Fostering green investments and tackling climate-related financial risks: which role for macroprudential policies?

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Abstract

In recent years, there has been a growing consensus between financial actors and policymakers on the need to address climate change. Nevertheless, the achievement of climate goals is still affected by the so-called "green finance gap". While there is a growing debate among researchers and practitioners on the possible role of central banks and financial regulators in supporting a smooth transition to a low-carbon economy, the information on which macroprudential instruments could be used for reaching the "*green structural change*" is still quite limited. The paper addresses these issues by proposing a critical review of existing, newly implemented, and possible *prudential approaches* to incentivizing the decarbonization of banks' balance sheets. The analysis carried out in the paper allows understanding under which conditions macroprudential policy could tackle low-carbon transition and promote green lending, while containing climate-related financial risks. Possible modifications of central banks' policy functions and governance structure are also proposed with the aim of accommodating a soft "green landing".

Keywords: Climate Change, Climate Finance Gap, Banking Regulation, Macroprudential Policy, Central Banking, Climate-finance risk.

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1 Introduction

There is now widespread recognition of climate change (Oreskes, 2004; Doran and Zimmerman, 2009; Cook et al., 2013). As pointed out by Rockström et al. (2009), three of nine interlinked planetary boundaries have already been overstepped and the ecosystem is heading toward a tipping point that poses an existential risk to society (Friedlingstein et al., 2014). To enhance a so-called green structural change, as shown in Figure 1, considerable investments are required in the sectors characterized by high capital costs, i.e., the building, industrial, transport and energy sectors (World Economic Forum, 2013). Additionally, considering green energy efficiency, it has been estimated that an eight-fold increase in annual investments is needed by 2035. Investments in the so-called low-carbon power generation (including renewable energy, nuclear energy, and carbon capture and storage) will need a three-fold increase, in order to be aligned with a green transition scenario (OECD/IEA, 2014).

The evidence for the "green finance gap", i.e. the lack of sufficient financial resources to be directed towards green investments (Buchner et al., 2017), is particularly relevant for the transition process described above, because it represents a serious hindrance for the achievement of the climate goals as discussed in COP (2015, 2016). However, the required investments are difficult to be met under the current financial framework (Mazzucato, 2013; Mazzucato and Semieniuk, 2018). A growing body of evidence suggests that investment processes, accounting frameworks, and financial regulatory regimes contain an intrinsic "carbon bias" that creates barriers to aligning the finance sector with sustainable transition roadmaps (see Volz, 2017; Campiglio, 2016, among others). In particular, macroprudential initiatives following the financial crisis, notably Basel III, seem to promote short-term "brown" investments at the expense of more long-term, climate-friendly investments (Gersbach and Rochet, 2012; Haldane, 2013; Thanassoulis, 2014). Moreover, some analysts have argued that the Basel III regulation, and the liquidity requirements in particular, might negatively affect banks' willingness to lend to green projects (Liebreich and McCrone, 2013; Narbel, 2013; Spencer and Stevenson, 2013; Caldecott and McDaniels, 2014). Indeed, although the nowadays financial regulatory framework made notable progress to detect, assess and contain systemic risks (BCBS, 2011), it still overlooks the possibility that systemic risk arises in case of a green transition. Moreover, at the current stance, the financial portfolios that are highly exposed to carbon-intensive "stranded" assets (Caldecott and McDaniels, 2014; Battiston et al., 2017) imply a potential threat for the *soft landing* scenario (Schoenmaker and Van Tilburg, 2016) and have implications for systemic risk (Gros et al., 2016).

While the climate-related risks have been identified as a material for the financial system and financial stability in general (Carney, 2015; Dietz et al., 2016; Battiston et al., 2017; Monasterolo et al., 2017; Volz, 2017), central banks and regulators affecting the

financial markets seem to overlook climate objectives in practice (Campiglio et al., 2018; Matikainen et al., 2017; Monnin, 2018; Monasterolo and Raberto, 2018)[1]. As a matter of fact, despite the rising awareness of the adverse impact of climate-related risk on financial stability (Carney, 2015; HLEG, 2018; DNB, 2017), there are no internationally agreed-upon regulatory schemes to withstand potential losses that those risks can cause to the financial sector.

