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THE ITALIAN CLIMATE CHANGE THINK TANK

CLIMATE RISK AND BANKS' CAPITAL REQUIREMENTS
A lever for the transition?

TECHNICAL REPORT
JULY 2024

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CONTENTS

EXECUTIVE SUMMARY

- In Europe and in Italy, credit represents the main channel for financing the economy, and potentially, it is also the most significant source of sustainable funding for the majority of agents. However, official data paints a general picture in which green loans continue to represent an extremely modest proportion of the loan portfolios of European banks (approximately 4%-5%). With the exception of a portion of real estate mortgages, **the European market for green loans thus appears not only marginal in terms of quantity, but is also unequipped to select green loans and to link credit supply to any logic of impact finance.**

- Solvency of financial intermediaries (above all banks) is an essential factor for the entire economy in terms of the allocation of resources, risk management and the administration of payment systems. The climate crisis is also resulting in a progressive increase in the risks faced by financial intermediaries, and measures to improve the ability of the latter to protect themselves from these risks is a fundamental aspect in the process of improving the instruments currently available to the authorities. In this light, the available empirical evidence shows not only that **European banks are financing activities, sectors and businesses that are incompatible with climate crisis mitigation (and therefore inconsistent with the Paris goals), but also that their exposure to climate risk vis-à-vis their capitalisation is so high as to pose a potential future threat to solvency.**

- **In addition, however, prudential regulation may serve as a decisive lever in redirecting significant flows of credit and financial investment to support ecological transition.** Two opposing positions have come to light within the debate that has emerged over the matter: one, similar to the position adopted by the current Basel framework (and recently recommended by the EBA), could be defined as *risk based*, while the other could be defined as *economic-policy oriented*, according to which capital requirements should be a way to redirect the financial resources managed by banks towards supporting sustainable investments. This second approach formed the basis of the original recommendations made to the European Commission by the *High-Level Expert Group on Sustainable Finance*, which initiated the European Green Deal[1] and which later led to a dispute that highlighted both its merits and shortcomings.

- Bank regulations are rapidly evolving in this direction. **The ongoing process of integrating climate risk into the new Basel core principles embraces practically all the aspects of pillar two and three of prudential regulation, in particular**: (a) Corporate governance; (b) internal controls; (c) risk management processes; (d) credit, market, liquidity and operational risk management. **However, what is proving more complex and controversial is the integration of climate risk into the first pillar**, which defines the quantitative criteria for

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[1] EU HLEG (2018), *Financing a Sustainable European Economy – Final Report*, European Commission High Level Expert Group on Sustainable Finance, Brussels, January, https://finance.ec.europa.eu/publications/high-level-expert-group-sustainable-finance-hleg_en

determining capital requirements and the methods for assessing the risks according to which they are scaled.

- **The integration of climate risks into the process of determining capital requirements is opposed by supervisory authorities, because of the methodological challenges of identifying climate risks with standard risk metrics.** This particular aspect is the real reason why supervisory authorities currently consider it problematic to adopt capital requirements as a way to orient bank loans in favour of ecological transition; i.e., the difficulty of translating the impacts (both direct and indirect) that the financed entities have on the environment into metrics to calculate the effective risk for the bank that is funding them.

- In accordance with current prudential supervision, risk metrics are formed on the basis of the damages and losses that a financial institution may suffer as a result of climate ("*single materiality*"), but do not take into account the harmful impact that the institution's activities may have on the external environment ("*double materiality*"). **However, the principle of "*double materiality*" is central to the classification of climate impacts and is a fundamental aspect of the European Green Deal and of the Taxonomy.** On the contrary, the concept of prudential regulation is based on the so-called *risk-based approach* and is aimed exclusively at ensuring that risks are correctly assessed and that the requirements established by regulations are adequate to defend financial institutions from said risks. Thus, prudential regulation is currently perceived exclusively from a "*single materiality*" point of view.

- The adoption of a "*double materiality*" logic in the first pillar of Basel would require a change in perspective; it would mean **recognising that capital requirements are also a way to orient the flow of credit to favour the decarbonisation of the economy** and not exclusively, as is currently the case, as a way to protect the capital of individual banks.

- **However, the application of capital requirements as a lever for the pursuit of general climate goals ("*double materiality*") does not necessarily imply, as is sometimes believed, the abandoning of the *risk-based approach* by authorities**, but rather its redefinition in systemic terms. The difficulty of identifying exposure to climate risks at the microprudential level and the recognition of their systemic nature is in fact better addressed by the field of macroprudential measures, i.e., the application of additional buffers to the traditional criteria for the weighting of RWA.

- The macroprudential approach recognises that systemic risks are endogenous to the system, i.e., they are the result of the collective behaviour of agents, and therefore takes measures to monitor and orient this behaviour in order to prevent the emergence of said risks. **From a macroprudential point of view, material risks are not only those that externally affect individual institutions, but also those that individual institutions contribute to generating or amplifying.** For this reason, climate risks, like all systemic risk factors, are generally underestimated and require the application of aggregate correction factors linked to indirect indicators of potential exposure. This implies that *risk-based* macroprudential regulation itself cannot ignore the role that the financial system, and banks in particular, may play in mitigating climate change; rather, in order to safeguard the stability of the system, it needs to be embraced as an instrument for policy at all levels.

- **From a macroprudential perspective, it would therefore make sense to consider not only a selective increase in systemic buffers (on the basis of the bank's relative concentration in sectors/areas at risk), but also an instrumental increase in solvency ratios, linking them to aggregate indicators of carbon footprint** and the overall emissions of the entities financed by the bank itself (e.g., the indicators required by disclosure regulations) and, preferably, also to forward-looking indicators of the alignment of the decarbonisation programmes of the companies financed with the climate goals of the European Union.

- Empirical evidence shows that capital requirements have a significant influence on both the volume of credit and the level of bank interest rates, and also demonstrates that, despite their limited worth as a stand-alone lever to drive climate change, the use of macroprudential capital requirements can play a decisive role in mitigating the risks of transition generated by aggressive decarbonisation policies. These findings therefore show that **macroprudential policies are a necessary complement to other climate policies in order to reduce the exposure to risk of financial intermediaries** who, without adequate capital requirements, could serve as an amplification channel of systemic risks. As climate policies become increasingly stringent, additional capital requirements linked to climate risks are ever more necessary.

- Furthermore, specific simulations demonstrate that the combined implementation of both "*brown*" penalising factors (BPFs) for higher-emission sectors/companies and of "*green*" supporting factors (GSF) for green sectors/companies **will allow the former to reduce the exposure of banks to the risks of transition and the latter to mitigate the adverse effects of credit rationing**, providing support for sustainable investments that could be crowded-out by climate policies.

- It is therefore advisable for the Basel Committee and the supervisory authorities to provide for the **adoption of globally harmonised differentiated capital requirements for banks in addition to existing measures and in support of governmental decarbonisation policies.** To this end, it would be necessary to design a clear framework for their application, in particular:
    - Defining a conceptual map that links Taxonomy sustainability criteria to a systemic risk potential grid for financeable assets that takes into account prospective decarbonisation programmes as well as the current carbon footprint.
    - Calibrating and prescribing parameters for increasing and/or decreasing capital requirements in line with the aforementioned systemic risk grid.
    - Indicating uniform and certified methods for verifying that decarbonisation programmes are aligned with the goals of the European Union and with the climate goals of the Paris Agreement.
    - Establishing binding monitoring procedures and KPIs in line with the previous points.
    - Integrating control and reporting procedures with those already existing for the second and third pillars of the Basel framework (internal controls, governance and disclosure).

1 INTRODUCTION

1.1 THE IMPORTANCE OF CREDIT AND THE DELAY OF THE EUROPEAN BANKING SYSTEM IN THE CLIMATE TRANSITION

In Europe and in Italy, credit represents the main channel for financing the economy, and as so, is also potentially the most significant source of sustainable funding for the majority of agents[2]. However, the results of a recent study by the *European Banking Authority* (EBA 2023b)[3] paint a general picture in which green loans[4] continue to represent an extremely modest proportion of the loan portfolios of European banks (approximately 4%-5%)[5]. With the exception of a portion of real estate mortgages, the European market for green loans appears not only marginal in terms of quantity, but is also unequipped to select green loans and to link credit supply to any logic of impact finance.

Although the extent varies from country to country, the loan portfolios of European banks still appear to be particularly exposed to the most energy and emission-intensive sectors (e.g. mining and energy); in fact, the weight in loan portfolios of exposure to the latter is more than proportional to the individual contribution to emissions of each sector (ECB-ESRB 2022) **[figure 1]**[6].

[2] In the Eurozone, as of the end of 2022, bank loans made to enterprises and families totalled almost EUR 3500 bn, with a total in Italy of more than 1340 bn.

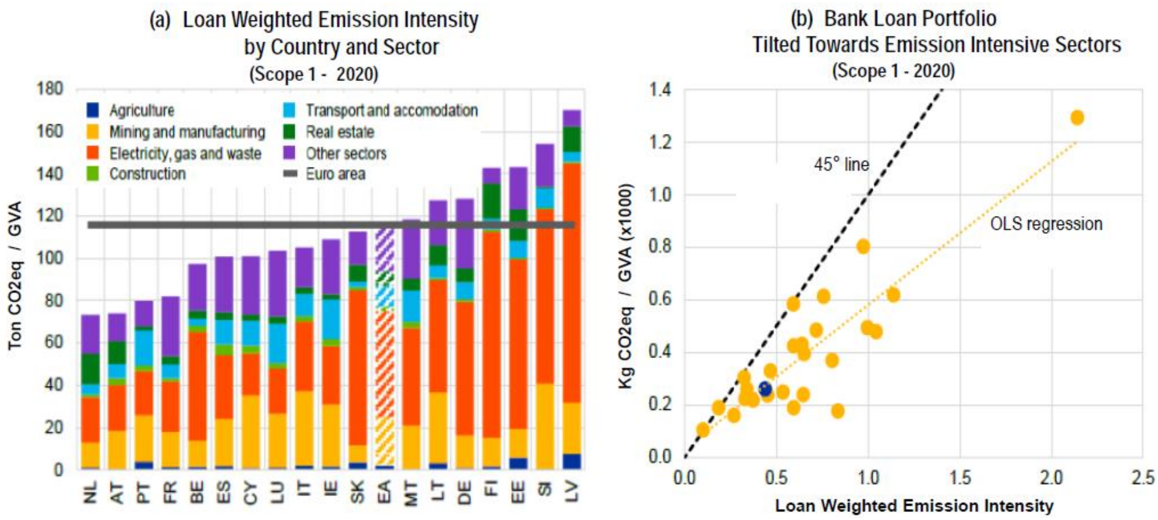
[3] The report, published by the EBA at the end of 2023, allows for the reconstruction of a consolidated view of the green-loans market under various profiles, as it (a) describes market practices, highlighting the most important segments, above all in relation to those in which private retail debtors and SMEs are most active; (b) differentiates between the various categories of loan (loans for energy efficiency, loans for renewable energy, loans for the modernisation of vehicle fleets or for sustainable mobility, etc.); (c) compares the methods adopted by banks to identify and classify green loans, and to assess their compliance with the definition of sustainability provided by EU Taxonomy and the SFDR; (d) provides a comparative assessment of advantages and costs for debtors of the various types of green loan and ordinary loan, as well as the risks related to the failure to achieve the agreed sustainability goals (e.g., early extinction of the loan, an increase in interest rates, etc.); (e) assesses administrative costs and benefits for financial institutions with regard to green loans. The study involved 83 EU/EEA financial institutions, representing 52% of all entities operating in the sector, 76% of which were universal banks, 8% retail banks and 4% corporate banks (EBA 2023b).

[4] The general expression "green loan" here refers to the many technical forms of credit granted for projects and/or activities aimed at environmental and/or energy sustainability and green innovation (e.g. green loans in the strict sense, sustainability-linked loans, energy efficiency mortgages etc.). cf. ECCO (2023)

[5] This small percentage is comprised mostly of mortgages for the purchase of real estate. The proportion of green loans for SMEs is extremely low, despite the heavy dependence of these entities on bank credit, and it is imagined that this is due to the difficulties faced by SMEs in producing suitable documentation. In the majority of cases, loans are, in fact, granted without any obligation or any monitoring by the bank regarding the eventual use of funding, and loans are classified by "default" as green on the basis of the sector in which the applicant entity operates.

[6] If the composition of loan portfolios were proportional to the emission intensity of each sector (tCO2e/GVA), the loan-weighted emission intensity [cf. the definition of CFALTL=1 in **Annex A.2.3**] would on the bisector (the 45° line). However, for all the banks examined, CFALTL sits below the bisector, indicating that the weight of extremely emission-intensive sectors in portfolios is more than proportional to their specific emission intensity.

Figure 1 – *Emission intensity of European bank loan portfolios compared to the emission intensity of economic sectors.* Source: ECB-ESRB (July 2022)



This excessive exposure of banks to the sectors with the largest carbon footprints is also confirmed when taking a wider perspective. Other recent academic studies, as well as analyses by the European Central Bank and the Banca d'Italia[7] demonstrate, in fact, that there is a significant and widespread misalignment between the credits and the investments in securities held by the leading banks and decarbonisation processes aligned with the goals of Paris[8]. Banks continue to grant a large proportion of their loans to enterprises whose future decarbonisation plans appear to be significantly incomplete (or even absent), and their exposure to the latter is, on average, double vis-à-vis their exposure to aligned firms. As many as 90% of the 95 banks analysed have loans and financial investments out of line with the goals of Paris and are therefore exposed to significant transition risk. Furthermore, 70% of those declaring decarbonisation policies in line with Paris appear non-compliant and therefore also subject to legal disputes. In addition, average exposure to climate risks (exposure at default, or EAD)[9] for capital equity tier 1 (or CET1)[10] appears to be fairly high, meaning that climate-related risks of insolvency are an element to be reassessed with regard to the adequate capitalisation of banks **[Figures 2b-2b par.3 infra].**

1.2 THE STABILITY OF THE FINANCIAL SYSTEM

Solvency of financial intermediaries (and in particular of banks) is an essential component of modern economies for allocating resources, for managing financial risk and for administering the

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[7] La Vecchia et al. (2022); Sastry et al. (2024); ECB (2024a);

[8] Cf. ECB (2024a); Faiella et. al (2020)

[9] In Basel's metrics for prudential regulation, EAD (*exposure at default*) identifies the amount of credit granted to a specific enterprise or sector [cf. Annex A.2.2]

[10] Cf. Annex A.2.1

payment system. This is why the financial system is always a "special supervised" subject; it is subject to specific regulation and strict supervision by the so-called *supervisory authorities*, which have been granted extremely wide-ranging powers regarding authorisation, information and inspection in order to safeguard the stability, the transparency and the efficiency of the entire system[11]. The notion of *prudential supervision* refers to the set of obligations and procedures aimed at preventing intermediaries from being exposed to excessive risk and at guaranteeing their solvency.

The climate crisis implies a progressive increase in the risks faced by financial intermediaries; it follows that measures to improve the ability of the latter to protect themselves from these risks is a long standing issue in the process of adjustment of the supervisory instruments available to the authorities (NGFS 2019b). In addition, however, prudential regulation may serve as a decisive lever in redirecting significant flows of credit and financial investment to support ecological transition. Empirical evidence shows that these flows have an influence on both the volume of credit and the level of bank interest rates[12], and the debate has recently embraced the opportunity to use this instrument to bring the actions of the banking system in line with the goals of Paris[13].

The very nature of climate risks and the crucial part that financial institutions can play in their systemic amplification require a rethinking of the role played by both prudential supervisors and monetary authorities in the mitigation of climate risks. Climate risks in fact impose an *"epistemological break"*, not only in terms of risk assessment metrics, but also in the posture of policy makers **[cf. Box 1 - A new epistemology of risk].**

Two opposing positions have come to light within the debate that has emerged over the matter: one, similar to the position adopted by the current Basel framework (and recently also recommended by the EBA), could be defined as "*risk based*", while the other could be defined as "*economic-policy oriented*", according to which capital requirements should be a way to redirect the financial resources managed by banks towards supporting sustainable investments. This second approach formed the basis of the original recommendations made to the European Commission by the *High-Level Expert Group on Sustainable Finance*, which initiated the European

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[11] There are many supervisory authorities in Europe. At European Union level, since 2011, coordination between national authorities has been the responsibility of the so-called ESAs (European Supervisory Authorities). The name ESAs refers, collectively, to the three European agencies: EBA (*European Banking Authority*), ESMA (*European Securities and Market Authority*) and EIOPA (*European Insurance Occupational Pension Authority*). The ESAs do not, however, have direct powers for supervision or control, but only for guiding the supervisory regulations of EU countries and ensuring their consistency. With exclusive regard to the countries within the Eurozone, since 2014 banking supervision has been carried out by the SSM (*Single Supervisory Mechanism*), which includes the European Central Bank (ECB) and the national central banks (NCBs) of the countries that have adopted the Euro. The EU countries that are not part of the Eurozone have maintained independent supervisory authority (such as, for example, the FCA, *Financial Conduct Authority,* and the PRA, *Prudential Regulation Authority,* in the United Kingdom).

[12] Aiyar et al. (2014); Akram (2014); De-Ramon et al. (2016); De Marco-Wieladeck (2015); Meeks (2017); Fraisse (2017); Imbierowicz et al. (2019)

[13] EU HLEG (2018); Schoenmaker-Van Tilburg (2016); D'Orazio-Popoyan (2019); Esposito et al. (2018 e 2020); Berenguer (2020); Oehmke (2022); ReCommon (2024)

Green Deal (EU HLEG 2018), and which later led to a debate that, as we will see further on, highlighted both its merits and shortcomings[14] .

