms, especially financial firms and firms from the utility, automotive and real estate sectors. Private firms are currently the most numerous issuers of green bonds, while the largest share of the volume of emissions belongs to financial issuers. The first government issues were at the end of 2016, and so far, 16 States have issued more than $80 billion of green bonds (OECD 2020b). These issues have rapidly reached the highest share among the various issuers (68 per cent), buoyed by the desire of issuers to diversify the investor base and to lengthen the maturity of their issues; green bonds typically have longer than average maturities since they are linked to the financing of long-term projects. A growing interest on the part of institutional investors has contributed to the strong market growth. With the outbreak of the pandemic, there was a slowdown in issues for environmental projects, against a strong growth in bond issues for financing social projects and in those that consider both aspects (sustainable bonds), fostered by the publication of the new ICMA principles in April 2020.

Despite its rapid growth, the green bond market is still limited and has a share of global bond issues equal to 5 per cent (IEA, 202b); the share is 0.1 per cent in the government sector of OECD countries.[4] The high demand for these instruments on the part of long-term investors contributes to making the secondary market illiquid and thin; as a result, the price signals available from the market and the comparisons of returns with ordinary bonds having similar characteristics are not very significant. Analyses for identifying systematic differences in returns between ordinary and green bonds have produced mixed results because of the differing definitions and characteristics of the instruments and the underlying green projects (Hachenberg et al., 2018; Karpf and Mandel, 2018; Alessi et al. 2019b; Zerbib, 2019). Nevertheless, it would seem that, even taking account of the additional costs for the structuring and reporting of green bonds (Ceci, 2016), issuers could benefit from lower interest rates on new issues than those for ordinary bonds, thereby reducing their capital costs (Gianfrate et al., 2019). This is prompted by the fact that firms that disclose more information and demonstrate greater corporate social responsibility are seen as being less risky by investors, who are therefore disposed to accept a proportionate remuneration (Oikonomou et al.; 2011; Polbennikov et al., 2016).

Figure A - Main features of the green bonds in circulation

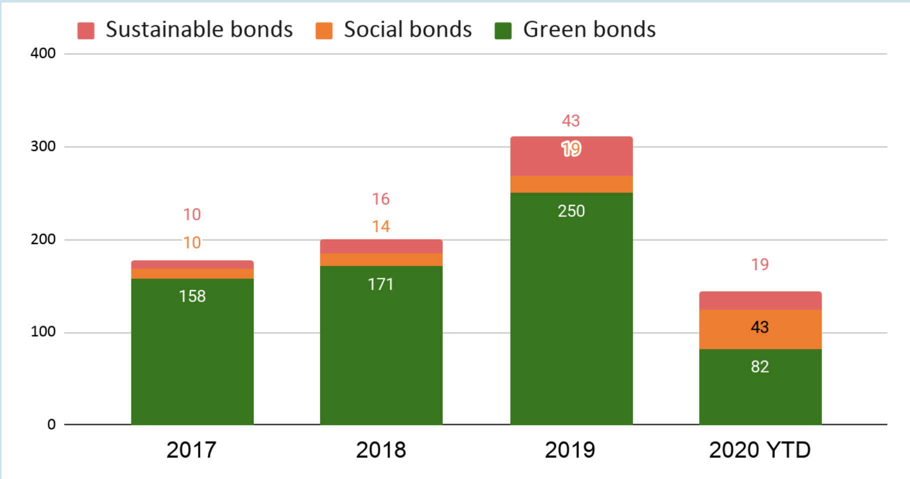
By issuer country *By sector*



Source: Our calculations based on Bloomberg data as at 26 November 2020.

Figure B - Yearly issues of green, sustainable and social bonds

(billions of euros)



Source: Climate Bond Initiative

The differences in the definitions envisaged by the various standards make it more complex for investors to assess the green content and positive impact of the projects financed and ultimately complicate any comparison of the instruments. This difficulty is increased by the differences in standards and certification between jurisdictions. Looking ahead, a greater harmonization of the definitions for green bonds, more transparency and easier access to information to foster the development of this segment of the sustainable financemarket are all recommended.

Another important aspect is linked to the significant market share of green bonds for firms with a high carbon footprint, which shows how the label on the issues does not necessarily indicate that the issuer is 'green'. In this regard, the dissemination of environmental ratings for issuers could integrate the current certification system for the individual bonds issued; it would be additional information for investors and an incentive for firms to improve their environmental impact (Elhers et al., 2020).

[1] Green bond issues are mainly directed at projects in the energy (34 per cent), real estate (25 per cent) and transport (17 per cent) sectors.