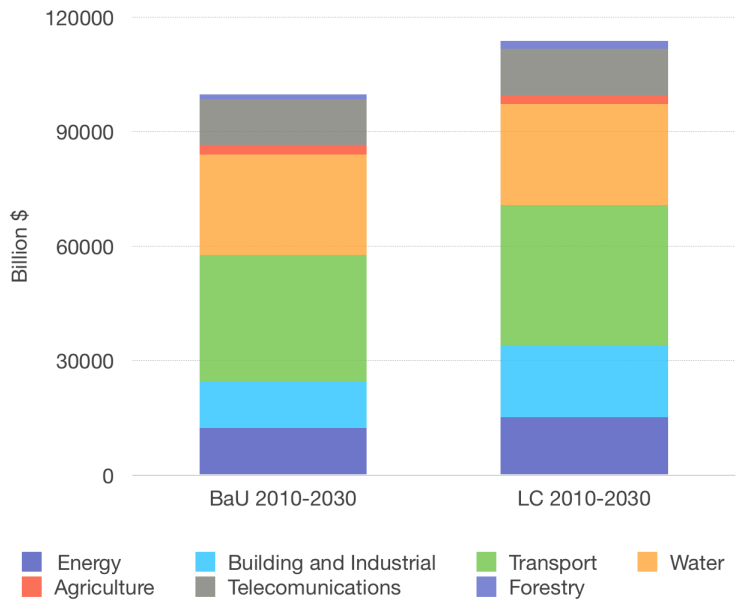

Figure 1: Annual estimated investments needed by sector in two different scenarios: Business-as-Usual (BaU) left bar, Low-carbon economy (LC) right bar. Data in billion US$2010 rates. The reported estimates show that to make the so-called low-carbon scenario effective, $14 trillion are needed over the period of 2010-2030; the annual average investment in green technologies in all the sectors considered in the study, should be on average $0.7 trillion.
Source: authors' elaboration based on data presented in World Economic Forum (2013). We refer the reader to the World Economic Forum (2013, Appendix 1) for more details on the methods used to gather and process the data.

To tackle climate-related financial issues, the attention of researchers has been so far devoted mainly to the interactions that originate from the low-carbon transition process to the financial sector (Carney, 2015; Covington and Thamotheram, 2015; Campiglio et al.,

[1] As noted by Sevillano and Gonzalez (2018), since the "models traditionally used by central banks, such as dynamic stochastic general equilibrium models, are not well suited to capturing the effects of climate change or the complexity of the economic transition" (Sevillano and Gonzalez, 2018, p.129), there is a new generation of the models arising to account for effects of climate change on financial and economic stability (Fontana and Sawyer, 2016; Dafermos et al., 2017, 2018; Monasterolo and Raberto, 2018; Bovari et al., 2018; Lamperti et al., 2018). See also Balint et al. (2017) for a review on different theoretical modeling approaches to study climate impact on economic dynamics.

2017; Delis et al., 2018; Bovari et al., 2018). Considering this link, *market-based measures* have been proposed (Stiglitz et al., 2017). However, carbon taxes, as well as policies based on subsidies aimed at fostering green technologies, seem to reflect a lack of awareness of the financial risks related to climate change[2] (World Bank, 2014, 2016).

Taking into account the current policy framework, as well as transition and systemic risks, the paper aims to investigate another important potential link; namely, the possible effects stemming from the financial sector and affecting the low-carbon transition process. We show these interlinkages in Figure 2. In our analysis, we focus in particular on the extent to which a prudential regulation, explicitly aimed at promoting a green economic transition, is a tool policymaker should use to foster green investments and mitigate climate-related financial risk.