The aim of this report is to explore whether, to what extent and under what conditions the minimum capital requirements imposed on banks by the prudential regulation of the Basel framework could contribute to:

- Reducing direct and indirect exposure of European banks to climate risks.
- Adapting the banks' capital resources on the basis of said risk.
- Dissuading the granting of loans to the enterprises most exposed to climate risks.
- Encouraging the funding of investments and firms that adopt transition plans in line with European climate goals.
- Increasing the flow of funding to innovation and green technologies.

To this end, the first step is to outline the current key characteristics of the prudential supervision regulation, i.e., the Basel Accords **(par.2)**. This is followed by a discussion of the logic behind macroprudential regulation, which was introduced in the wake of the 2007-08 financial crisis **(par. 3)**. The implications of applying additional "climate" capital requirements will be discussed, with an examination of simulative evidence **(par. 4)**, followed, lastly, by a series of provisional conclusions **(par.5)**. To facilitate presentation, many technical details are provided in the **Annexes**.

BOX 1 – A NEW EPISTEMOLOGY OF RISK

Extreme climate risks are characterized by rare and catastrophic events that cannot be predicted with sufficient accuracy or quantified with standard statistical techniques. Through various channels (the actions and expectations of agents and institutions), these could also become financial risks that can either be mitigated by regulation or potentially exacerbated by its inadequacy (transition risk). Climate risks and their interaction with the financial system require analysis of complex systems, in which even the smallest variation of any single variable can lead to significant and unexpected deviations in others (Ackerman 2017; Sayama 2015). Recognition of the complex nature of climate events has led to the emergence of a sort of "epistemological break" from traditional approaches to risk management (Bolton et al. 2020). In other words, climate risks fit better into the logical category of "uncertainty" than in the category of "risk". Paraphrasing Knight[15], risk can take the form of a "known unknown", one for which probability can be captured, but it can also remain in the realm of "unknown unknown", i.e., unable to be reduced to a quantified probability. This latter category includes the "radical uncertainty" that many attribute to climate (Baranovic et al. 2021; Chenet et al. 2022; Smolenska-vant'Klooster 2022).

Despite the difficulty of translating climate uncertainty into risk metrics, there are at least three good reasons to adopt prudentially defensive policies against climate risks:

[14] Matikainen (2017); Dankert et al. (2018); Van Lerven-Ryan Collins (2018); Esposito et al (2018 e 2020); Berenguer (2020).

[15] The reference is to Frank Knight (1921), for the application of the concepts of risk and uncertainty to risk-management techniques, reference is made to Diebold et al. (2010)

(1) considering that climate change is a result of global warming, which is irreversible and cumulative, extreme climate events tend to increase progressively and inexorably in both frequency and intensity. The probability of being affected cannot be calculated, but this does not mean that it is nil, and it undoubtedly increases over time. Where and how these events may strike is uncertain, but their destructive power is "certain". Unlike with financial events, in which a broader exposure to risk is also associated with increased opportunity, climate risk has only one tail: loss and damage.
(2) Like financial crises, the climate crisis is systemic, but the complex nature of the chain reactions and the "cascading" impacts that it can cause once some *tipping points* have been exceeded is immeasurably broader and more destructive than that typical of financial crises (Lenton 2019; Sharpe-Lenton 2021).
(3) Climate threat is existential, that is, it undermines economic and social organisation, and, in the long term, the very survival of the biosphere and of the humanity (Ripple 2017, 2021, 2022; IPCC 2018; 2021; 2022; 2023).

Climate risks cannot be ignored or underestimated, and the fact that they cannot be statistically analysed is no excuse for agnosticism or fence-sitting. On the contrary, it calls for an approach that is radically different from traditional forms of risk management, which tend to base management and economic coverage exclusively on statistically appraisable parameters. For climate change, the appropriate strategy is, instead, to accept that there can be no suitable protection other than precautionary policies of a general nature, independent of any specific quantification of risk (Weitzman 2009, 2011; Lenton 2019). Addressing climate change requires systemic, active and coordinated measures aimed first and foremost at eliminating the causes while, at the same time, providing lines of defence that are based on the worst-case scenarios; an approach that not only focuses on the specific exposure of individual economic entities, but on collective and converging action guided by clear policy priorities and backed up by adequate resources that actively and synergically involves all institutional entities (policymakers, governmental agencies and financial institutions) (Aglietta-Espagne 2016; Stiglitz 2019; Bolton et al. 2020).

2 THE BASEL ACCORDS AND PRUDENTIAL REGULATION

In Europe, with the implementation of the Green Deal[16], the banking sector was also involved in the issues related to climate change, above all in terms of the proper management of risks deriving from lending and from financial investments.

The current prudential EU legislation is based on three main sources of regulation: the *Capital Requirements Directive* (CRD)[17] and the *Capital Requirements Regulation* (CRR)[18] for banks, and the *Investment Firms Directive* (IFR) for investment firms[19], which implement the regulatory framework of the 2004 Basel Accords (Basel 2), and their subsequent evolution (Basel 3).

With the general guidelines issued by the EBA, the ECB and the Banca d'Italia regarding prudential supervision[20] and the updating of the Basel Accords[21] climate risks have been incorporated into bank regulation.

In order to understand the mechanisms involved, it would be useful at this point to summarise the general architecture of current prudential regulation and identify the (actual or possible) modifications required to align it with climate crisis mitigation goals.

The overall architecture of prudential supervision of banking systems is based on the so-called Basel Accords issued by the Basel Committee on Banking Supervision (BCBS)[22]. The logic of Basel has evolved over time and the most recent version, known as *Basel 3*, takes the form of three pillars: (1) the first pillar is represented by capital requirements; (2) the second pillar concerns procedures for internal risk management and supervision; (3) the third pillar sets out regulations for transparency and disclosure aimed at guaranteeing so-called market discipline, i.e., the ability of investors and depositors to assess the effective risk exposure of each bank.

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[16] European Parliament (2018)

[17] European Parliament and Council (2013a)

[18] European Parliament and Council (2013b)

[19] European Parliament and Council (2019)

[20] EBA (2019, 2021b, 2022b, 2023a); ECB (2020a); Banca d'Italia (2022a)

[21] BCBS (2022, 2023a, 2023b)

[22] The Basel Committee (BCBS) is a body that was set up in 1974 and is composed of representatives from the banking supervisory bodies of 27 countries (central banks or other supervisory authorities). It is hosted by the Bank of International Settlements (BIS). The BCBS does not possess any formal supranational authority, and it issues guidelines, recommendations and standards that have no direct legal force in the member countries. However, the regulations recommended by the Committee allow for the coordination and convergence of international regulations and supervisory procedures regarding the stability of banking systems. The BCBS is coordinated by a permanent Secretariat and is structured in four subcommittees that report to a joint body composed of the governors and supervisory heads of the member countries.

2.1 PILLAR ONE: MINIMUM CAPITAL REQUIREMENTS

With regard to the first pillar, which indicates the entity and the methods for calculation of minimum quantitative capital requirements, the Basel Accords were initially based on an extremely simple scheme that established that the bank's capital should be prudentially equal to (or higher than) a certain "safety" threshold in order to be able to handle any unexpected losses. Adequate capitalisation is in fact the main line of defence against possible insolvency but, for this reason, it is also a factor enhancing investor and depositor trust in the stability of the bank, and therefore tends to prevent also potential episodes of panic leading to the withdrawing of deposits. The original Basel Accords established that the minimum bank capitalisation threshold, known as the "solvency ratio", should be the same on an international level (in order to avoid competitive distortions among different jurisdictions) and should be eight percent of the bank's risk-weighted assets (RWA). In the original set-up (Basel 1), risk weighting was dictated directly by the authorities and was applied exclusively to the various forms of credit, ignoring other aspects of banking activity, such as investments in securities and proprietary trading or operational risks. The framework was gradually enhanced over the decades that followed, including the latter types of risk and allowing for more analytical methods that were increasingly based on models elaborated by the banks themselves (albeit validated by the authorities)[23]. Technically the system has become much more complex, but the basic framework has always remained the same; on the one hand to assess, in an increasingly detailed manner, the effective exposure to risk of every form of bank's asset (in order to achieve an ever-more granular and precise weighting), and on the other to align the bank's capital with the assets weighted according to those risks. The financial crisis of 2007-2008 provided new insights on the shortcomings of this framework, making apparent its vulnerability to systemic risk **[Annex A.2.1]**.

2.2 BEYOND MICROPRUDENTIAL REGULATION; THE MACROPRUDENTIAL APPROACH

The idea behind the original Basel framework was that the microeconomic stability of each individual bank was a *necessary and sufficient* condition for the stability of the entire system. However, the 2007-2008 crisis was a dramatic demonstration that suitable capitalisation of individual banks is indeed a *necessary* condition for the stability of the system, but that, contrary to what had previously been assumed, it is not also a *sufficient* condition. As banks are intertwined by a complex network of reciprocal relationships, and they simultaneously operate on the same markets, they are exposed to potential systemic shocks that can lead to the collapse of the entire system, even in cases where every individual bank is properly capitalised for the risks that it has individually assumed. Systemic dynamics are like electric shocks that originate in a weak node of the network (in 2008, the collapse of Lehman Brothers) and spread through the "nervous web" of the financial system, forcing all the banks to take the same actions at the same time, such as

[23] The standard weighting defined by the authorities was initially subdivided by class according either to the nature of the counter parties, the technical characteristics of the relationship or the execution of the same. As an alternative to this standard method, banks are now able to adopt their own methods, defined as Internal Ratings-Based (IRB), i.e., based on internal risk-rating systems, or the Internal Models Approach (IMA), i.e., based on the banks own risk-assessment models (BCBS 2005).

draining interbank credit (thus reducing its liquidity), rationing credit to the economy or selling-off securities (thus reducing their worth). During a systemic crisis, the capital set aside for ordinary risks proves insufficient to re-establish the required ratio of capital to risk-weighted assets, forcing all the banks to recapitalise at the same time or reduce their assets. However, recapitalising during a financial market crisis is extremely difficult and costly, which means that the other option - a reduction in assets - prevails, fuelling a push towards recession, provoking further falls in market value and exacerbating the problem. This process, known as deleveraging, tends to go into a spin because banks are forced to re-establish a fixed proportion between capital and risky assets. In a systemic crisis, the solvency ratio operates in a *procyclical* factor, amplifying the spin dynamic. The procyclical effect of a fixed solvency ratio may also operate perversely in the opposite direction; in positive phases, with rapid growth of financial markets (or even speculative bubbles), operators' expectations tend to align in an upwards spiral, with the volatility of quotations falling. As volatility is one of the ingredients in statistical risk assessment, its reduction also tends to restrict the risk-weighting of assets. When a market is rising, lower volatility leads to the risk factor of assets to be underestimated, resulting in a proportional undersizing of bank capitalisation. Against the evidence of systemic risks, Basel's prudential framework has been updated (Basel 3), providing for two further components for adapting capital in addition to the original solvency ratio (eight percent): on the one hand, a so-called *countercyclical capital buffer* (i.e., increased provisions in periods of expansion to be reabsorbed during periods of market contraction), and on the other a second increase, known as a *systemic risk buffer*, as a further line of defence against any unexpected shocks of this nature (EBA 2023a; ECB-ESRB 2022).

In addition to the reset minimum capital requirements, the first pillar also endows the supervisory authorities with the power to intervene with regard to the conditions applied by banks when granting loans, for example allowing them to set limits on the maximum debt level for recipients, prescribing maximum loan thresholds in relation to the income of the assignee (loan-to-income) or to the value of the asset financed and/or put up as guarantee (loan-to-value).

Lastly, the framework of Basel 3 is completed with other complementary measures aimed at limiting overall bank debt and bolstering their resilience against any liquidity crises: maximum leverage sets a limit on the ratio between total non-risk-weighted assets and overall assets; the LCR (Liquidity Coverage Ratio) establishes that each bank has enough liquid assets to allow it to survive for at least 30 days without having to turn to the interbank market or to refinancing from the central bank; the Net Stable Funding Ratio (NSFR) sets a balance between loss and profit over the medium-long term **[Annex A.2.1]**.

2.3 THE SECOND PILLAR: INTERNAL RISK MANAGEMENT

The Basel's second pillar concerns internal controls and, for each bank, takes the form of compulsory organisational protocols for monitoring and managing risk, the precise attribution of tasks and responsibilities to the various bodies involved (line management, risk management, administrative bodies and internal audits), and the structuring of reporting to the authorities as well as the supervisory processes of the latter (which take the form of periodical in-depth diagnostic analysis[24]). Over recent years, the scope of each of these processes and the redefinition of organisational profiles has also been extended to include climate and environmental risks[25].

2.4 THE THIRD PILLAR: DISCLOSURE OF EXPOSURE TO RISK

The Basel's third pillar is partly derived from the second, and sets out the methods, formats and level of detail of information to be disclosed by each bank to the public. In this area, the EBA has, for example, provided recommendations regarding the methods and metrics for assessment and disclosure (KPIs) that institutions are required to adopt in terms of ESG information, and has also set out specific operational indications. This documentation now offers a wide-ranging and detailed reference framework for linking loans granted by financial institutions to an unambiguous definition of sustainability, or "greenness". In order to extend transparency requirements to sustainability related characteristics of bank's assets and allow investors and other stakeholders to make comparative assessments of ESG risks and vulnerabilities among different institutions, third-pillar requirements establish the format, content and measurement metrics for information also regarding decarbonisation and environmental aspects **[cf. Annex A.1]**[26].

Given their importance, the regulations already require the publication of quantitative information with reference to climate and environmental risks (both physical and related to transition): starting in 2024 (with reference to 2023) banks must publish the so-called Green Asset Ratio (GAR), regarding exposure to all financed counterparties who are in turn subject to compulsory disclosure-according to the CSRD[27]. On a voluntary basis, banks can also publish the so-called Banking Book Taxonomy Alignment Ratio (BTAR) regarding the alignment of activities with the European Taxonomy (including exposure to counterparties not covered by the CSRD). Both indicators must be complemented with the description of mitigation measures and the qualitative representation of a wider range of risks concerning not only the environment but also social and governance

[24] The main examples are, on the one hand, ICAAP (*Internal Capital Adequacy Assessment Process*) and ILAAP (*Internal Liquidity Adequacy Assessment Process*) aimed at annually assessing capital and liquidity adequacy in terms of risks, and on the other, the SREP (*Supervisory Review and Evaluation Process*) which annually assesses all the managerial aspects of the bank (assets, economics, organisation, strategy, etc.).

[25] EBA (2021a, 2022a); ECB (2020a); Banca d'Italia (2022a)

[26] EBA (2021a, 2022a)

[27] European Parliament and Council (2022), Dir 2022/2464/EU

aspects. Despite the significance of these indicators is still subject to shortcomings as far as the calculation method is concerned, they undoubtedly represent an important step forward[28].
With regard to physical risks, the bank needs to identify and highlight exposure to the sectors and geographic areas that are potentially most exposed to adverse climate and/or environmental impacts both acute and chronic.

With regard to transition risk, the requirements call for clear explanations of the exposure to the sectors that are the main contributors to climate change, highlighting both the proportion of the sectors most dependent on fossil sources and the overall level of alignment with European Taxonomy. This information also covers the carbon footprint (in terms of Scope 1, 2 and 3 GHG emissions) of corporates financed by the institution, the alignment of their projected decarbonisation processes with the goals of Paris and the embedded energy efficiency of the real-estate mortgage portfolio of the bank.

In a nutshell, the integration of climate risk into the new Basel core principles embraces practically all the aspects of pillar two and three of prudential regulation: (a) Corporate governance; (b) internal controls; (c) risk management processes; (d) credit, market, liquidity and operational risk management. It also extends the tasks and the priorities of supervision carried out by the supervisory authorities to climate risks (BCBS 2022). However, what is proving more complex and controversial is the integration of climate risk into the first pillar, which defines the quantitative criteria for determining capital requirements and the methods for assessing the risks according to which they are scaled. Hereafter, we will focus only on the latter issue.

[28] Publication of the GAR became obligatory for EU banks in January 2024. However, the GAR is seen as an insufficient and unreliable measure of the "greenness" of bank assets because it is limited to large corporates (for which CSRD reporting is obligatory) and thus excludes from the calculation of the ratio a large portion of banking activity concerning SMEs, whatever their carbon footprint. To overcome this limitation, a complementary indicator has been introduced, the BTAR, which also includes categories of firms not covered by the CSRD, but which banks could publish only on a voluntary basis, and which is presumably derived from estimates made by the banks themselves on the basis of non-homogeneous methodologies and unverifiable data, given that SMEs are not subject to disclosure obligations. A further methodological limitation of these indicators is that, with reference to Taxonomy classification criteria, they do not take into account any prospective efforts of the firm regarding decarbonisation, or any support that the banks provide for the transition plans of the most energy and emission-intensive entities (EBF 2024).

3 CLIMATE RISK AND MACROPRUDENTIAL CAPITAL REQUIREMENTS

With regard to the first pillar, climate risk assessment covers various aspects of the current regulation for capital requirements on both a micro- and macroprudential level, while excluding others with differing objectives **[cf. Annex A.2.1]**. This is, for example, the case of the LCR, the NSFR and maximum leverage; none of these measures is based on risk metrics, and their function is exclusively to mitigate imbalances that may compromise the liquidity of banks in the short term. Their value is therefore general in nature and is irrespective of the specific origin and nature of the shocks (ECB-ESRB 2022).

Instead, a prudential form of reasoning related to climate risks could easily be applied to the maximum limits on lending to debtors (LTI and LTV). In this case, there is a direct link between climate risks and credit risks, as the first can result in the insolvency of the debtor or the devaluation of the assets provided as guarantee for the loan. The limits tend to mitigate the maximum exposure of the lending bank to the vulnerability of the debtor to climate impacts and, by limiting the relative entity of the borrower's debt, they also reduce the probability of insolvency[29]. Again in this case, the limits could be modulated in an extremely flexible manner on the basis of the sustainability indicators of the borrowers (for example, their energy efficiency and/or the presence of insurance coverage), the vulnerability of their geographic location and/or that of the sectors in which they operate. The problem in this case is that this criterion can only be applied to new credit flows, without involving existing loans; the impact of this element can, in particular in long-term contracts such as property mortgages, be extremely limited and diluted over time. In any case, the imposition of this type of limit requires harmonisation at the international level in order to avoid market segmentations due to uneven application at the country level (EBA 2023a; ECB-ESRB 2022).