[2] In the case of the BEI, these were 'climate awareness bonds'. In 2008, the World Bank issued the first 'green bonds'.
[3]https://www.climatebonds.net/2020/12/1trillion-mark-reached-global-cumulative-green-issuance-climate-bonds-data-intelligence.
[4] OECD (2020c)

Box 7.5 SUSTAINABLE INVESTMENT AND THE PANDEMIC

The tendency of markets to favour sustainable investment has continued uninterrupted following the crisis triggered by the COVID-19 pandemic. The marked fall in the stock markets that ensued was caused by the economic effects of the public health emergency and by the fact that the pandemic crisis took investors by surprise, as they had focused more on environmental and technological risks (WEF, 2020). In this situation, the prices of mutual funds and ETFs with high ESG scores withstood the sharp fall in share prices seen in February-March 2020 better on average than other securities on the market. Although this is partly due to the composition of ESG funds, which are not usually very exposed to firms linked with fossil fuels and with a large share of big US technological firms, the importance given to environmental, social and governance factors seems to have played an important role (Morningstar 2020a). Ferriani and Natoli (2020) show how, between the end of February and the beginning of May 2020, equity investment funds composed of firms with low ESG risks were the only ones with net inflows; of the ESG components, the environmental one also appears to have played a significant role, not directly linked to the need to safeguard against further falls in prices because of the pandemic. The same thing has been observed in the bond market, where the European indices for corporate bonds with the best ESG scores recorded a performance with better returns thanks to lower downside risks (Morningstar 2020b). This tendency may persist over the next few years, supplying capital to, amongst others, low-carbon sectors.

8. The Bank of Italy and sustainable finance

Based on the evidence of the positive relationship between good ESG practices and risk-return profiles, since 2019, the Bank of Italy has been integrating sustainability criteria into its investment policy to improve the management of financial and reputational risks and to help achieve its sustainable development objectives. This has led to significant improvements in its carbon footprint and has been extended to other types of activity.

For some years now, the Bank of Italy has stepped up its analysis and actions to measure and manage risks using sustainability criteria, being aware of their importance for carrying out its institutional mandate and managing its investments.

The Bank has indeed included sustainability criteria into its investment policy, based on the fact that good ESG practices are usually associated with better economic and financial performances. Indeed, most studies show that, from an investor point of view, paying attention to ESG profiles has positive effects on limiting legal and reputational risks, on the operational performance of firms in portfolios (thanks to the care taken in innovating processes and products) and on the perception of firms' own risk profiles. All of these factors help to reduce the risk premium of the investment and the cost of equity, bringing advantages in terms of risk-adjusted financial performance.[43]

The recent experience during the outbreak of the COVID-19 pandemic has confirmed previous evidence (Hoepner et al., 2020). Securities with high ESG scores - both individual firms and investment funds - have proved more resilient to sudden market corrections, because greater assets' sustainability, especially from a social and environmental point of view, are perceived as safer in times of heightened risk aversion (see Box 7.5).

With these considerations in mind, in 2019, the Bank of Italy began to include sustainability criteria in its financial investment policy, also to signal its commitment to fostering sustainable growth and its attention to social and environmental issues.[44] The new investment policy was initially applied to the equity segment, where ESG information is more readily available, and focused on the Italian and European markets. The integration of ESG profiles into investment management has taken place gradually, taking into account the limits of the available ESG scores and the evolution of the scoring techniques for different providers. Analyses and simulations have been used to assess the best ways to select the most relevant ESG data from different providers, in order to create financially efficient portfolios.

In 2020, the ESG strategy was extended to equity investments in United States and Japan markets by shifting capital to ETFs with good sustainability profiles; this strategy was also applied to the management of corporate bonds using ESG benchmarks. Furthermore, the Bank has started to also purchase green bonds issued by supranational agencies. The Bank regularly provides the general public with information on the results achieved in the Report on Operations and Activities, the Environment Report and on its website. In addition, the Bank continues to carry out analysis and research to support the investment and methodologies adopted, in part to overcome the above mentioned problems of these assessments (see Box

[43] Friede et al (2015). Clark et al. (2015).
[44] 'The Bank of Italy values sustainability in its financial investments', Bank of Italy website.

7.1). In order to set an example and be a reference point for other investors, the Bank's experience of sustainable investment practices was published in the NGFS Guide for sustainable investment by central banks and in the subsequent Progress Report (NGFS, 2019a and NGFS, 2020e).