A number of research works have been studying possible modifications of standard central banking to include instruments to support the green transition, considering for example green bonds or green quantitative easing (Batten et al., 2016; Matikainen et al., 2017; Volz, 2017; Campiglio et al., 2018). In our paper, instead, we shed light on the regulatory instruments that can be implemented within the existing monetary policy framework. In particular, we focus on the following research questions: Is the current macroprudential regulatory framework "green enough" to enhance a low-carbon transition?; If not, how policymakers can make it "greener" and what are the possible (unintended) consequences the existing regulatory framework can have on the transition? How can a green macroprudential policy be integrated into the existing monetary and regulatory policy institutional setup? We consider these questions of particularly relevance since the "green transformation" of the global economy may occur paired with high market volatility and disturbances in capital flows, causing systemic risks for the financial sector.

The contribution of the research carried out in the paper is fourfold. First, a critical review of existing, newly implemented, and possible *prudential approaches* to incentivizing the decarbonization of banks' balance sheets is presented. Second, by reviewing official central banks documents, it provides an up-to-date mapping of green prudential regulations and tools at the OECD and European level. Third, by building on existing evidence of macroprudential policies, the paper analyses under which conditions macroprudential policy could tackle two interconnected goals, i.e., support low-carbon transition and promote green lending while containing risks for the financial system. Fourth, it suggests possible modifications of central banks' policy functions to include climate goals in order to address the so-called "green finance gap" and tame climate-related financial risks.

[2]Related to carbon price, as noted by Campiglio (2016), there are two additional issues that are worth considering."[P]*roposals of carbon taxes or carbon markets are likely to encounter strong political and social resistance on the grounds that they will harm business and increase energy bills* (Campiglio, 2016, p.224). Moreover, "*even a stable and credible carbon price may not be sufficient to steer the required amount of economic resources to green investment. This is due to the existence of an additional market failure, related to the process of creation and allocation of credit, which may lead banks and other investors not to react as expected to price signals*".

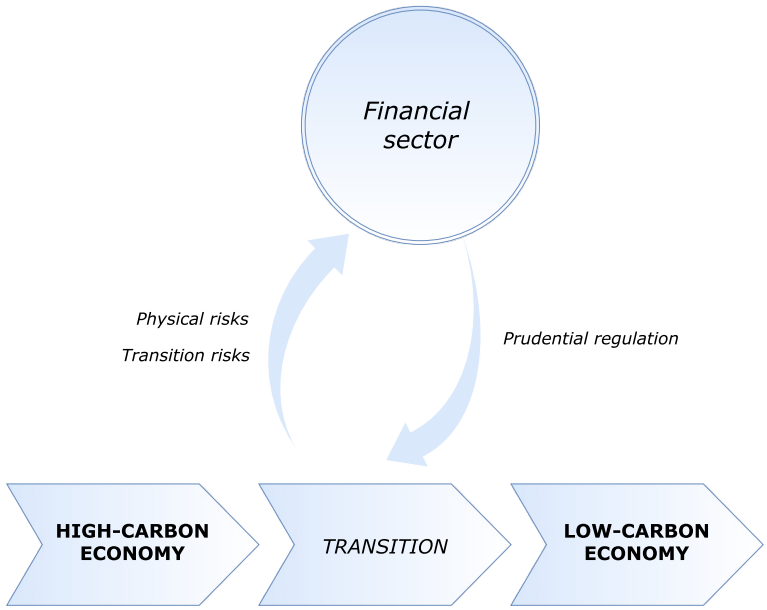

Figure 2: Basic interaction between the transition process and the financial sector. The high-carbon economy is characterized by a "business-as-usual approach" which implies investments in infrastructures to support global growth. The low-carbon economy is characterized by a "green growth approach" which implies that existing and new infrastructures need to be greened. Hence, additional investment is required to achieve green growth.
Source: authors' elaboration.