However, the integration of climate risks in determining banks' capital requirements is opposed by supervisory authorities, mainly because of the methodological challenges of identifying climate risks with standard risk metrics (EBA 2023a).

3.1 MICROPRUDENTIAL CAPITAL REQUIREMENTS AND SYSTEMIC RISK

On a microprudential level, the task is to integrate climate risks into the weighting criteria for RWA with reference to the specific exposure to risk of the subjects financed. However, the application of this framework to climate risks presents a series of methodological challenges that basically stem from the fact that all the components required to estimate expected losses (EL) are based on historical data **[cf. Annex A.2.2].** In particular, with reference to probability of default (PD), statistical inferences are based on frequencies observed over long periods of time, extended over differing economic cycles and oscillating around the average value (i.e. mean reverting processes). On the contrary, the frequency and intensity of climate impacts tends to increase over time and to assume new dynamics, with the result that the distribution of past data is a poor representation of future trends. Furthermore, forecasting models are often based on linear (logistic) regressions, which are

[29] For the definition of LDG (Loss for Given Default) and PD (Probability of Default) see **Annex A.2.2**

unable to meet the complexity (non-linear nature) of climate factors, which are characterised by the interweaving of multiple feedback loops among the variables in play (Bolton et al. 2020; Baranovic et al 2021; Sydow et al. 2021).

The difficulty of identifying exposure to climate risks and recognising their systemic nature on a micro-analytical level is therefore better addressed by the field of macroprudential measures, i.e., the application of additional "fixed" buffers to criteria for the weighting of RWA (Smolenska-van't Klooster 2022; Bossinot et. al 2022; ECB-ESRB 2022)[30].

Climate risks, like all systemic risk factors, are, in fact, generally underestimated and require the application of aggregate correction factors linked to indirect indicators of potential exposure. The differentiated application of additional systemic buffers would therefore require the prior identification and classification by the supervisory authorities of the sectors of activity and/or the geographic areas in which the banks operate on the basis of their exposure to systemic risk, and would also require the assessment of the degree of concentration of the bank's assets on these sectors and/or activities. European Taxonomy could, in this regard, offer an initial conceptual framework (Battiston et al. 2017; 2021; Alessi-Battiston 2022), even though the criteria need to be harmonised at an international level, by the Basel Committee (CBI 2022). Furthermore, the Taxonomy is a high-level classification of macrosectoral contributions to greenhouse gas emissions which should be re-mapped in terms of risk exposure, as well as requiring more granularity. The mapping of the carbon footprint or environmental impact of economic activities in terms of risk is by no means automatic, unless one considers carbon intensity as a proxy for transition risk, without considering forward looking decarbonisation plans[31].

This last aspect appears to be the real reason why supervisory authorities currently consider it problematic to adopt capital requirements as a way to re-orient bank loans in favour of ecological transition; i.e., the difficulty of translating the impacts (both direct and indirect) that the financed entities have on the environment into metrics to calculate the effective risk exposure for the bank that is funding them. It is inevitable that certain economic activities are likely to be penalised by the transition, but their future exposure to risk does not necessarily depend on their present carbon intensity. Rather it depends on the effectiveness and credibility of their decarbonisation plans and, at the same time, on the effectiveness of the measures for adaptation that each activity is going to implement.

This consideration introduces the criteria of "transition finance" into the relative conceptual framework, i.e., the need for analysis, and therefore also regulation, to explicitly link risk assessment above all to the existence and implementation of decarbonisation plans that are in line with the goals of Paris **[cf. Box 2 - Transition finance].**

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[30] In general, climate risks should not concern the countercyclical capital buffer (CCyB), as climate dynamics are not related to fluctuations in the economic cycle. Instead, they could affect the capital conservation buffer (CCoB), and above all the systemic risk buffer (SyRB), which is currently differentiated exclusively on the basis of the systemic entity of the bank and does not consider climate risks. The flexibility of the latter also appears to be well suited to being opportunely reconfigured in order to embrace the differences in individual exposure to climate risks (ECB-ESRB 2022) **[cf. Annex A.2.1]**

[31] Battiston et al. (2017 and 2021); Faiella-La Vecchia (2020); Carbone et. al. (2021); Alessi-Battiston 2022)

3.2 MACROPRUDENTIAL SUPERVISION AND DOUBLE MATERIALITY

In accordance with current prudential supervision, risk metrics are formed on the basis of the damages and losses that a financial institution may suffer as a result of climate ("single materiality"), while not also taking into account the harmful impact that the institution's activities may have on the external environment ("double materiality"). The principle of double materiality plays a central role in the classification of climate impacts, but so far, prudential regulation appears to ignore it[32]. The concept of prudential regulation is, in fact, based on the so-called *risk-based approach* and is aimed exclusively at ensuring that risks are correctly assessed and that the requirements established by regulations are adequate to defend each financial institution from said risks.

The current risk-based approach of prudential supervision thus dismisses *a priori* that regulation can be used as a tool to govern the external impacts of financial activities, unless a conceptually and statistically robust correlation between said external impacts and the resulting additional vulnerability of the assets of the bank could be established (EBA 2023a)[33]. In other words, if it were possible to map the relationship between the (present and future) carbon footprint of the subjects receiving credit and the potential risk of losses for the bank, there would be no apparent contradiction between the risk-based logic and the adoption of selective criteria based on carbon footprint. Unfortunately, this mapping is ambiguous and hard to quantify, and it is for this reason that the supervisory authorities appear reluctant to directly connect the Basel's first pillar to decarbonisation indicators (EBA 2023a; ECB 2022a).

The adoption of "double materiality" criteria in setting up the first pillar requires a change in perspective for the authorities; it would mean recognising that capital requirements are not exclusively to protect the solvency of individual banks, as is currently the case, but can be instruments for mitigating the overall climate risks by the re-orientation of credit to favour decarbonisation[34].

This would undoubtedly constitute a significant change in approach, but it would not be a change that is inconsistent with the general philosophy behind the concept of the Green Deal, which, through the Taxonomy, explicitly grants finance an active role in supporting transition. On the contrary, in our opinion, macroprudential logic itself would, in the specific case of climate risks, justify the adoption by the supervisory authorities of the principle of "double materiality" (Gourdel et al. 2023). As a matter of fact, in the wake of the 2007-08 financial crisis, the authorities themselves recognised the need to combine the traditional microprudential methods of Basel with a macroprudential approach in response to systemic risks.

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[32] Oman-Svartzman (2021); Täger (2021); Bossinot et al.(2022)

[33] In this regard, the report by the EBA dedicated to the role of environmental and social risks in the prudential framework reads (p 22): *"The analysis presented in this report is not aimed at using prudential regulation to increase demand for environmentally and socially sustainable assets or penalize environmentally and socially harmful assets. While this could be the effect of the risk-based approach to the extent that the environmental and social profile of certain assets coincides with the underlying risks, EBA is of the view that a dedicated prudential treatment which would explicitly aim to redirect lending could have undesirable and unintended consequences, which could have an impact on financial stability."* (EBA 2023a p.22)

[34] Smolenska-van't Klooster (2022); Chenet et al. (2022); Bossinot et al. (2022); Berenguer (2020)

3.3 SYSTEMIC RISK AND EUROPEAN TAXONOMY

The current interpretation of the risk-based approach by supervisory authorities is extremely restrictive and appears to be contradictory to the logic of the European Taxonomy, which identifies sustainable economic activities on the basis of the contribution that they can potentially make towards achieving at least one of the climate and environmental goals without compromising any of the others[35]; in other words, the Taxonomy adopts a criteria of higher/lower contribution of economic activities to safeguarding the climate and the external environment (i.e. "double materiality"), but without explicitly reclassifying them on the basis of their level of risk[36].

For the two forms of logic to be reconcilable, there is no doubt that a conceptual map is required to connect "sustainability" and "risk"[37]. However, this does not necessarily imply that systemic risk must be statistically measurable. According to the supervisory authorities, the first condition is, from a conceptual point of view, achieved (and it is, in fact, applied to the second and third pillars), but it is the absence of the second condition, measurability, that hinders the capital requirements of the first pillar from being calibrated in accordance with climate risks. This is why they abstain from quantitative measures, relying for the moment exclusively on the internal audit processes of intermediaries (the second pillar) for the assessment of climate risk exposures. For the time being, the supervisory approach seems to rely just on a progressive fine-tuning of prudential instruments. However, this "adaptive" approach taken by the authorities risks being unfruitful and hazardous, as the "radical uncertainty"[38] that structurally characterises climate impacts will never allow for the appropriate quantification of probabilities, leaving the financial system defenceless against climate systemic risks, while, at the same time, denying a decisive policy lever for mitigating those risks (Bossinot et al. 2022; Smolenska-van't Klooster 2022).

3.4 MACROPRUDENTIAL LOGIC AND A RISK-BASED APPROACH TO SYSTEMIC RISK

The application of capital requirements as a lever for the pursuit of general climate goals ("double materiality") does not necessarily imply, as is sometimes believed, the abandoning of the risk-based approach by authorities (Binder 2022), but rather its reframing from a systemic point of view. **The extension of the risk-based approach at the macroprudential level reconciles protection against risk with policies to orient credit through systemic capital requirements.**

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[35] Delegated Regulation (EU) 2021/2139 of 4 June 2021 *(EU Platform on Sustainable Finance*), linked to the Taxonomy (Regulation (EU) 2020/852) has defined screening criteria for more than one hundred different types of economic activity on the basis of their contribution to mitigating and/or adapting to climate change.

[36] Paradoxically, mechanically adopting the Taxonomy as risk-based criteria would result in considering all activities not classified as sustainable as potentially risky. However, as the Taxonomy classifies only 2% of investments as sustainable, almost all of the remaining activities would require prudential coverage without any criteria for grading the level of risk.

[37] Alessi-Battiston (2022)

[38] Cf. Box 1 (infra) "A new epistemology of risk"

The macroprudential approach in fact recognises that systemic risks are endogenous to the system, i.e., they are the result of the collective behaviour of agents, and therefore takes measures to monitor and orient this behaviour in order to prevent their emergence. From a macroprudential point of view, material risks are therefore not only those that externally affect individual institutions, but also those that individual institutions contribute towards generating or amplifying.

The Green Deal and the Basel Accords themselves consider the mitigation of negative externalities deriving from emissions as currently being one of the dominant factors of systemic risk[39]. The speed and intensity with which these negative externalities emerge are not independent from the dynamics of the financial system; to the extent to which it drives and supports said externalities, the financial system makes a decisive contribution to determining them, and the resulting effects may compromise its own stability (NGFS 2019b; Battiston et al 2021; Carattini et al 2021). This is exactly what happened with the financial crisis of 2007-08, because the microprudential regulation in force at the time proved unable to deal with it[40]. Similarly to the financial crisis, the climate crisis has a systemic valence that needs to be considered by macroprudential regulation, recognising that the emergence of climate risks depends also on the aggregated behaviour of the financial system (Aglietta-Espargne 2016; Dafermos-Nikolaidi 2021). **This implies that risk-based macroprudential regulation itself cannot ignore the role that the financial system (and banks in particular) may play in mitigating climate risk and suggests that macroprudential regulation can be embraced as an instrument for climate policy in order to safeguard the stability of the system.**

From a macroprudential perspective, it would therefore make sense to consider not only a selective increase in systemic capital buffers (on the basis of the bank's relative concentration in sectors/areas at risk), but also an instrumental increase in solvency ratios, linking them to aggregate indicators of carbon footprint/overall emissions of the entities financed by the bank (e.g., the indicators required by disclosure regulations) and, in addition, also to forward-looking indicators of how the decarbonisation plans of the financed companies align with the climate goals of the European Union[41]. This would mean directly linking the determination of capital requirements of the first pillar to the same KPIs adopted for the third[42].

The exposure of individual banks to transition risk is above all related to the composition of their loan portfolios, because this is the channel through which the vulnerability of firms to climate-related events[43] is passed on to the bank. An excessive proportion of loans to highly energy/emission-intensive activities that do not have plans to align with energy and climate goals

[39] BCBS (2021a, 2021b); EBA (2021b)

[40] Danielsson (2008); Danielsson et al (2009); Haldane (2013); Onado (2009 e 2017); Gualandri-Noera (2014); Meeks (2017)

[41] Cf. Box 2 - Transition finance

[42] Cf. Annexes A.1 and A.2.3

[43] For example increases in energy or coal costs, as well as insurance premiums, and/or the devaluations of their market value (stranded assets) due to the climate crisis and mitigation measures requested by the authorities.

also results in exposure to any extra costs related to the late adaptation to regulations, as well as the associated legal disputes and the possible consequential economic and reputational harm[44].

In this light, the available empirical evidence shows not only that **European banks are excessively financing activities, sectors and businesses that are incompatible with climate crisis mitigation (and therefore inconsistent with the Paris goals), but also that their exposure to climate risks in relation to their capital is so high as to pose a potential threat to their solvency** (ECB 2024a) [45]. It is in fact true that European banks are extending credit to certain sectors whose dependence on fossil energy sources appears to be diminishing (for example the oil & gas and automotive sectors), but in others, their prospective exposure still appears to be too high (for example towards the coal and the energy generation sectors); furthermore, they are not providing sufficient support to renewable energy or alternative technologies. Over a five-year horizon, their loan portfolios are destined to finance activities whose overall carbon footprint is still 10%-20% higher than the level compatible with European climate goals (ECB 2024a)[46]. The average entity of loans to enterprises in line with climate goals is still extremely modest (lower than 100 million), and the exposure of banks (EAD) to unaligned firms is, on average, 30%-50% higher than that to aligned enterprises **[fig. 2a].** Practically all the European banks with higher exposure have loan portfolios out of line with the goals of Paris, and their exposure often represents more than 20% of their capital (CET1), and sometimes even higher than 40% **[fig. 2b].** Exposure would actually be twice as much if all the approved lines of credit were fully utilized[47].

Although they do not outline a functional relationship in terms of probability, as the authorities would like, these evidences clearly suggest both the need to intervene, from a risk-based viewpoint, on determining capital requirements to protect banks' future solvency and the opportunity to actively use the policy lever of capital coefficients to increase the support of the banking system to the European climate goals.

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[44] In the analysis by ECB (2024a), 70% of the 95 banks analysed falsely declared they had plans aligned with the climate goals of Paris and were therefore exposed to compliance risks.

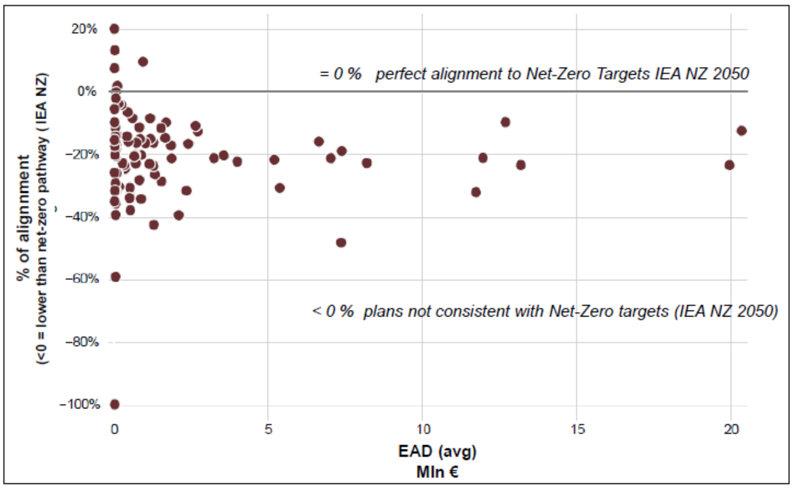
[45] The analysis by the European Central Bank (ECB 2024a) concerns the loans made by the 95 main banks of the Eurozone to enterprises whose decarbonisation plans are compared with the "net zero" scenarios of the International Energy Agency (IEA 2021) over a period of 5 years, with the use of the Paris Alignment Capital Transition Assessment (PACTA 2020) methodology. The analysis covers 15 technologies applied to 6 high-emission-intensive sectors, which are jointly responsible for approximately 70% of the industrial sectors GHG emissions (oil & gas, coal mining, electricity generation, automotive, steel, cement). With regard to Italy, an analysis carried out by Banca d'Italia in reference to 2018 (Faiella et al. 2020) set the portion of exposure of Italian banks to the sectors most exposed to transition risk at between 8% and 10.2% of total assets.

[46] *European Climate Law* (European Parliament and Council 2021)

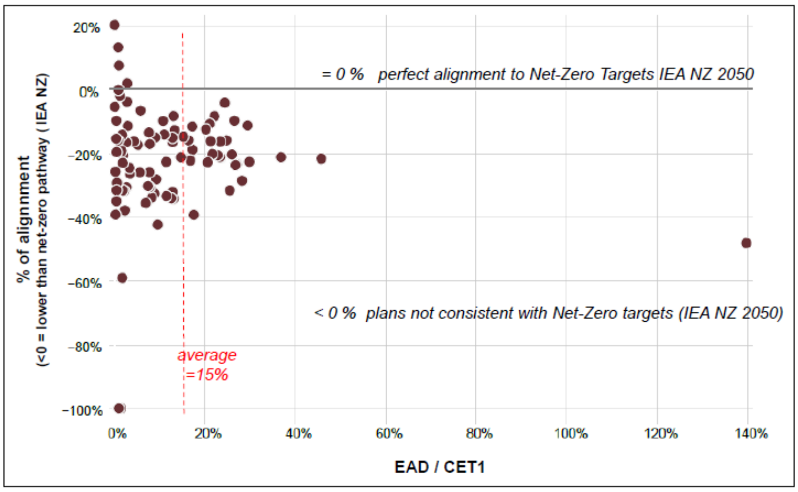
[47] Above all, the larger enterprises have a ratio of utilized/granted credit of around 50%; therefore the weight of the larger enterprises unaligned with the goals of Paris would greatly increase if exposure to granted credit instead of utilized credit were calculated.