The methods for integrating ESG considerations into equity portfolio management are inspired by the principles of diversification and market neutrality (see Box 6.4) that are typical of a central bank's investment policy, and supplement them with criteria based on ESG factor assessments (see Box 8.1). Taking account of the current evolution in the ESG rating methodologies, it was decided to proceed gradually, keeping customized benchmarks and based on market capitalization, with no specific ESG filters.

Box 8.1 The Bank of Italy's sustainable investment policy

The management of the listed equity portfolio, globally diversified between Italy, other euro-area countries and, to a lesser extent, the USA and Japan, is inspired by a general principle of market neutrality (see Box 6.4), and is implemented by replicating benchmarks. In order to steer investment towards sustainability objectives, this principle has been integrated criteria based on ESG factors. The ESG criteria adopted envisage: 1) excluding from the investment universe those companies mainly operating in sectors not compliant with the United Nations Global Compact (tobacco and controversial weapons[2]); and 2) favouring companies with the highest ESG scores, according to the assessment made by a carefully selected data provider ('best in class' approach). The general objective is to maximize the ESG score of portfolios while reducing their carbon intensity (ratio of greenhouse gas emissions to turnover).[1]

These integrated investment policies apply the following criteria to each of the portfolios specialized into geographical areas.

The Italian portfolio replicates an Italian stock exchange index, made up of firms with an average capitalization of over €500 million, and suitably customized to exclude securities from the banking, insurance, financial services and media sectors. The weights of this customized index are proportional to the market capitalization of each security, and the portfolio is constructed with the following constraints:

- the stake in each company in the portfolio can vary according to the ESG scores by ±0.25 per cent compared with the corresponding stake in the customized index;
- the weight of each sector cannot exceed the corresponding weight in the index by more than 3.5 per cent;
- the carbon intensity must be below that of the benchmark.

The euro area's equity portfolio replicates a broadly diversified market index, which excludes Italian shares and bank, insurance and financial services securities. To reduce the transaction and operational costs, the replica is made with a sampling method, employing a subset of securities. The econometric model for the sampling replication is based on five macroeconomic factors and includes the ESG criteria, excluding securities with an ESG score lower than a predefined threshold.

The replication framework is controlled by minimizing the deviation of the expected return of the portfolio compared with the benchmark (measured by the standard deviation of the relative return, or tracking error volatility) and by complying with the following constraints:

- the deviation of each sector's exposure compared with the index is within a constraint of about 1 per cent;
- any shifts in the weight of each security are limited compared with both the security's weight in the index and the corresponding shareholding in the index.

The US and Japanese equity portfolios consist of units of collective investment undertakings selected among those that implement a passive strategy of ESG indices.

The equity portfolios of Italy and the rest of the euro area are subject to a quarterly rebalancing to adjust their composition to variations in the benchmarks.

As mentioned previously (see Box 7.5), in the months following the outbreak of the COVID-19 pandemic, the performance of equity portfolios with ESG criteria was better than the respective traditional non-ESG benchmarks, in terms of higher yields and lower volatility.

The corporate bond portfolios are composed respectively of bonds denominated in euros and in US dollars. In 2020, the management of the former was internalized, while that of the latter remained under external management; ESG-type benchmarks were adopted for both portfolios.

Investments in green bonds began in 2019 through subscription to a Bank of International Settlements (BISIP) fund that invests in dollar-denominated green bonds mainly issued by supranational institutions. Green bond investments were subsequently expanded via purchases of securities denominated in a number of currencies and issued by governments, agencies and supranational bodies.

[1] The application of a carbon intensity criterion occurred following research into techniques for selecting ESG indicators that are the most relevant for creating equity portfolios that are efficient from a financial point of view. These analyses were conducted by applying machine learning techniques (Lanza et al., 2020).

[2] The weapons banned by the Ottawa Convention (anti-personnel mines) and the Oslo Convention (cluster munitions).

At the end of 2019, the equity portfolio supplemented with ESG factors was characterized by carbon emissions that were 18 per cent lower than the benchmark and 30 per cent lower than the previous portfolio at end-2018. The energy consumption associated with the portfolio was 12 per cent lower than the benchmark and 34 per cent lower than in the portfolio at end-2018. Water consumption was 43 per cent lower than the benchmark and 16 per cent lower than in the previous portfolio. These improvements in the savings portfolios in terms of environmental impact are equivalent to cancelling the annual energy consumption of about 140,000 households and the water consumption of more than 123,000 households. The results are also significant for the reduction of greenhouse gases: the decrease is equivalent to 185,000 households cutting their annual emissions to zero.