The remainder of the paper is organized as follows. Section 2 introduces the topic of financial regulation aimed at tackling climate change, by presenting the state-of-the-art in the existing regulatory framework. Section 3 presents a detailed discussion of possible extensions of existing prudential regulations explicitly aimed at fostering green investments and tackle climate-related financial risks. A review of the available green macroprudential tools is presented, along with their pros&cons. In Section 4, we discuss the implications of green macroprudential tools in a more general institutional framework and suggest possible institutional arrangements between a monetary and green macroprudential policy. Finally, Section 5 concludes.

2 Financial regulation and climate change

Financial stability has been particularly relevant in the last decades when policymakers, from emerging to advanced economies, have been working to implement macroprudential policy tools, including coordination efforts among central banks, governments and regulatory authorities[3]. In particular, the introduction of financial regulation as a new "policy

[3]See Goodhart and Schoenmaker (1995) and Oosterloo and de Haan (2004) for an early analysis on coordination issues, and Kahou and Lehar (2017); Galati and Moessner (2017) for recent reviews on

mandate" has been accelerated by the 2008 financial crisis[4]. By echoing the *Financial Stability Hypothesis* (Minsky, 1992), the financial crisis raised the awareness that it is important to catch the early-warning signals of crises and address, already in "normal times", the potential risks that could affect the financial system. One of its key lessons has been indeed that "*[...] stability is destabilizing*" (Minsky, 1982, p.101) and that price stability can coincide with the build-up of excessive financial risk.

In addressing the concerns raised by the financial crisis, the regulators decided to improve the existing framework by going beyond the Basel II approach, which was concerned with the safety and soundness of individual financial institutions. The post-crisis "new normal" was featured by a new regulatory framework, namely Basel III, that instead explicitly tackles systemic risks[5]. However, under the existing Basel III accord, climate-related financial risks are narrowly defined, and regulatory capital and liquidity regulations (under Pillar 1) do not explicitly require banks to assess the impact of climate-related risks on bank's exposures (BCBS, 2016; ESRB, 2016a). Moreover, the existing Basel III reinforces short-termism[6] in financial markets (Haldane, 2011), hence creating obstacles for capital mobilization aimed at green investment projects (King, 2013; Spencer and Stevenson, 2013; Bhattacharya et al., 2015). The latter require indeed long-term "patient" financial capitals that are, by definition, riskier than short-term assets (Dore, 2008; Mazzucato, 2013).

Considering the existing framework, we argue that it is crucial to develop an adequate incentives' system to enhance lending to sound environmental projects. By taking into account externalities that can give rise to financial stability distortions, regulatory authorities can suggest measures that could allow banks to increase long term lending, without harming the system's stability. This is needed, in particular, because capital requirements in the existing Basel III regulatory framework could make banks more hesitant regarding green lending, and liquidity requirements tend to penalize long-term loans (Blundell-Wignall and Atkinson, 2010; Allen et al., 2012; Angelini et al., 2015).

Bearing these caveats in mind, we suggest the implementation of a set of regulatory tools to enhance the soft landing. We focus mostly on measures that are already defined under Pillar I, by emphasizing the "green potential" they entail (see Table 1). Regarding Pillar II, we maintain that it should be extended to include climate-related risks, and that the identification of early warning risk indicators is fundamental in the macropudential

macroprudential policies.

[4]As emphasized by Galati and Moessner (2017), it is worth noting that measures to support the domestic financial system applied in the 1930s and 1950s have been considered as macroprudential tools. Additionally, many developing and emerging economies have usually relied on tools that fall under the "macroprudential umbrella" but they used to define them in a different way.

[5]For a comparison between Basel II and III, see Table 3 reported in the Appendix A.

[6]In the paper, we adopt the following definitions: a short-term financial instrument is one that has 1 to 3 years of maturity; a long-term asset is one that is characterized by more than 7 years of maturity.