***Figure 2** – Alignment of decarbonisation plans financed by European banks to the IEA 2050 net-zero scenario-*
Source: ECB-ESRB (Jan 2024) Tab. 4.5 p.249

(2a) Distribution of banks in the Eurozone by percentage of alignment and average entity of EAD (Exposure at Default)



(2b) Distribution of banks in the Eurozone by percentage of alignment and EAD/CET1 ratio



BOX 2 – TRANSITION FINANCE

In its recommendation 2023/1425 of June 2023[48], the European Commission stressed that it sees "sustainable finance" not only as the active financing of businesses that are already "environmentally friendly", but also of those who have undertaken a process of transition that over time will lead to same levels of sustainability, and that, although the European Union does not yet have a legal definition of "transition finance", the latter should be understood to be *"the financing of climate and environmental performance improvements to transition towards a sustainable economy, at a pace that is compatible with the climate and environmental objectives of the EU."*[49].

On an international level, the EU is aligned with the reference framework defined by TCFD (2021b), OECD (2022), G20 (2022), IPSF (2022), UN HLEG (2022).

"Transition" is therefore understood to mean the process *"that leads from present levels of environmental and climate performance to a climate-neutral situation that is resilient to climate change and sustainable from an environmental point of view"* over a period of time in line with the climate goals of Paris and the European Union. Therefore "transition finance" defines the overall financing of investments and assets that are compatible with the "transition", granted by whatever technical instrument (green loans or other loans for sustainability; green bonds or bonds for sustainable development; equity financing and specialised loans; green guarantees, etc.)[50]

In the field of "transition finance", the definitions of sustainability inspired by European Taxonomy[51] are not to be interpreted as exclusion criteria, but as trends towards conditions to be achieved over time, through planned action.

"Transition finance" is therefore, by nature, forward looking, and takes the form of connecting specific forms of finance to:

a) the definition of environmental, energy and/or climate objectives in line with the goals of Paris and EU policies (*target setting*).
b) the planning of the process for achieving said goals over a defined period of time (also in line with European and international climate policies).
c) the identification of specific actions instrumental for the purpose (*action plan*).

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[48] European Commission (2023), *On Facilitating Finance for the Transition to a Sustainable Economy*, Recommendation (EU) 2023/1425 of 27/6/2023

[49] Points (4) and (5) of the introduction to Recommendation (EU) 2023/1425. The same concept also provided the basis for the communication from the Commission itself in 2021 on the financial strategy of the EU (*Strategy for Financing the Transition to a Sustainable Economy* COM/2021/390), where it stressed *"the need for an inclusive approach to sustainable finance irrespective of sector, geographic location, type of agent or their differing starting points in transition"*.

[50] Cf. ECCO (2023)

[51] European Commission, Regulation (EU) 2020/852 (18/06/2020)

d) the periodical monitoring of the alignment of actions with the plan (*monitoring and disclosure*).

The identification of the end goals and the processes of convergence needs to be based on scientific evidence (*science based*)[52], to be comparable with official sector scenarios[53] (IEA 2021), or, in the case of investments in securities, with certified market benchmarks[54].

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[52] Cf. SBT (2019, 2022)

[53] IEA (2021); IPCC (2018, 2022); NGFS (2023b)

[54] The regulations regarding Climate Benchmarks, adopted in November 2019, introduces two types of benchmark: *"EU Climate Transition Benchmarks"* (EU CTB) and *"EU Paris-aligned Benchmarks"* (EU PAB), and also defines appropriate disclosure rules for the benchmarks themselves. Cf. European Parliament and Council, Regulation (EU) 2019/2089 (27.11.2019) amending Regulation (EU) 2016/1011 as regards *Climate Transition Benchmarks.* https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-climate-benchmarks-and-benchmarks-esg-disclosures_en

4 THE DEBATE OVER THE EFFECTIVENESS OF BANK CAPITAL REQUIREMENTS IN DECARBONISATION POLICIES

The modification of capital requirements in macroprudential terms, connecting them to the current and prospective carbon footprint of the entities financed, needs to be in line with the pursuit of climate goals, while at the same time contributing to the stability of the system. However, the two goals could sometimes be in conflict with each other, requiring careful assessment of the potential trade-offs. Unfortunately, on this issue, the analysis carried out so far by the authorities is of little help.

4.1 SCENARIO ANALYSIS AND STRESS TESTS

The difficulty of capturing climate risks statistically, the uncertain future projections of this category of risks, and the conditionality of future climate paths to the mitigation policies that are implemented, have driven the authorities to develop two methods for assessing the potential impacts of the climate crisis: scenario analysis and stress tests. Neither the scenario analysis nor the stress test are forecasts; rather they are counterfactual exercises aimed at exploring the characteristics of a range of possible futures (not necessarily probable or desirable), in order to assess the suitability of available policies and/or scale up their possible consequential impacts.

Scenario analysis simulates the future evolution of significant macroeconomic variables (physical climate damage, energy and carbon costs, inflation, growth, etc.) under alternative hypotheses[55]; stress tests, on the other hand, estimate the potential impact of the scenarios on the income account and the balance sheet of financial intermediaries in order to assess the suitability of their available capital to withstand extreme shocks[56].

The meaningfulness of stress tests depends on the reliability of the counterfactual scenarios and the structure of the models on which they are based. In assessing the resilience of the system, worst-case scenarios are usually used as input for the stress tests, and the models often adopt drastic simplifications in order to make policy shocks manageable (e.g., carbon pricing and/or carbon tax) [57]. In order to assess the relative effectiveness of alternative policy tools, the structure of the scenario simulation models needs instead to be much more clearly articulated, and to adhere as much as possible to the actual institutional environment. The structure of the models mostly adopted so far by the authorities for scenario analysis does not have the characteristics suitable for this second form of use, and therefore tends to underestimate the importance of the interaction between climate risks and the behaviour of the financial system. It has, however, been demonstrated that by better specifying the role of banks and financial intermediaries, capital

[55] NGFS (2023a; 2023b; 2023c; 2024)

[56] Alogoskoufis et al (2021); Baudino-Svoronos (2021); ECB (2022a,2023a); ECB-ESRB (2022);

[57] As will be shown further on, the models used by monetary authorities to simulate the short-term impacts of climate policies are generally of the DSGE (*Dynamic Stochastic General Equilibrium*) type, which examine both climate policies and the role played by the financial system in an extremely stylised manner.

requirements can represent a valuable tool to counter the macroeconomic shocks caused by the climate[58].

The importance of system-wide stress tests

The potential interaction between climate and financial shocks is the main source of systemic risk, but it requires stress tests to also include the behaviour of the financial system, which embraces all of the categories of intermediaries[59], and to use simulation techniques other than those generally adopted[60]. Neither of these two conditions characterise the microprudential stress tests that are periodically carried out by the supervisory authorities on the banking system[61].

The channels of distribution of shocks within the financial system depend on the close relationship that tightly binds all the institutions operating on the financial and credit markets. The main channels of contagion from shock affecting the financial system derive from the dense network of interconnected positions of debt/credit within the sector, and the major overlap between the securities portfolios of the various operators. The worsening of the financial position of enterprises and families due to climate impacts translates, in fact, into increased losses on loans for banks as well as on the market value of the securities they hold.

Significant falls in securities affect the value of the portfolios of insurance companies and investment funds, which are the main holders. In the short term, investment funds are the main vehicle for contagion. A fall in the value of their portfolios would instantly be passed on to the shares held by end investors (families and enterprises). If the resulting capital account losses are substantial, they can lead to significant disinvestment by the latter, which in turn tends to reduce the liquidity of the funds themselves. The funds may therefore find themselves forced to sell off significant portions of their own portfolios in order to meet payments, feeding a negative spiralling of the securities market value[62].

In turn, losses on loans and securities positions can force banks to firstly drain their interbank liquidity and to turn to financing from the central bank as lender-of-last-resort, while, at the same time, liquidating their own positions in mutual funds and securities, aggravating the liquidity shortage of the former.

Banks and insurance companies have slower reaction times, but these are no less hazardous. Furthermore, regulations set minimum capital requirements on both categories, which are

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[58] Gerali et al. (2010); Matikainen (2017); Dankert et al. (2018); Van Lerven-Ryan Collins (2018); Esposito et al (2018, 2020); Berenguer (2020); Carattini et al. (2021).

[59] Anderson et al. (2018); Brazier (2017)

[60] Schmieder et al. (2012); Gai-Kapadia (2010); Gai (2013); Wiersema et al. (2019), Aickman et al. (2019); Cont et al. (2020); Farmer et al. (2020); Sydow et al. (2021); Dubiel-Teleszynski (2022).

[61] EBA (2018); ECB (2022a, 2023a)

[62]Unlike banks, investment funds do not have access to refinancing from the central bank and can only react to liquidity crises by releasing the securities portfolio. It is however possible that in particular situations, hedge funds take countercyclical positions, mitigating rather than amplifying the final effects of stress (Gourdel-Sydow 2022)

calculated on the market value of their risk-weighted assets[63]. Losses on loans and securities caused by climate shocks have the dual effect of eroding the value of assets and increasing risk coefficients. In order to respect the regulatory requirements, banks and insurance companies need to ration credit and to sell part of their financial portfolio. The reaction of banks and insurance companies to shocks therefore tends to also gradually feed downward spiralling in financial markets and reduce credit for the economy.

The more firms and consumers are financially vulnerable, the broader are the negative effects of feedback on the economy. If the former have excessive debt, the worsening of access to finance forces them to turn to deleveraging (i.e., to releasing assets to pay off accumulated debt), and may even lead many towards insolvency. If the shocks are significant enough, or the level of financial fragility of operators is high, these dynamics can degenerate into serious solvency crises for the entire system, spreading from firms to banks, from banks to financial markets, and from financial markets to investors.

In order to take into account the potential systemic risks resulting from the chain-reaction of the system to initial shocks, stress tests need to be able to dynamically reconstruct the entire sequence of events. In other words, models cannot limit themselves to the *comparative statics* of traditional exercises; they need to be iteratively resolved through sequential scenarios, in which each scenario has serial impacts on rates of insolvency and market values. In the sequence, the reaction of operators to the first shock generates cascading reactions in the following stages, until the chain reaction ceases to cause further losses and the process dies out[64].

With regard to the European context, interesting results have emerged from simulations of this kind carried out by the Bank of England and the European Central Bank[65]. In both cases, the simulations have empirically confirmed how stress tests that include multiple categories of financial operators (system-wide stress tests), and in which shocks are simulated in multiple successive rounds, lead to the emergence of highly significant amplifying impacts.

The simulation by the European Central Bank (Sydow et al. 2021), based on historical data from the end of 2019 and replicating the scenario of the "COVID-19 Vulnerability Analysis of 2020"[66], shows that the inclusion of investment funds alongside banks in the sequential analysis leads on average, over the course of just two quarters, to an additional erosion of bank capital of more than 1% over that estimated in the 2020 stress test. The main channel of impact in this case is the simultaneous liquidation of securities portfolios characterised by heavy overlap between banks and funds. The exercise does not, in fact, take into account other elements that may further amplify initial shocks (such as, for example, derivative positions and the implicit leverage of setting margins), nor does it

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[63] The minimum capital requirements for banks are defined by the Basel Accords (cf. **Annex A.2 infra)**. Instead, European insurance companies are subject to similar regulation, which is governed by the Solvency II Directive.

[64] Montagna-Kok (2016); Aickman et al. (2019); Farmer et al. (2020); Sydow et al. (2021).

[65] The reference to the institutions does not necessarily reflect their official positions. However, the working papers they publish take into account developments in the technical and theoretical tools available to the authorities.

[66] Cf. ECB (2020), *Covid-19 Vulnerability Analysis. Results Overview*, July 28 2020, https://www.bankingsupervision.europa.eu/press/pr/date/2020/html/ssm.pr200728_annex~d36d893ca2.en.pdf

consider the behaviour of other important categories of intermediary such as insurance companies, hedge funds or financial market management companies (central counterparties or CCP) [67].

The exercise carried out by the Bank of England (Farmer et al. 2020) is also interesting for another three reasons: (a) because it bases estimates on the specification of a structural model that endogenises the dynamic behaviours of differing categories of intermediary (banks, investment funds and hedge funds); (b) because it takes into account multiple channels of contagion (overlapping of portfolios, interbank networks, exposure to credit risk, setting margins and derivatives); (c) because it offers results that are directly comparable with those of the EBA stress test (2018), as in both exercises, the initial exogenous shocks are the same. Unlike microprudential stress tests, the system-wide exercise carried out by Farmer et al. (2020) confirms that extending the analysis to also include the behaviour of intermediaries other than banks and identifying multiple channels of contagion produces systemic risks much higher than those identified by traditional stress tests (as much as five times greater)[68].

4.2 THE CHANNELS OF TRANSMISSION OF CAPITAL REQUIREMENTS

The effectiveness of any macroprudential policies correlated with climate risk depends on the design and calibration of the actions, which can be of varying form but that, in general, involve integrating climate and environmental risks in weighting RWAs.

There are fundamentally four solutions taken into consideration in academic debate **[cf. Annex A.3.1]:**

a) The introduction of a brown penalizing factor (BPF), i.e., an additional risk weighting associated to the exposure of the bank to high-emission-intense sectors/firms.
b) The introduction of a *green supporting factor* (GSF), i.e., a reduction in weighting associated with green and sustainable assets.
c) The simultaneous application of both a BPF and a GSF.

[67] The carrying out of the wide stress test by the ECB does not even take into account possible compensatory reactions from the monetary authorities in favour of banks, which would obviously mitigate the impacts, as was the case during the pandemic with Emergency Liquidity Assistance (ELA). In the same spirit, neither is any analysis made of other forms of crisis management by the authorities, as was done for example in Fukker-Kok (2021), where optimal control techniques for the management of endogenous interbank recovery rates were simulated under various alternative methods for liquidating securities by intermediaries.

[68] The EBA stress tests (2018) with which the system-wide exercise is compared are in line with the general guidelines of the ESCB (2018) and are based on scenarios in which the shocks to the main macroeconomic variables (GDP, unemployment, value of real estate and shares) are created by drawing on the most severe experiences of the past and on the current level of exposure of banks to risk. In the ordinary stress tests, the level of the final impacts is proportionally dependent on the degree of the initial shock alone, the higher the intensity of the initial shock, the greater the impact. The exercises by the EBA, in other words, identify the overall effect of extreme historical events, but they do not highlight the internal dynamics of sequential amplification of the shocks. However, this dynamic is of great importance, as, once it has been identified and reproduced, it shows that severe final impacts can derive not only from extremely heavy shocks, but also from modest initial shocks. It is, in fact, the mechanism of endogenous self-feeding that greatly amplifies systemic risk.

d) The so-called Environmental Risk Weighted Assets (ERWA) method, which consists of multiplying each traditionally weighted RWA by a corrective coefficient with a value of between 0.5 and 1.5 in accordance with the climate-environmental impact of the asset in question, and where values lower than one are assigned to assets with no impact or positive impact on the environment (Esposito et al. 2018, 2020).

Alternatively, the adjustment could take the form of a reward (GSF) or penalty (BPF) not with regard to the calculation of RWAs, but rather to that of the additional systemic solvency ratio, connected, for example, to the level of the bank's *Green Asset Ratio* (GAR) and the *Banking Book Taxonomy Alignment Ratio* (BTAR) **[cf. Annex A.2.3]**.

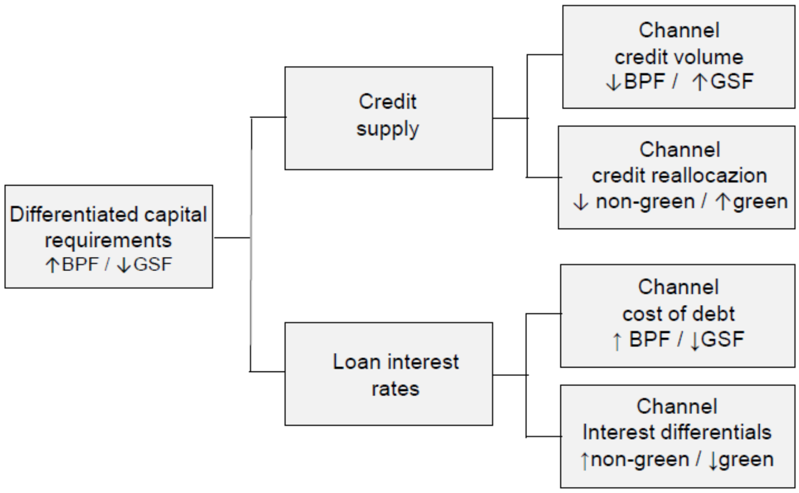
The introduction of a BPF would raise the cost of capital for banks that fund activities that are not in line with the goals of Paris and the Green Deal and, *ceteris paribus*, would also increase selectivity in the recomposition of risk-weighted assets, encouraging the banks to adopt stricter climate and environmental assessment criteria. The entire banking system would thus be encouraged: (a) to save capital by both increasing interest rates on loans granted to "non-virtuous" (or *brown*) entities, and by rationing credit to these counterparties, (b) to adopt ever stricter environmental risk assessment criteria, and (c) to increase the proportion of "sustainable" securities in their portfolio. The introduction of a GSF would set in motion the same selective process, but this time working in favour of "virtuous" (or *green*) debtors. For this reason, the adoption of a green supporting factor was the method originally indicated by the EU HLEG (2018).