9. Conclusions

The climate change under way and the forecasts about its future course have brought to light the risks that climate events entail for the economy, and the need to rethink economic development to make it more sustainable. In recent years, the issue of environmental sustainability has swept through the financial system, generating growing flows of resources to activities considered sustainable. The speed with which these trends have taken hold has not yet made it possible to devise methodologies to evaluate sustainable activities that are sufficiently robust and solid.

According to the available estimates – which, however, have significant limitations in terms of data and methodologies – the climate risks our country faces seem to be concentrated in some economic sectors and geographical areas and do not appear particularly critical overall...

In terms of physical risk, the effects of climate change are already visible, both as chronic events, such as the growing deviation of temperature and rainfall from their historical trends, and acute events; for the latter, it is not easy to determine how much their effects are ascribable to the climate change underway and how much to poor land use. According to the climate scenarios available, these trends will continue and will be accompanied by an intensification in acute weather events, for example flooding and heat waves. With the exception of the RCP8.5 extreme scenario, whose adoption as the business-as-usual scenario is being increasingly disputed in the climate-related literature, the available economic assessments indicate that the magnitude of these events is negligible for the Italian economic system as a whole. However, it is significant for some sectors and geographical areas characterized by a high concentration of risks.

Similarly, transition risk does not appear especially high for the Italian financial system in the short term. Italy shares with the other EU countries the goal of pursuing net-zero emissions by 2050 and this process will bring about an increase in the energy spending of firms and households. However, the transition process is still marginal and is linked to the widespread adoption of renewable sources in the electric and heating sectors; in 2018, fossil fuels still accounted for just under 80 per cent of Italy's total energy needs. The pandemic crisis has caused an abrupt reduction in their role, but this apparent transformation is largely due to the temporary contraction in energy demand stemming from the decline in economic activity and the reduction of mobility.

…though they must be monitored carefully, given the share of assets potentially exposed and the possibility that the interlinkages between the economy and the financial system could amplify their effects.

Both these risks must be monitored as they can impair the ability of households and firms to meet their financial obligations and lead to significant reductions in the market value of the exposed assets, spreading the contagion to the financial system. The quantification of climate risks for individual banks and for the financial system as a whole is necessary to ensure the stability of the financial system and an orderly transition to a decarbonized economy. This exercise, which is unprecedented in recent history, requires changes to traditional financial analysis (e.g. by using climate scenarios that combine data from the natural sciences with economic assessments) and is often limited by the scarce information available for measuring the exposure and vulnerability of individual agents or businesses. An estimate of the overall exposure to climate risk of the bank credit granted to non-financial firms suggests that, at the end of 2018, some 37 per cent of the amount of loans was exposed to transition risk only, 15 per cent to physical risk only, and 14 per cent to both. Essentially, only one third of credit to firms was not exposed to any type of climate risk.

Central banks must monitor climate risks carefully, because they could interfere with their institutional tasks. The Bank of Italy is no exception.

Climate risk can affect the soundness of individual banks and the stability of the financial system or interfere with the monetary policy transmission channels and with price stability. Central bank action to counter these risks is complicated by the specific characteristics of these risks. Analysing them means introducing new elements to the tools normally used, such as the stress tests that are employed to assess the stability of the financial system or the models used to conduct monetary policy. Going forward, central bank intervention in the economy cannot avoid taking into account climate change and its economic implications. Greater involvement on the part of the central banks in countering climate change is the subject of ongoing debate. One aspect of this conversation is tied to the principle of market neutrality.

The green finance paradigm is grounded in the idea that activities with higher sustainability scores are, in the long term, more resilient to shocks and can therefore guarantee superior risk-return combinations, thereby benefiting investors and society as a whole.

The considerable resources needed to fund the transition, and investors' increasing focus on environmental issues and sustainability have stimulated the development of new financial instruments. The consolidation of this process will hinge crucially upon the quality and reliability of the data. Only with a shared system of data, methodologies and reporting rules that makes it possible to evaluate the true impact of the investments on sustainability, and in particular on the exposure to climate risk of those investments, will it be possible to achieve an efficient shift of private capital towards the desired objectives.

This private interest is accompanied by a public interest in pursuing sustainable and lasting development: this is the foundation of the Bank of Italy's investment strategy.

Based on the predominant evidence of a positive relationship between good ESG practices and the risk-return profiles of investment, the Bank of Italy has decided to integrate sustainability criteria into its investment policy to contribute to sustainable development and improve the management of the financial and reputational risks of its investments. This sustainable investment policy has led to significant improvements in its carbon footprint and has been extended to several asset classes. This process will continue as part of an overall strategy that is in line with the decarbonization and sustainable growth objectives of Italy and the European Union.

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