In general, the adoption of either a BPF or a GSF has similar effects on the behaviour of banks, but can lead to different macroeconomic impacts according to the relative elasticity of the response from the various operators. Manoeuvres involving capital requirements tend, in fact, to influence macrofinancial variables through four main channels: (i) overall credit volume; (ii) reallocation of credit between sectors and firms; (iii) the general level of bank interest rates and (iv) the discriminating effect of differentiated bank interest rates **[fig. 3].** Historically, each of these channels has proven to be important within the European institutional context, where the central role played by banks in the transmission mechanism tends to heighten the restrictive impact of supply shocks and to smooth the effects of adverse demand shocks (Gerali et al. 2010).

- The first channel is the overall dynamic of bank credit; a higher/lower capital requirement is, in fact, mirrored by a lower/higher offer of credit for the economy from the entire banking system. In the case of the BPF, the total volume of credit tends to diminish, while in the case of the GSF, it tends to increase.
- This primary effect is joined by a second, related to the revision of the weightings associated to the level of risk of loans in the calculation of RWAs and to the application of stricter assessment procedures by banks. In both cases, the overall effect is a reallocation of the loan portfolios of banks from brown to green loans, and the intensity of this process depends on the responsiveness of the receivers of funds to the new banking procedures.
- The third channel, related to the average level of lending rates, cannot be defined in advance, as it depends on the balance created in the market between demand for and supply of credit, which is, in turn, the result of other variables (such as monetary policy and the economic cycle). As demonstrated by the financial crisis, an increase in the BPF coefficient tends to accentuate the procyclical nature of bank behaviour, while a reduction in the GSF tends to attenuate it (in both directions).
- As far as taxes are concerned, all other conditions remaining the same, the BPF raises bank rates and reduces demand for credit from the penalised sectors; while the GSF, by lowering

capital requirements, reduces the cost of credit and increases demand from the rewarded sectors. Lastly, for debtors, the differentiated assessment of credit risk results in more discriminating rates in the case of the BPF and in more beneficial rates in the case of the GSF.

Figure 3 – *Transmission channels of green and non-green differentiated capital requirements.*
Source: Dafermos-Nikolaidi (2021)



The combination of these channels influences the intensity of the effects, but does not change the direction which, in all simulations, results in a net reduction of credit to less climatically virtuous assets and a net shifting of resources in favour of green assets, with a consequentially more intense and accelerated decarbonisation process.

4.3 PROS AND CONS OF GSF AND BPF

The effects of substituting brown loans with green loans, redirecting bank assets towards presumably more resilient activities would also result, in the medium to long term, in a lower exposure of the banks themselves to climate risk.

This does not however mean that, in the short term, they will also be immune to transition risk. If the reduction in the flow of financing to non-green sectors/firms is, for example, too intense and rapid, this may have a destabilising effect on the solvency of the sectors/firms concerned, and would have negative feed-backs on the banks themselves; in addition, if at the same time there is an excessively heavy and accelerated diversion of resources to green sectors/firms, this could lead to undesirable speculative *green* bubbles.

This last shortcoming appears to be particularly pertinent in the case of application of GSFs.

- The main purpose of capital requirements is to defend banks from unexpected shocks, and their reduction would only be justified if green loans were uniquely associated with a lower risk of insolvency of borrowers. This relationship has, however, not been empirically proven. On the contrary, there is a possibility that credit risks for green loans could sometimes be even higher, for example in the case of funding for start-ups or new technologies that may, over time, prove unsuccessful. An exclusive focus on the green aspects of financed projects may therefore lead to other, non-climatic risks being underestimated, fostering opportunistic behaviour (*moral hazards*), encouraging excessive indebtedness of borrowers and thus creating a context of more rather than less vulnerability. In this case, faced with an higher financial fragility, the banks would find themselves endowed with lower capital defences. If the current levels of capitalisation are to be considered well suited to protecting banks against non-climate risks, there is no reason to reduce these defences. Taking into account other risk factors, such as climate, should be part of a logic of addition, not of substitution, in capital requirements.

- GSFs are inevitably linked to the adoption of an exclusively *policy-oriented* logic, in which priority is given to diverting resources towards green investments, irrespective of protection from risk[69]. However, even accepting the idea that GSFs are adopted purely for the purpose of encouraging credit reallocation, there are doubts over their true effectiveness in promoting green investment. The experience in Europe with a coefficient that favours small and medium enterprises (*SME supporting factor*) has not, in fact, produced the hoped-for results in terms of the allocation of credit to these entities, but it has resulted in a reduction in the overall capitalisation of the banking system (EBA 2016; Mayordomo et al. 2018; 2DII 2018; Dietsch et al. 2020) [70].
- Lastly, even if the GSF stimulates green loans, there is no guarantee that the increase in the latter will result in a parallel reduction in brown loans.

The adoption of the BPF, i.e., a penalising factor for the most pollution intensive sectors/firms, therefore appears to be preferable to rewarding green entities with the GSF. BPFs could easily be modulated in order to not have disruptive effects, and to gradually adopt the system in a process in line with the EU climate goals (for example connecting them to prospective decarbonisation programmes rather than to current carbon footprints), sending the right signals to operators. BPFs do not erode the overall asset protections of banks; rather they bolster them, and they therefore do not appear to contradict the *risk-based* logic of prudential supervision. On the contrary, on the basis of the assumption that the market is unable to correctly assess climate risks (particularly with regard to their systemic valence), and that these are generally either ignored or underestimated, the BPF appears to be a correction that is not only suitable, but also necessary.

However, the adoption of the BPF is not without potential problems (Berenguer 2020):

- it is possible that the higher cost of capital penalises weaker counterparties, such as SMEs, and those without access to alternative technological options (the so-called hard-to-abate

[69] However, in this case, the potential collateral effects on risks of a different nature cannot be ignored and need to be compensated with an increase in the other components of the solvency ratio related to risk factors other than those related to climate, in order to keep the overall level of bank capitalisation at a suitable level.

[70] In 2014, the European Union introduced two incentives that acted on capital requirements in favour, respectively, of SMEs (SME supporting factor or SME SF) and of infrastructure (Infrastructure supporting factor, or ISF), with the aim of reducing the cost of capital by 15%-25% for SMEs and by 25% for infrastructure. The ISF applied conditions that limited risk for the financing agent, for example that at least two thirds of the capacity for repayment of the loan should be generated by the project being financed. This increased the predictability of cash flows and guaranteed increased financial sustainability, compensating a lower ISF. Instead, for the SME SF, no mechanisms were provided for to mitigate the risk of loans, and the results in terms of reallocation proved controversial; with a saving in capital for the European banking system estimated at 12 bn (EBA 2016), loans to SMEs in the two successive years increased by 10% (Dietch et al. 2020), impact often appeared to be uneven and leaned towards medium and large firms, i.e., those in better credit risk classes, indicating that in reality, the banks had not modified their previous criteria for allocation (Mayordomo et al. 2018).

sectors). In these cases, connecting penalising factors to prospective decarbonisation goals (*forward-looking* targets) rather than to current carbon footprint indicators appears to be an inevitable measure in order to encourage rather than hinder the implementation of transition plans.

- With all other circumstances being equal, by increasing the overall capital requirements for banks (and therefore its cost), BPFs tend to reduce the supply of bank credit, and it cannot be assumed for sure that credit rationing is to the exclusive detriment of "brown" sectors.
- Even if BPFs prove to be effective in discouraging the most harmful activities, they provide no incentive for investing in more promising enterprises, and therefore they provide no guarantee that the reallocation of resources will be directed towards solutions and technologies aimed at accelerating ecological transition.
- Lastly, the application of penalising coefficients could shift part of the demand for financing to lenders that are not subject to supervisory regulation, thus encouraging the so-called *shadow banking* (which played a dominant role in the spread of the financial crisis in 2007-08) or forcing banks to free capital through the securitisation of unsustainable assets (which points to the necessity for specific regulation of the latter[71]).

An intermediate option for minimising any possible distorting effects could be the simultaneous adoption of both appropriately calibrated GSFs and BPFs (Dafermos-Nikolaidi 2021).

4.4 EMPIRICAL SIMULATIONS

The empirical evidence shows that capital requirements have a significant influence on both the volume of credit and the level of bank interest rates[72]. As a consequence, the debate has recently widened to also include the possibility of using this tool to align the behaviour of the banking system to the goals of Paris[73], even though contributions to quantitatively assessing the implications are few[74].

As is well known, in macroeconomics, the drawing up of policies for short-term stabilisation is subject to widely divergent theories which cannot be examined here. However, two from this field can be considered the main approaches; the DSGE (Dynamic Stochastic General Equilibrium)[75] and

[71] Cf. ECCO (2023)

[72] Aiyar et al. (2014); Akram (2014); De-Ramon et al. (2016); De Marco-Wieladeck (2015); Meeks (2017); Fraisse (2017); Imbierowicz et al. (2019)

[73] EU HLEG (2018); Schoenmaker-Van Tilburg (2016); D'Orazio-Popoyan (2019); Esposito et al. (2018 e 2020); Berenguer (2020); Oehmke (2022); ReCommon (2024)

[74] Thomä-Gibhardt (2019); Punzi (2018); Dunz et al. (2020); Dafermos-Nikolaidi (2021).

[75] DGSE models have been implemented for some time and have seen widely differing evolutions. Originally, these were strictly neoclassical in nature, with perfect markets, the behaviour of operators creating optimal conditions at microeconomic level, rational expectations and a spontaneous tendency to long-term stability. Economic policy (fiscal and monetary) played no role in these models. Disturbances in the economic cycle and uncertainties resulted exclusively from supply shocks due to technological innovation. Further on, DGSE models also gradually incorporated hypotheses typical of the neo-Keynesian tradition, i.e., imperfections and friction in market operations and, above all in the wake of the 2007-08 financial crisis, they also considered - in various ways - the role of financial intermediaries and the redistributive effects deriving from the disaggregation of the behaviour of certain categories of agent (Christiano et al. 2018; Coenen et al. 2018; 2023; Annichiarico et al. 2021).

the SFC (Stock-Flow Consistent)[76] models. The first is by far the most dominant, adopted by governments, international institutions and central banks; the second, instead, represents an alternative approach, one that is more attentive to interactions between various agents and in particular to the role of the financial system.

The DGSE-type models used by monetary authorities to simulate the short-term impact of climate policies tend to underestimate the collateral effects of decarbonisation policies. Generally, these models use the price of carbon (or the carbon tax) as the sole policy tool, assessing the impact on the main macroeconomic variables, without taking into account the potentially destabilising behaviour of the financial system[77]. It is only in recent years, in the wake of the 2007-2008 financial crisis, that standard DSGE models have been expanded to explain these aspects[78], and even the models of the ECB have recently incorporated this (Coenen et al. 2018). However, according to the logic of this type of model, the actions of financial intermediaries are specified in an extremely generalised manner and are treated exclusively as generators of "friction" that disturb the natural process of adjustment towards market stability[79]. These models are therefore not useful for

[76] SFC models are inspired by post-Keynesian-type theories that emphasise the role of aggregate demand in processes of growth and the physiological instability of the system. SFC models have an extremely disaggregated structure, in which the behaviour of each category of agent (families, firms, financial intermediaries and the public sector) generates real decisions (consumption, savings and investments) and financial flows (variations in financial assets and liabilities) that interact and modify the composition of their budgets and impact market equilibria. The macroeconomic behaviour of agents is neither optimised nor rational, but is, instead, governed by behavioural heuristics (*bounded rationality*), and markets are not perfect. The interaction between these forms of behaviour, therefore, does not necessarily lead to full employment and stability. The correction of imbalances and "market failures" requires the intervention of active economic policies. This type of models is able to understand phenomena of imbalance and instability, above all those that have an impact on the financial system (or even originate from within it). Cf. Goodley-Lavoie (2012); Caiani et al. (2016); Dafermos et al. (2017, 2018); Dafermos-Nikolaidi (2020,2021,2022); Monasterolo (2020); Dunz et al. (2021, 2023)

[77] For example, a simulation of the impact of short-term climate policies carried out by Coenen et al. (2023) with the econometric model of the ECB (modified to differentiate between the behaviour of fossil-energy producers with that of renewable-energy producers) shows that a significant increase in the price of carbon leads to only a temporary increase in inflation and a permanent reduction in GDP, the entity of which fundamentally depends on two factors: the elasticity of substitution between fossil energy and clean energy, and monetary policy. Through the reduction in energy consumption and the substitution of fossil energy with green energy, emissions are reduced to a greater extent than GDP, although this reduction is still insufficient with regard to European goals. In order to obtain effects on emissions in line with these goals, a much broader variation in the price of carbon (or of the carbon tax) would be necessary, and consideration would also have to be made of other types of action that the model does not consider (public investment, supervisory policies, etc.). The model therefore provides a misleadingly reassuring picture of the trade-off between a reduction of emissions and the evolution of economic activity and tends to underestimate the risks of transition. In the exercise in question, the increase leads progressively to a price of 140 $/tCO_2$ in the 2022-2030 period, in line with the forecasts of ECR (Effective Carbon Rates) made by the OECD; this variation in the price of carbon leads to a moderate slowing down in consumption (-0.7%) and a more significant fall in investments (-2.5%), with a permanent negative impact on GDP (-1.2%), i.e., an extremely modest annual reduction in product (-0.125%). The parallel effects on inflation (driven by energy costs) are of limited duration (4 quarters) and restricted impact (+0.2%), and they gradually return to initial levels over the period considered by the simulation. GHG levels fall overall by 7% over the period in question, an irrelevant amount in comparison to the goals to half emissions set by the European Union.

[78] Gerali et al. (2010); Gertler-Karadi (2011); Gertler-Kiyotaki (2015); Gertler-Kiyotaki-Prestipino (2016); Christiano-Motto-Rostagno (2014)

[79] Traditional DGSE models typically adopt the so-called approach of the "financial accelerator" or ILF (Intermediation Loanable Funds), in which the banks only lend funds previously gathered in the form of deposits and optimise in the margin between the cost of their gathering and the returns from their use. In these models, the constraints of family and company budgets are determined by the availability of savings, and the impact of banking

examining the implications of the application of differentiated capital requirements with a sufficient level of realism.

There are, however, a number of interesting exceptions. In certain academic DGSE exercises designed to analyse the macroeconomic impact of climate policies, additional elements are introduced that further specify the role of intermediaries, and these demonstrate that the use of macroprudential capital requirements, while proving of little importance as a stand-alone lever for climate policy, can however play a decisive role in mitigating transition risk generated by aggressive decarbonisation policies (Punzi 2020; Carattini et al. 2021). These findings therefore show that **macroprudential policies are a necessary component of climate policies in terms of reducing the exposure to risk of financial intermediaries** who, without suitable capital requirements, serve only as channels for the amplification of systemic risks. As climate policies become increasingly aggressive, additional capital requirements linked to climate risks are ever more necessary.

Carattini et al. (2021), using an E-DGSE[80] model calibrated to the US economy, has, for example, simulated the impact of the sudden introduction of a carbon tax both in the absence and in the presence of additional capital requirements for banks[81]. The unanticipated introduction of a carbon tax has the effect of generating an accelerated substitution of "brown" sectors with "green" sectors, reducing the value of the former (stranded assets) and generating losses in bank assets to which banks react by reducing credit. These losses increase in line with the initial share of loans to "brown" sectors rather than "green" sectors; if the share is high, the losses suffered by banks leads to an indiscriminate reduction in credit that also affects "green" sectors, with recessive impacts on the entire economy. As the level of transition risk for banks depends on their exposure to the "brown" sectors when the carbon tax is adopted, macroprudential policies that use selective increases in capital requirements to force banks to reduce the weight of "brown" sectors in their portfolios are fully in line with the mandate of the supervisory authorities to protect the financial stability of the system.

Macroprudential policies thus render the banking system less reactive to any adverse impact of climate policies, making them more effective, eliminating the destabilising feed-backs that they may generate[82]. **Climate policies and macroprudential policies are therefore complementary, and one is not a substitute for the other.** The simulations of the model show, in fact, that using macroprudential policies as an alternative for other climate policies is not efficient. When macroprudential policies are simulated in the absence of the carbon tax, the dynamics of product

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behaviour on the stability of the system only emerges in the form of a reallocation of available resources through the varying of bank interest rates (Jakab-Kumhoff 2019).

[80] DGSE models adapted to assess the impact of climate policies are known as E-DGSE (Ecological-DGSE).

[81] The model uses the carbon tax as a proxy for climate policy and the setting of a limit on bank leverage in the form of additional capital coefficients as an element of "friction" in the granting of credit by banks.

[82] The model used by Carattini et al. (2021), not only to simulate the impact of the implementation of a carbon tax but also to carry out exercises in reverse engineering, endogenising optimal policies, i.e., resolving the model in accordance with end goals provided in an exogenous manner (reduction of emissions and growth) and comparing the outcomes of various combinations of climate policies (carbon tax) and macroprudential policies (capital coefficients). The results confirm that the adoption of a mix of climate policies that also includes suitable macroprudential measures optimises the trade-off between carbon tax, growth and financial stability.

are higher, but so also are emissions. However, using capital requirements that are differentiated between "brown" and "green" assets does not result in effects on emissions that are significantly different from a single requirement that is the same for all assets. **The results of the model confirm that two goals require two policy tools; the carbon tax affects emissions, and capital requirements safeguard stability.**

Dafermos-Nikolaidi (2021) demonstrate that the use of well-balanced differentiated capital coefficients results in a reduction of the exposure of the banking system to climate risk. **The combined implementation of the BPF and the GSF allows the first to reduce the exposure of banks to transition risk and the second to mitigate the adverse effects of credit rationing (supporting sustainable investments that may suffer as a result).** Even in this case, two goals (financial stability and decarbonisation) have two distinct corresponding tools.

The Dafermos-Nikolaidi model has a theoretical framework that differs greatly from the DGSE models adopted by the authorities[83], and it has characteristics that are particularly suited to offering a granular study of the effects of differentiated capital requirements for banks (GDCR or *green differentiated capital requirements*); the structure of the model in fact specifies in a detailed and distinct manner the factors that influence the supply and demand for credit while at the same time separately identifying the carbon footprint of various types of loan.

The model not only distinguishes between loans for green assets and conventional loans, but also differentiates assets in terms of the relationship between emissions and the added value of the sectors to which they belong.

The approach adopted by Dafermos-Nikolaidi (2021) in specifying the role of banks is similar to that of Jackab-Kumhof (2019) known as FMC (financing through money creation), in which banks create money (deposits) endogenously through the granting of loans, i.e., providing depositors with resources in excess of their initial liquid balances (overdrafts). This approach to bank models allows for an exploration of the possibilities of banks extending the budget constraints of firms and families, resulting in an additional dependence of their behaviour on the regulatory constraints to which banks are subject. In this manner, the conditions for the supply of credit can be studied separately from those that determine demand, allowing the analysis of credit rationing by quantity and by price discrimination. This modelling strategy appears more realistic than the one adopted by the majority of DGSE models and takes into account the more significant role played by the financial system in amplifying shocks to real macroeconomic variables.

[83] The DEFINE 1.1 (*Dynamic Ecosystem Finance Economy*) model by Dafermos et al. (2017; 2018; 2022) is of the SFC (Stock-Flow Consistent) or agent-based type, in which the behaviour of the various agents (financial intermediaries included) is specified in a granular nature in the form of their balance sheets, which are modified by the flows deriving from their interactions (real and financial transactions). The dynamics of the resulting system are complex and non-linear. Unlike in the DGSE models, the agents are unable to optimise their behaviour in an intertemporal manner; they act in conditions of bounded rationality and in a situation of radical uncertainty. The markets are not perfect, and the system does not spontaneously tend towards stability; it is instead intrinsically unstable (Goodley-Lavoie (2012); Caiani et al. 2016; Monasterolo 2020) **[cf. Annex A.3.2]**.

The simulations carried out by Dafermos-Nikolaidi (2021)[84] confirm that capital requirements contribute to decarbonisation by shifting the allocation of credit from "brown" sectors to "green" sectors, but that by themselves do not offer sufficient policy leverage and need to be used to complement other specific policy instruments (carbon tax, green tax allowances, etc.). **On their own, capital requirements do not sufficiently accelerate the passage to non-fossil energy, and therefore do not significantly slow-down emissions or sufficiently reduce the resulting "physical" climate risks**. **They do, however, bolster the effectiveness of combined decarbonisation policies, and above all they generate collateral benefits for the financial system[85].**

In the exercise by Dafermos-Nikolaidi, the application of the various policy instruments is compared with a baseline scenario in which no other mitigation policies are applied beyond those already in force[86]. In the baseline scenario, climate change drives a progressive fall in productivity and, together with an increase in extreme climate events, progressively reduces both growth of GDP and the profitability of firms. The situation, however, tends to assume a particularly destabilising dynamic once global warming passes the 2°C threshold (just after mid-century). Beyond this threshold, the exponential increase in adverse climate impacts accelerates the deterioration in the profitability of firms and increases their rate of insolvency (which could be considered a proxy for the impact of physical risks). In turn, business losses result in a progressive erosion of banks' capital, despite the adoption of tighter and more selective credit policies. Both the depletion of banks' capital and the increase in leverage have a ceiling set by minimum regulatory requirements, and once the limit has been reached, banks will be forced to recapitalise and/or reduce assets.

In the exercise conducted in the absence of other climate policies (carbon tax, public investment and/or allowances), the lever provided by obligatory capital requirements (in any combination) is unable alone to halt the deterioration of the climate, which, in all scenarios, results in the progressive reduction of bank capitalisation. However, this outcome is of varying intensity, depending on the combination of the differentiated capital requirements applied to the banking system. Therefore, the possible benefits of the adoption of differentiated capital requirements can be explored in relative terms, vis-à-vis the baseline scenario.

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[84] The numerical simulations are calibrated on global data and the key parameters, where pertinent, are deduced from previous studies and, when unavailable, are estimated econometrically by the authors. The simulations cover the 2018-2100 period, but macroprudential policies have effect from 2022

[85] In the model-based simulations, the conclusive reduction of GHG emissions directly related to the application of differentiated capital requirements appears to be fairly modest, above all because in the models, the conclusive effects are the result of a long chain of actions (policy tools➔banks➔economy➔GHG), each characterised by partial elasticities that reduce their impact. This evidence has often been used to support the idea that capital requirements are ineffective as a credit policy tool, and that they should focus exclusively on covering risk. This, which is actually a common characteristic of exercises carried out with models of differing structure and theory, is a result that emerges not only with regard to capital requirements, but also for the climate impacts of other macroeconomic policies (monetary, fiscal and of carbon pricing), confirming the impression that none of these policies alone are decisive, but that their convergent application could be.

[86] The simulations examine the impact of different combinations of policy tools and compare the trends in emission, energy and macroeconomic variables with a baseline in line with the IPCC SPP (*Shared Socioeconomic Pathways*) scenarios, in which mitigation policies either remain in line with those already implemented (SSP2) or are slowed by geopolitical fragmentation and conflict (SSP3). The baseline scenario tends towards a level of warming of +3.2°C by the end of the century.

The exercise shows that the simultaneous adoption of both BPFs and GSFs always generates relatively more favourable dynamics than the baseline scenario **[cf. Annex A.3.3][87]:**

- In both cases (the separate adoption of BPFs and GSFs alone), there is a reallocation of credit in favour of "green" investments, which are favoured by lower credit costs and which, with the progressive increase of their proportion of the total, also reduce the overall risk exposure of bank assets; this, in turn, encourages the expansion of the volume of credit (with a further increase in bank leverage, i.e., the ratio between assets and capital) and also lowers the weighted average of bank interest rates. Furthermore, the reallocation of credit towards sustainable investments accelerates the transition to non-fossil energies, slowing emissions and reducing the degree of climate harm.
- However, BPFs and GSFs have differing effects on the level of credit rationing and on bank rates; BPFs alone lead to a higher, generalised rationing of credit, an increase in firms' insolvency and consequently less support for economic activities; on the contrary, GSFs provide support for some firms and reduce their financial deterioration.
- In the case of the application of GSFs alone, the greater increase in bank leverage compared to the BPFs could be considered an indicator of the increased relative vulnerability of the system and its latent instability; vice versa, the application of BPFs alone results in a lower exposure of the banks (less leverage), but this difference appears negligible when compared to the much greater degree, in all scenarios, of the erosion of banks' Tier 1 capital resulting from the direct and indirect impacts of climate change.
- The joint adoption of BPFs and GDFs tends, instead, to improve all these dynamics (to an extent that obviously depends on how the tools are calibrated in relation to the key parameters of the model[88]), but, in any case, either versus the baseline scenario or versus the alternative scenarios with the application of BPFs or GSFs alone, it provides unambiguous qualitative indications:
    - Lower relative losses in terms of GDP.
    - Higher relative proportion of renewable sources in energy production.
    - Improved dynamics of GHG emissions and lower global warming.
    - Improved profitability and lower rates of insolvency among firms (i.e., lower impact of physical risk).
    - Lower credit rationing and lower spread of interest for green enterprises.
    - Higher credit rationing and higher spread of interest to brown enterprises, in line with the baseline scenario.
    - Lower increase in bank leverage (i.e., lower vulnerability to transition risk).
    - Slower deterioration in bank capital.

[87] Obviously, the simulation produces results that must be read in terms of their qualitative value, since their quantitative intensity depends on how the instruments are calibrated. In the exercise by Dafermos-Nikolaidi (2021), the GSF is represented by a 25 percent reduction in the risk weighting of green loans, and the BPF by an equal increase in weighting for brown loans.

[88] In the DEFINE 1.1. model, the key parameters are: (i) the elasticity of the offer of credit, the elasticity of the level of bank credit rates and the elasticity of the spread of rates compared to the capital ratio of the banks (RWA/capital) and compared to the credit risk of the enterprises granted credit (measured by their level of debt to income(; (ii) the level of credit rationing and the sensitivity of rates to the level of greenness of loans (GHG/VA of enterprises granted loans), where it is assumed that rationing is a positive result of their climate risk (i.e., of the weight of each particular category of loan in the RWAs) and that sensitivity is a negative result of the desired proportion of green loans in the portfolio (the more a bank is inclined to grant green loans, the lower the rates on said loans). Cf. **Annex A.3.3**

5 CONCLUSIONS

The importance and the centrality of banking systems in modern economies explains the heightened focus from regulatory bodies on their stability. Banking systems, however, also play a decisive role in connecting the goals of public policy with the behaviour of agents. An extremely significant proportion of the flow of loans to corporates and families passes through the banking system, and the decisions taken by banks therefore condition decisions regarding investments.

In a significant moment in history, in which climate change is proving to be one of the greatest threats to economic stability and prosperity, it is therefore inevitable that banking systems also have to protect themselves from these risks, adapting their procedures and strengthening their capital base.

At the same time, in a period in which public policy is setting ambitious goals for mitigating global warming, it appears equally unavoidable that the banking system would be called on to re-direct the flow of intermediate resources to supporting the huge efforts currently required to reconvert and adapt economic systems.

Macroprudential minimum capital requirements are a feasible and effective lever for both defending the stability of the system from ever increasing physical and transition risks and for reorienting financial flows to support the transition.

The objection put forward so far by the supervisory authorities that the use of capital requirements for the purpose of policy would be a betrayal of the rigidly risk-based approach of prudential regulation does not appear justified in light of the systemic and radical nature of climate risk, which is the recognised basis of macroprudential supervision itself. The rationale of macroprudential capital requirements, which were introduced in the wake of the 2007-08 financial crisis, is in fact rooted in the recognition that the behaviour of the banking system is endogenous to the development of crises and tends to have an amplifying effect. A recomposition of the flow of credit towards less carbon-intensive uses (both present and prospective) thus contributes not only to reducing exposure of banks to climate risk, but also contributes to mitigating said risks.

Macroprudential logic also resolves the objection that differentiated capital requirements against climate risk would not be methodologically calibrated due to the statistical intractability of said risk. The relative literature, in fact, argues that it is this very intractability that suggests the adoption of a precautionary and insurance based approach rather than the traditional risk management logic.

In considering the adoption of prudential tools in order to reorient the flow of credit towards sustainable applications, it would however be necessary to take into account the potential trade-offs and pragmatically calibrate them on the basis of empirical evidence. To date, the simulations available for this purpose are few, but they appear to confirm that the introduction of capital buffers against climate risk are the necessary complement to other climate policies (carbon tax, subsidies to green activities, public investments, etc.), in particular whenever the latter become particularly aggressive and concentrated over time. Furthermore, the joint application of differentiated coefficients to the detriment of "brown" loans and in favour of "green" loans appears instrumental for the further reduction of transition risk.

It is therefore advisable for the Basel Committee and the supervisory authorities to rapidly embrace the adoption of differentiated capital requirements for banks in addition to and in support of governmental decarbonisation policies and, to this end, define a clear framework for their application. In particular:

- defining a conceptual map that links Taxonomy sustainability criteria to a systemic risk potential grid for financeable entities that takes into account prospective decarbonisation programmes as well as the current carbon footprint.
- calibrating and prescribing parameters for increasing and/or decreasing capital requirements in line with the aforementioned systemic risk grid.
- setting out uniform and certified methods for verifying that decarbonisation programmes are aligned with the goals of the European Union and with the climate goals of Paris.
- establishing binding monitoring procedures and KPIs in line with the previous points.
- integrating control and reporting procedures with those which already exist for the Basel's second and third pillars (internal controls, governance and disclosure).

ANNEX A.1

Tab. A.1 – The guidelines of the EBA for the disclosure of climate and environmental risk (*)

KPI	Metric of measurement
Emissions	
Total GHG emissions (differentiated between Scopes 1, 2 and 3)	Tons of CO_2eq
Emissions of atmospheric pollutants	Tons of pollutants
Emissions of pollutants into water	Tons of pollutants
Emissions of inorganic pollutants	Tons of pollutants
Carbon footprint	Tons of CO_2eq (GHG as a % of VA or other)
Fossil energy sectors (art. 4 Directive 2009/33/EC	% of total
Policies for the reduction of fossil energies	Presence / Absence (which?)
Policies for the reduction of GHG	Presence / Absence (which?)
Compliance with the goals of Paris	Targets/timeline/certification
Energy efficiency	
Energy consumption intensity	GWh
Use of renewable energy	% of total energy consumption
Policies for the increase of renewable sources	Presence / Absence (which?)
Use of water	
Intensity of the use of water	% of total - weight in tons
Production of waste	
Production of toxic/harmful waste	% of total - weight in tons
Recycling/reuse	% of total - weight in tons not recycled
Policies for the reduction of waste	Presence / Absence (which?)
Biodiversity and ecosystems	
Presence in zones with soil deterioration	% of total (own and of the value chain)
Presence in protected areas	% of total (own and of the value chain)
Presence in sensitive areas (not protected)	% of total (own and of the value chain)
Presence in IUCN red-list areas	% of total (own and of the value chain)
Climate and environment	
Presence in heatwave zones	% of total (own and of the value chain)
Presence in zones affected by drought	% of total (own and of the value chain)
Presence in zones with flooding/landslides	% of total (own and of the value chain)
Presence in zones with coastal corrosion	% of total (own and of the value chain)
Presence in zones affected by fires	% of total (own and of the value chain)

(*) EBA (2021a) REP/2021/10 Annex 1 and EBA (2022b) ITS/2022/01

ANNEX A.2

A.2.1 Basel 3 capital requirements (Pillar 1) (*)

The Basel Accords require that the Regulatory Capital (K) of banks are proportional to the risk-weighted assets (RWA), where the factor of proportionality is the solvency ratio (s), the calculation of capital requirements is therefore based on the following formula

(1)
$$K = s\,(RWA)$$
where
$$RWA = \sum_i w_i\, A_i$$

with A_i = *i-th* asset and w_i = percentage i-th asset weighting on the total assets

Fig. A.1 – Example: Calculation of RWA and capital requirements

Weight %	Asset cathegory (€)
0	• Liquidity • Government bonds (domestic / OCDE)
20%	• Bonds/Loans to public entities • Bonds/Loans to banks and investment firms
50%	• Real estate guaranteed mortgages
100%	• Loans to non-financial firms
200%	• Participatory stakes in non-financial firms (suffering 2 yrs losses)

Asset cathegory	(a) Asset stock (md €)	(b) Basel 1 weight (%)	(axb) RWA (md €)	min Regulatory Capital (md €)
Liquidity Gov. bonds	50	0	0	
Loans to banks	60	0,20	12	
Mortgages	140	0,50	70	
Loans to non-fin firms	250	1,00	250	
TOTAL	500		332	26,56

solvency ratio (x 0.08)

The evolution of the Accords, from Basel 1 of 1988 to Basel 3 of 2012, has gradually perfected:

a) the perimeter of the tools allowed for the definition of Regulatory Capital (K) which is divided into (i) primary capital, known as Tier 1, which is in turn distinguished as capital in the strict sense, made up of capital and reserves (CET1, or *common equity Tier 1*) and additional Tier 1 and (ii) supplementary capital or Tier 2, composed of hybrid capital tools, revaluation reserves and subordinate tools.
b) the calculation of RWA, through the inclusion of other forms of risk and the adoption of more precise metric for calculating said risk.
c) the entity of the solvency ratio, to correct the procyclical impact of the ratio and to take into consideration exposure to systemic risk.

In the current system (Basel 3), the risks taken into consideration in the calculation of RWA are:

- credit risk
- concentration risk
- risk deriving from securitisation
- market risk
- interest-rate risk deriving from activities other than trading
- operational risk
- liquidity risk

In Basel 3, the solvency ratio (s) applied by each bank is currently based on the sum of the various components (EBA 2023/REP/34):

- The base coefficient (currently set at 8%).
- An additional fixed coefficient, known as Capital Conservation Buffer (CCoB), aimed at structurally bolstering the capacity to absorb losses (currently set at 2.5%).
- An additional variable countercyclical coefficient, known as the Countercyclical Capital Buffer (CCyB), is, as a preventive measure, increased in periods of strong expansion of credit (or of a rise in systemic risk) and then reabsorbed in periods of stress.
- A further buffer is the Systemic Risk Buffer (SyRB), which is calibrated on the basis of the systemic characteristics of the bank to take into account the increased importance of larger national and international banks (Systemically Important Financial Institutions) [89] (calibrated in accordance with five risk classes, from 1% to 3.5%).
- Additional individual buffers attributed by the ECB to single banks on the basis of the results of the pillar-two SREP (*Supervisory Review and Evaluation Process*), which provides a periodical evaluation of all the financial and managerial aspects of the bank (capital, liquidity, economic results, organisation and strategy, etc.).

As well as minimum capital requirements, pillar-one prudential regulation also provides for further restrictions aimed at mitigating risk:

- Supervisory authorities can intervene with regard to the conditions applied by banks when granting loans, for example they can set limits on the maximum debt exposure for recipients, prescribing maximum loan thresholds in relation to the income of the assignee (loan-to-income or LTI) or to the value of the asset financed and/or put up as guarantee (loan-to-value or LTV);
- The asset must be at least 3% of total assets (not weighted), including off-balance-sheet assets (leverage limits).
- An amount of liquid reserves sufficient to tolerate at least 30 days of cash outflows without having to turn to emergency financing from the central bank (liquidity coverage ratio or LCR).
- The balance between assets and liabilities with a residual duration of more than one year weighted by average duration (available stable funding) and level of liquidity (required stable funding), with the former no lower than the latter (net stable funding ratio or NSFR), aimed at limiting the maturity mismatch between assets and liabilities of the bank.

Lastly, in addition to the obligations of Basel pillar one, the European regulation introduced in 2016 (Banking Union) regarding the sharing of the risks of insolvency by bondholders (bail in), credit institutions are also required to maintain a minimum proportion of their assets as liabilities other than capital, i.e., debt securities and hybrid tools (*Minimum Requirement for own funds and Eligible Liabilities* or MREL).

(*) Onado (2021)

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[89] For macroprudential purposes, financial institutions are categorised by the ECB as systemically important financial institutions or SIFI) and non-systemically important institutions. Within the category of SIFIs, a further distinction is made between global systemically important institutions (G-SII) and “others” (O-SII).

A.2.2 Metrics for assessing microprudential risk

For each type of risk, the internal models adopted by banks are based on estimates of *expected losses* (EL), breaking them down into three main components: *Loss for Given Default* (LDG)[90], *Exposure at Default* (EAD), and *Probability of Default* (PD), i.e.,

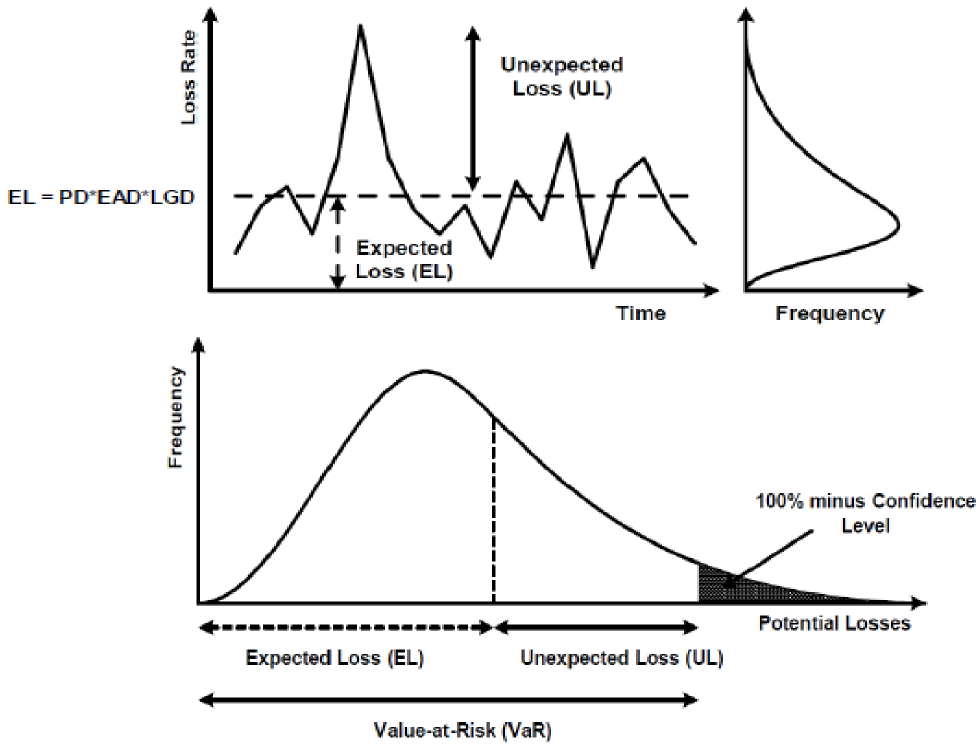
$$EL = LDG\ x\ EAD\ x\ PD$$

For each position, the expected losses (EL) represent the central estimate of average exposure to risk, on the basis of which banks apply suitable provisions in the budget. However, expected losses do not represent the potential sum of possible losses because extreme events and unexpected losses may occur. *Unexpected losses* (UL) can only be quantified on the basis of statistics and are estimated as the dispersion of losses around the mean (EL). As *expected losses* (EL) are covered by specific provisions, capital requirements represent coverage against *unexpected losses* (UL) and must be calculated accordingly[91] (BCBS 2005) **[Fig. A.2].**

[90] The entity of LGD (*Loss for Given Default*) is not the average, but must refer to the most negative phases of the economic cycle, in order to not underestimate EL.

[91] The entity of capital requirements as a proportion of the entire credit portfolio also needs to be corrected in accordance with the level of correlation between exposures: a high correlation between the latter, due to strong ties between debtors (for example related to sector or territory) or a strong correlation with common risk factors (for example the evolution of the economic cycle), leads to increased exposure to risk for the bank. Similar corrections are also provided for in order to take into account the different rates of maturity of the positions, as long-term positions pose a higher risk than short-term ones. (BCBS 2005)

Figure A.2 – Estimate of expected and unexpected risk

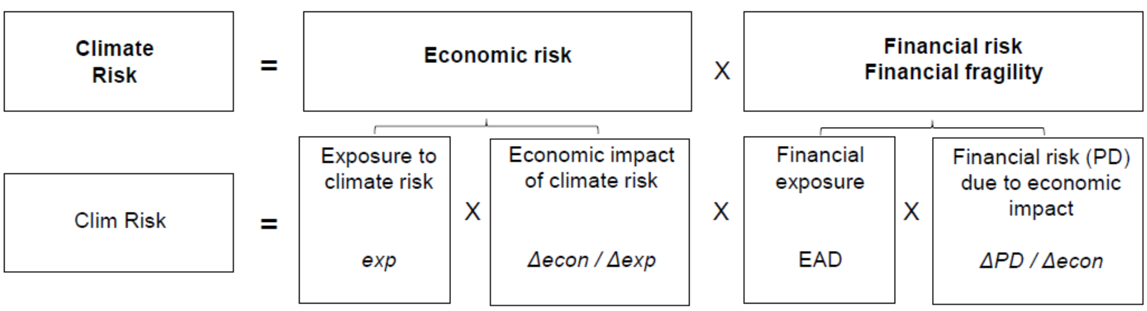


Source: BCBS (2005)

A.2.2 Metrics for assessing climate risk

In general, the assessment of climate risk can be illustrated as in **figure 1**, i.e., as the interaction between the economic impacts of climate events (physical and transitional) and the effects that the latter can have on the financial stability of the firm/intermediary. Economic impacts depend on the level of exposure to climatic events (*exp*) and on the sensitivity of the main economic variables (revenue, costs, profits) to the occurrence of climatic events (Δ*econ*/Δ*exp*); financial impacts depend, in turn, on the financial exposure (*EAD*), i.e., the total value of current loans, and the sensitivity of the probability of insolvency (*PD*) to shifts in the economic status of the firm/intermediary (Δ*PD*/Δ*econ*).

General framework for assessing climate risk



Source: ECB-ESRB (2022)

From a practical point of view, it is necessary to associate appropriate indicators to each of the elements in the diagram.

Exposure to climate risk

As far as financial institutions are concerned, climate risks are mainly of an indirect nature, as they are the result of the exposure to risk of the entities financed. The assessment of the exposure to climate transitional risk of such entities is therefore the basic ingredient and it is generally associated with the carbon footprint of the subjects financed or with that of the economic sector to which they belong. With regard to physical risks, risks are instead mainly correlated to geographic location.

A. Indicators of exposure to risk for non-financial sectors

Emission Gap. The difference between effective emissions and the availability of free ETS allowances is an indication of the potential exposure of each individual economic unit to variations in the price of carbon (i.e., the market value of purchased ETS allowances). Every year, each economic unit included in the ETS perimeter is required to provide a number of carbon allowances corresponding to the volume of emissions created. A portion of the allowances, set to decrease over time, is granted freely by the EU; the entities with emissions in excess of the portion covered by the freely granted allowances must purchase the difference from the market, while those whose recorded emissions are lower can sell the extra-allowances on the market. The price of allowances is determined by the ETS market by the balance of supply and demand. The number of free allowances varies according to sector, and their relative concentration among sectors results in a different exposure to potential losses due to variations in the price of allowances. On the basis of the distribution for 2022, ECB and ESRB estimated that an increase of EUR 100 in the price of allowances would translate to more than 30 billion in cumulative losses in the mining, energy, food and transportation sectors alone, distributed among European countries in accordance with the relative weight of these sectors (ECB-ESRB 2022 chart 1 p. 13). The extension of the ETS system to other sectors (for example to residential construction and private transportation) will make this indicator increasingly important and sensitive (European Commission 2021c).

TAC and ***TEC.*** One approach that links assessment of risk exposure to the European Taxonomy is represented by the indicators proposed by Alessi-Battiston (2021). The *Taxonomy Alignment Coefficient* (TAC) maps enterprise activities in accordance with the European Taxonomy sustainability classification scheme, thus measuring the level of alignment of the portfolio with the Taxonomy. The *Transition Risk Exposure* (TEC) coefficient, instead, directly measures the exposure to transition risk of each individual firm, classifying the firm in a grid of high-emission-intensity activities that need to undertake a process of transition both in order to reduce their level of dependence on fossil sources and to improve their energy efficiency[92]. This method is therefore not based on data provided by the financed entity, but on its position on a map of general risk, and can therefore be applied even in the absence of specific information regarding the entity in question.

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[92] The TAC and the TEC are estimated by Alessi-Battiston (2021) using NACE (Statistical classification of economic activities in the European Community) coefficients up to level four, i.e., an elevated level of granularity.

Market Climate Risk. The exposure to market risks ($MRisk_i$) of financed enterprises is not based solely on their current carbon (GHG_i) and physical (H_i) exposure, but connecting them to the reactivity of the equity and bond values of the i-th firm to the same impacts (val_i) .

$$Mrisk_i = \sum_i \left(GHG_i \; x \frac{\Delta \pi_i}{\Delta GHG_i} + \; H_i x \frac{\Delta A_i}{\Delta H_i}\right) x \; \left[EAD_i x \left(\frac{\partial val_i}{\partial \pi_i} + \frac{\partial val_i}{\partial H_i} + \frac{\partial val_i}{\partial H_i \partial \pi_i}\right)\right]$$

B. Indicators of exposure to risk of the financial sector

The TAC and TEC of the portfolio. By applying the TAC and TEC indicators associated with each financed entity (through credit or the underwriting of securities), it is possible to show the overall exposure of the entire portfolio both in terms of its alignment/misalignment with Taxonomy (as the weighted average of the individual TACs) and in terms of exposure to transition risk (as the weighted average of the individual TECs).

CFALTL or Loan-weighted Emission Intensity. The average emission intensity of loans is equal to the International Monetary Fund's CFALTL (*Carbon Footprint-Adjusted Loans to Total Loans*) and represents the indirect carbon footprint of the loan portfolio of a bank, calculated as average emission intensity (GHG_i/Y_i, i.e., the ratio of emissions to added value or of emissions to revenue) of the sectors/firms to which credit has been granted, weighted by the share of loans to each sector/firm in the portfolio (EAD_i/EAD_{tot}).

$$CFALTL = \sum_i \frac{GHG_i}{Y_i} \; x \; \frac{EAD_i}{EAD_{Tot}}$$

where *i* indicates the i-th sector/firm; *GHG* is emissions expressed in tons of CO_2 equivalent (tCO_2eq); Y is the VA of the sector or the turnover of the firm (in EUR billions/millions). The same method can also be applied to the securities portfolio (shares and/or bonds), substituting in *EAD* the amount of loans with the amount of securities held.

GHG emissions of financed entities are generally identified in terms of direct emissions (Scope 1) and indirect emissions related to the consumption of electricity (Scope 2). With the progressive application of enterprise disclosure regulations (CSRD, ESFS), the data available should become more detailed over time, and extend to cover also the indirect emissions of the entire value chain (Scope 3). Initial assessments carried out by the authorities indicate that bank exposures in all European countries still lean towards the most emission-intensive sectors (energy, mining, food and transportation), and that any differences are mainly related to the differing economic weight (in terms of added value) that the sectors have in the various countries (ECB-ERSB 2022 p. 14).

Loan Carbon Intensity (LCI). CFALTL is applied in a bottom-up manner at varying levels of detail of loan portfolios and requires the availability of granular data. The same indicator can be applied top-down to aggregate loan portfolio: the Loan Carbon Intensity (LCI) i.e., the ratio between total financed emissions and the total loan portfolio ($GHG_{tot}/Loans_{tot}$).

$$LCI = \frac{1}{Loans_{tot}} \sum_i GHG_i = \frac{GHG_{tot}}{EAD_{tot}}$$

Since 2015, the progressive shifting of loans towards less-emission-intensive sectors and the parallel reduction in the emission intensity of said sectors has led to a reduction of this indicator at European level (ECB-ERSB 2022 p.16).

GAR and ***BTAR.*** The Green Asset Ratio (GAR) is a similar indicator to the LCI, but it takes into account not only loans, but all the bank's assets ($GHG_{tot}/Total\ Assets_{tot}$). According to European regulations, the GAR only includes exposures to counterparties who are, in turn, subject to disclosure requirements in accordance with the CSRD.

Publication of the GAR became obligatory for EU banks in January 2024. However, the GAR is seen as an unreliable measure of the "greenness" of bank assets because it is constructed in such a manner as to exclude from the numerator of the ratio a large proportion of bank assets, whatever their carbon footprint: (a) the reference to the CSRD in fact excludes a significant portion of enterprises (above all SMEs and non-European enterprises), leading to distortions in interbank comparisons (banks with higher exposure to these categories of enterprise have a lower GAR); (b) similarly, the numerator implicitly excludes all assets not considered by European Taxonomy (derivatives, interbank accounts, etc.) but that are part of the denominator; (c) the difficulty faced by firms and families in providing documentation regarding the respect of the *Do No Significant Harm* (DNSH), *Technical Screening Criteria* (TSC) and *Minimum Safeguard* (MS) conditions required by the Taxonomy (art. 8) in relation to the assets financed.

To overcome limit (a), a complementary indicator, the *Banking Book Taxonomy Alignment Ratio* (BTAR) has also been introduced, which, in practice, represents the application of the TAC by Alessi-Battiston. The BTAR is published by banks on a voluntary basis, and also includes categories of firms not covered by the CSRD. The indicator is presumably based on estimates made by the banks themselves, considering that SMEs are not subject to disclosure requirements. The greatest limitation of these indicators is that, with reference to Taxonomy classification criteria, they do not take into account any prospective efforts of the firms regarding decarbonisation, or any support that the banks provide for the transition plans of the most energy- and emission-intensive entities.

C. Combined indicators of transition risk and financial vulnerability

For a financial institution, climate risk is, however, not only posed by indirect exposure to the climate vulnerability of the financed entity, but also by the interaction of the latter with more traditional indicators of financial risk: probability of default (PD), leverage ($Loans_{tot}/Total\ Assets_{tot}$) and market risk (VaR).

TCI. *Transition to Credit Risk Intensity* (TCI) is an indicator that considers the exposure to climate risk of financial institutions (measured by the LCI) and the weighted probability of default (PD):

$$TCI_{PD} = \frac{1}{Loans_{tot}} \sum_i \frac{GHG_i}{Y_i} x \left(PD_i x \frac{Loans_i}{Loans_{tot}} \right)$$

Similar indicators can be constructed with reference to other proxies for financial vulnerability, such as the level of leverage:

$$TCI_{leverage} = \frac{1}{Loans_{tot}} \sum\nolimits_i GHG_i \, x \, \frac{Loans_i}{Tot.Assets_i}$$

CRS. The *Credit Risk Sensitivity* (CRS) indicator is, instead, based on the sensitivity of the bank's loan portfolio to the impact of climate risks on profitability (β_{RoA}), which is measured by return on assets, and financial vulnerability (β_{lev}), measured by the level of leverage of the enterprises financed

$$CRS = \frac{1}{Loans_{tot}} \sum\nolimits_i (\beta_{RoA} \Delta RoA_i + \beta_{lev} \Delta leverage_i) \, x \, \frac{EL_i}{EAD_i}$$

where $\frac{EL_i}{EAD_i} = LGD_i \, x \, PD_i$ measures the financial vulnerability of each enterprise financed.

ANNEX A.3

A.3.1 Possible methods for correcting pillar one in terms of climate risk (**)

Proposals for correcting the RWA weightings in order to include climate policy targets are, essentially, the following. Supposing, for simplicity, to identify only two groups of assets, one of "*green*" or "sustainable" loans/investments, and one of "*brown*" assets, i.e., not green or not sustainable, the equation (1) in Annex A.2 would be modified as follows:

1. GSF (*green supporting factor*) consists in a reduction in the weighting of loans and investments classified as "green" or "sustainable"

   $$K = s\,[\sum_i w_i BrownAsset_i + \sum_j (w_j - GSF) GreenAsset_j]$$

   where w_i and w_j represent the original weightings of each asset by non-climatic risks.

2. BPF (*brown penalizing factor*), which, on the contrary, consists in the introduction of an additional factor associated with increased exposure of the bank to sectors/firms considered to be "not sustainable" or "brown" (emission intensive).

   $$K = s\,[\sum_i (w_i + BPF) BrownAsset_i + \sum_j w_j\, GreenAsset_j]$$

3. The simultaneous application of both a BPF and a GSF

   $$K = s\,[\sum_i (w_i + BPF) BrownAsset_i + \sum_j (w_j - GSF) GreenAsset_j]$$

4. ERWA (*Environmental Risk Weighted Assets*), where each original RWA weightings are multiplied by a coefficient λ with a value of between 0.5 and 1.5 in accordance with the climate/environmental impact of the asset in question (with values lower than one for greener assets).

   $$K = s\,[\sum_i \lambda_i (w_i\, Asset_i)]$$

   where w_i represents the original weighting of each i-th asset by non-climatic risks and λ_i is a coefficient graded in accordance with the carbon footprint of the i-th asset, with a value of between 0.5 ≤ λ ≤ 1.5 (with $\lambda_i < 1$ for zero-carbon-impact assets or those compatible with the goals of Paris).

Alternatively, given the systemic nature of climate risks, the correction could take the form of further additional systemic buffers (positive and/or negative) for calculating the solvency ratio related to the levels of the *Green Asset Ratio* (GAR) and the *Banking Book Taxonomy Alignment Ratio* (BBTA) for the bank, i.e., respectively

$$K = (s + BPF)\,[RWA]$$

or

$$K = (s - GSF)\,[RWA]$$

where: $BPF = f(GAR; BBTA)$ and $GSF = f(GAR; BBTA)$, with $f'_{GAR}>0$ and $f'_{BBTA}>0$

(**) D'Orazio-Popoyan (2019); Esposito et al. (2018; 2020)

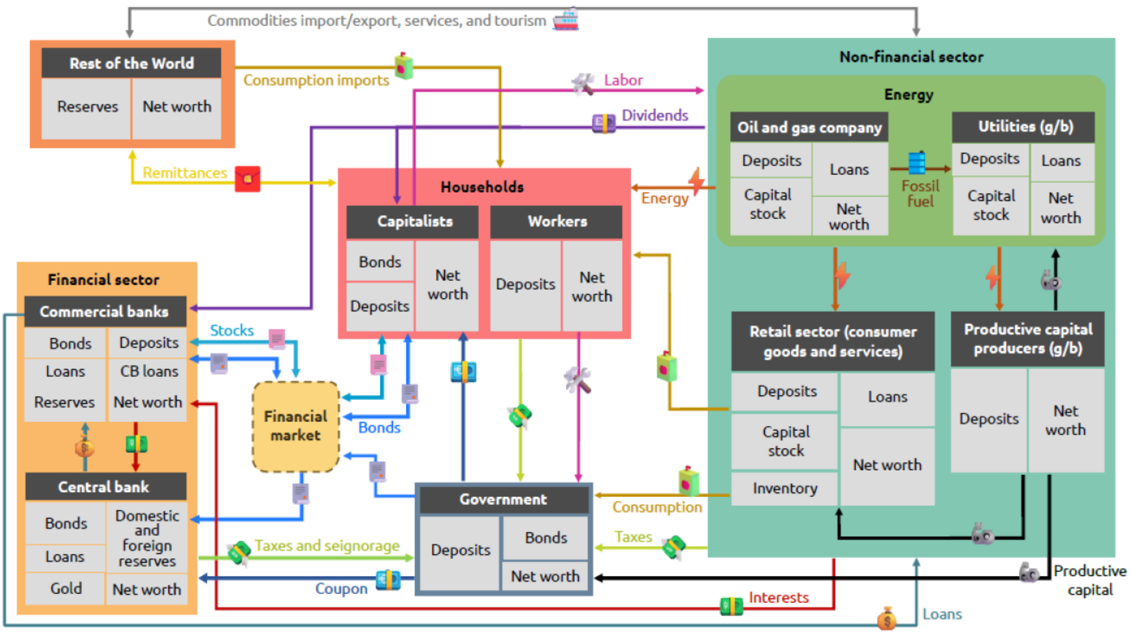
A.3.2 General characteristics of Stock Flow Consistent (SFC) models

SFC (*Stock-Flow Consistent*) models are inspired by post-Keynesian-theories that emphasise the role of aggregate demand in processes of growth and the physiological instability of the system. SFC models have an extremely disaggregated structure, in which each category of agents (families, firms, financial intermediaries, the central bank and the public sector) makes decisions on real variables (consumption, savings and investments) and generates financial flows (variations in financial assets and liabilities) that interact with each other, modifying the composition of their stocks of assets and liabilities, and determining the price dynamics of financial assets and goods. The macroeconomic behaviour of agents is heuristic (*bounded rationality*) rather than rational and optimized and the markets are imperfect. The interaction between these forms of behaviour, therefore, does not necessarily lead to full stability. The adjustment of imbalances and the correction of "market failures" therefore requires the intervention of active economic policies. This type of model is able to highlight phenomena of instability, in particular all those that have an impact on the financial system or even originate within it[93].

SFC models also paint an institutionally realistic picture of the behaviour of the banking system and, in general, of the functioning of the financial system. The approach adopted by Dafermos-Nikolaidi (2021) in specifying the role of banks is similar to the one known as FMC (*financing through money creation*), in which banks create money (deposits) endogenously through the granting of loans, i.e., providing depositors with resources in excess of their initial liquid balances (overdrafts). This approach to bank models allows for the possibility of banks extending the budget constraints of corporates and households, which become dependent on the regulatory constraints to which banks are subject. In this manner, the conditions for credit supply can be studied separately from those that determine credit demand, allowing the detailed analysis of any phenomena of credit rationing (Jakab-Kumhof 2019).

[93] Cfr. Goodley-Lavoie (2012); Caiani et al. (2016); Dafermos et al.(2017, 2018, 2022); Dafermos-Nikolaidi (2021); Monasterolo (2020); Dunz et al. 2021 (2023)

Fig. A.3 – Diagram of transaction flows in an SFC-type model



ECB_Gourdel-Monasterolo-Dunz et al (2023) , «Double Materiality of Climate Physical and Transitio Risk»

A.3.3 Simulation of the impact of differentiated capital requirements with an SFC model

The simulations carried out by Dafermos-Nikolaidi (2021) regarding the impact of differentiated BFP and GSF coefficients are based on an SFC-DEFINE-1.1-type model (Dafermos-Nikolaidi (2018; 2022), the working of which can be summarised as follows:

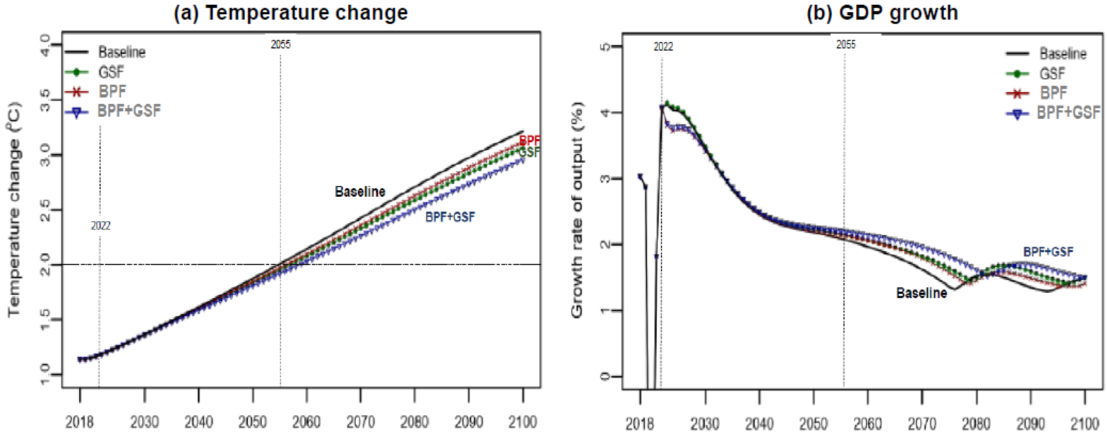
- Firms decide the overall amount of investments on the basis of several factors, of which the most significant are profitability and expectations of the future evolution of demand;
- a proportion of the investments is green;
- as the investments required are not completely covered internally by profits, firms finance them also by issuing bonds or by bank loans (credit demand function);
- the banks decide how much of the credit demand to satisfy and at what interest rate (credit supply function); the decision of the banks is made on the basis of both an assessment of the sustainability of the borrowers, and of their own level of capitalisation (subject to minimum capital requirements); as long as the banks' capital is higher than regulatory minimums, the increase in overall supply of credit is not constrained and bank leverage (the ratio between assets and capital) can increase;
- if the authorities introduce differentiated capital coefficients (BPF and/or GSF), these affect the supply of credit (in terms of volume, composition and rates) and influence both the decisions of firms on whether to invest and the level of economic activity.
- the composition of investments (either green or brown) sets the balance between fossil and renewable sources, and thus acts on dynamics regarding emissions and global warming.
- a rise in global warming leads to harmful climatic events and loss of productivity that feed-back on the profitability of firms , on their rate of insolvency, and indirectly also erodes bank capitalisation; when the latter hits minimum regulatory requirements, banks are forced to recapitalise.

For the technical details of the model, please refer to Dafermos-Nikolaidi (2022). Below are the results of simulations for the application of BPFs and GSFs (both separately and jointly) in the absence of any other policy action. The evidence from the exercise shows that the joint adoption of BPFs and GSFs tends to improve all these dynamics (to an extent that obviously depends on the calibration of the key parameters of the model[94]), and provides unambiguous qualitative indications both vis-à-vis the baseline scenario and with regard to the scenarios where BPFs or GSFs are applied separately:

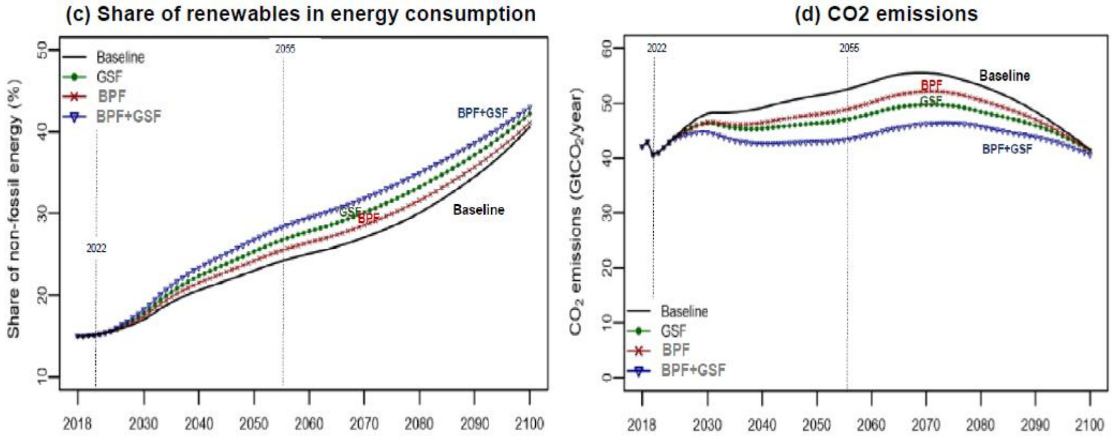
- lower losses in terms of GDP **(fig. ib)**.
- a higher proportion of renewable sources in energy production **(fig. iic)**.
- improved emission dynamics, lower warming **(figs. ia and iid)**.
- improved profitability and lower rates of insolvency among firms (i.e., lower impact of physical risk) **(figs. iiie and iiif)**.
- a lower rationing of credit and a lower interest spread for green enterprises **(figs. ivg and ivh)**.
- a rationing both of credit and interest spread for brown activities, which remain in line with the baseline scenario **(figs. vi and vf)**.
- a lower increase in bank leverage (i.e., lower vulnerability to transition risk) **(fig. vim)**.
- a slower deterioration in bank capital **(fig. vin)**.

[94] In the DEFINE 1.1. model, the key parameters are: (i) the elasticity of the offer of credit, of the level of bank credit rates and of the spread of rates compared to the capital ratio of the banks (RWA/capital) and of the credit risk of the enterprises granted credit (measured by their level of debt to income); (ii) the level of credit rationing and the sensitivity of rates to the level of greenness of loans (GHG/AV of enterprises granted loans), where it is assumed that rationing is a positive result of their level of risk (i.e., of the weight of each particular category of loan in the RWAs) and that sensitivity is a negative result of the desired proportion of green loans in the portfolio (the more a bank is inclined to grant green loans, the lower the rates on said loans). (Dafermos-Nikolaidi 2022)

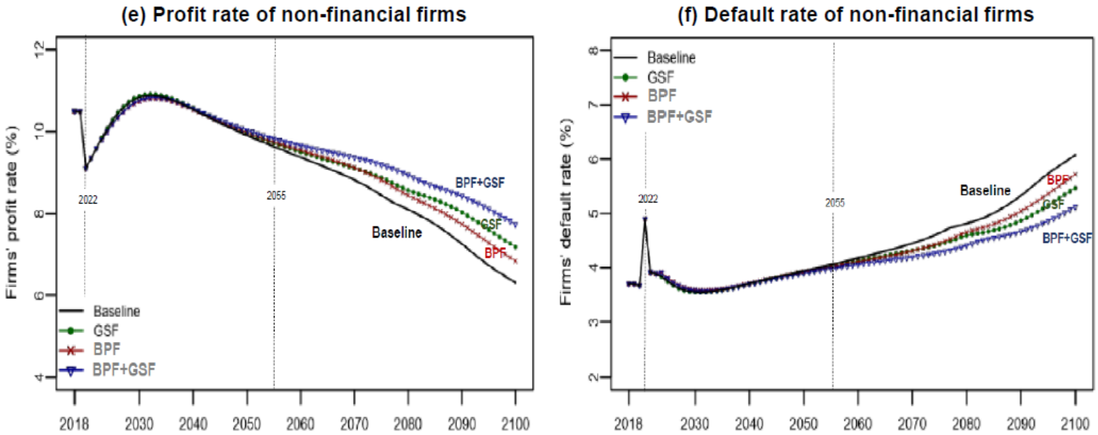
(i) Global warming and economic growth



(ii) Renewable energy and CO_2 emissions

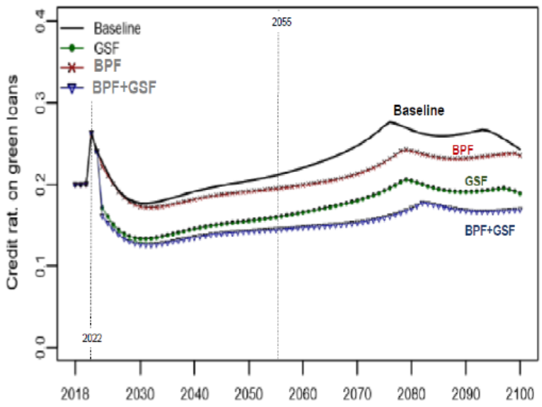


(iii) Corporate sector

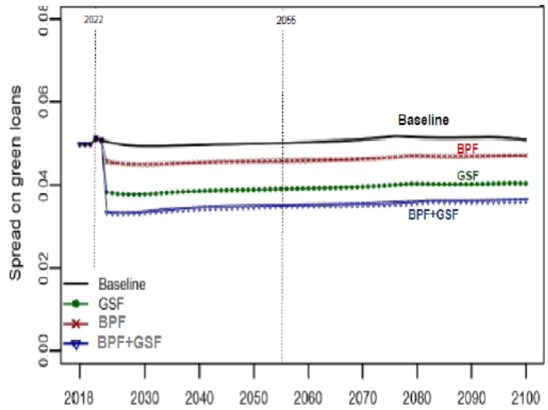


(iv) Credit market: green sectors

(g) Credit rationing on green loans

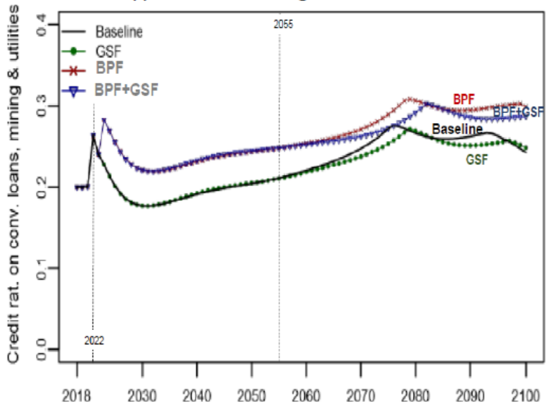


(h) Interest rate spread on green loans

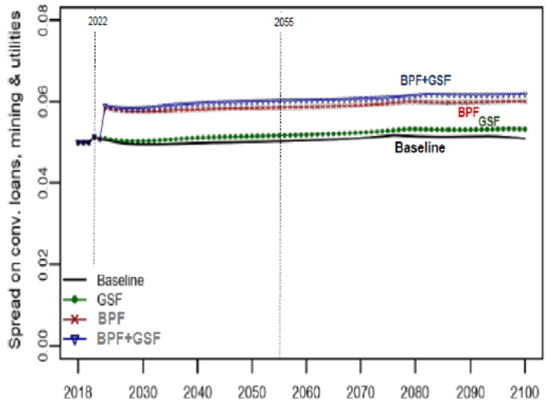


(v) Credit market: brown sectors

(i) Credit rationing on brown loans

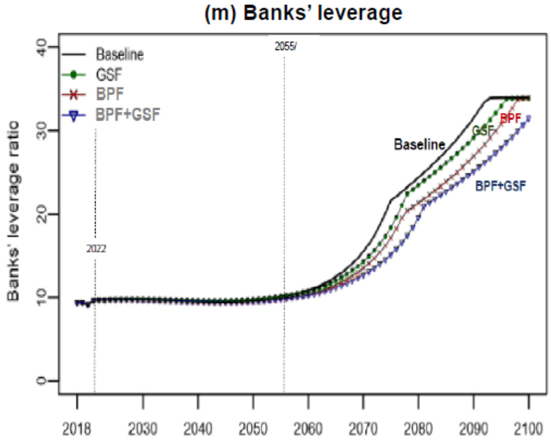


(h) Interest rate spread on brown loans

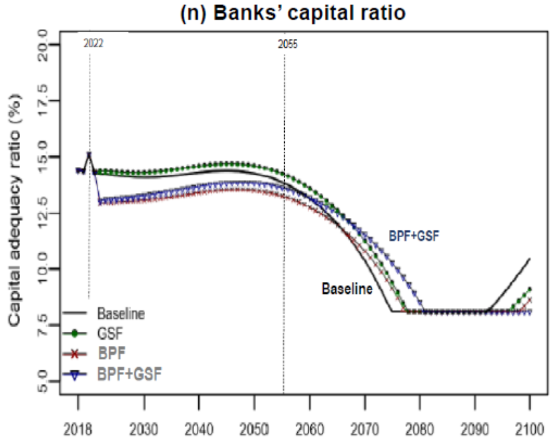


(vi) Financial stability of the banking sector

(m) Banks' leverage



(n) Banks' capital ratio



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Publication date:
17 July 2024