GREEN BASEL III		
Pillar I **Enhanced capital & liquidity requirements**	**Pillar II** **Enhanced supervisory review**	**Pillar III** **Enhanced risk disclosure & market discipline**
- *Liquidity coverage ratio* (LCR) - *Net Stable Funding Ratio* (NSFR) - *Leverage ratio* - *Capital conservation buffers* - *Countercyclical capital buffers* - Enhanced loss absorption clause - Securitization - Trading risk - Counterparty credit risk	- Internal capital adequacy assessment process (ICAAP) - Supervisory review Evaluation process - Stress tests - *Green stress tests*	- Regulatory capital components - Regulatory capital ratios - Securitisation exposures - Enhanced disclosure * *(qualitative disclosure)* * *(quantitative disclosure)*

Table 1: The enhanced Basel III framework considering climate-related financial risk concerns. Instruments discussed in the paper are in italics.
Source: authors' elaboration.

policy setting process. In this respect, climate-related stress tests[7] are of vital importance to assess the extent to which financial institutions are exposed to carbon-intensive assets (Kelly and Reynolds, 2016; Battiston et al., 2017; Monasterolo et al., 2017). Regarding Pillar III, we claim that disclosure requirements, both quantitative and qualitative, should be included so that investors can fully learn the risks to which specific banking institutions are exposed[8]. Similar proposals regarding the enhancement of Pillars II and III have been discussed by the European Systemic Risk Board (ESRB), according to which, in the short-term, disclosure should be enhanced to include climate-related risks in regular stress tests, while carbon stress tests are more appropriate for the medium/long-term (see ESRB, 2016b). An analogous view has been expressed by the EBF (2018); it stresses however, also the crucial importance of the establishment of a common taxonomy and disclosure framework before any modification of the existing regulation. We deem the last point of particular importance as the extent to which a financial asset can be considered "green" plays a crucial role in the definition of a bank's portfolio. To the best of our knowledge, it does not exist a common defined taxonomy nor an agreed-upon disclosure framework, as advocated by the Financial Stability Board-Task Force on Climate-related Financial Disclosures[9]. Nevertheless, for the sake of clarity of the analysis carried out in the paper,

[7] A climate-related stress test aims at evaluating the resilience of the financial system to adverse environmental shocks. It does so by analyzing the possible impact of hypothetical climate-related shock scenarios on the stability of individual financial institutions and the financial system in its complexity. Despite raising awareness about the climate-related risks and exposures, developing a robust stress test is a very important first step to calibrate and evaluate green macroprudential tools. Indeed, information filtered from the stress tests could be used to define minimum capital standards, risk weights, credit caps and floors for a particular type of asset.

[8] For discussions about "green-related" measures under Pillar II and III, we refer the reader to ESRB (2016b); Battiston et al. (2017); Monasterolo et al. (2017); Stolbova et al. (2018); EBF (2018), and the references therein.

[9] Progresses in this direction are made in the past months. For example, in May 2018, the EU Commission set up a Technical Working Group on Sustainable Finance. Its main tasks are to assist the Commission in the development of: (1) an EU taxonomy of environmentally sustainable economic activities; (2) an EU Green Bond Standard; (3) a category of "low carbon" indices for use by asset and portfolio managers as a benchmark for a low carbon investment strategy; (4) metrics allowing improving disclosure on climate-

we suggest a possible definition of the "green" attribute to be attached to any financial asset that meets the requirement. In our view, a green asset is one related to the financing of a green investment, which is in turn defined as a project aimed at energy efficiency, renewable energy development, sustainable water management, clean transport systems development, sustainable agriculture, pollution prevention, climate change adaptation[10].

An interesting analysis emerges by looking at countries' experiences in the development and adoption of green prudential requirements. We offer an overview (as of March 2018) of the state-of-the-art climate-related regulations, as summarized in Figure 3. Additionally, we try to draw a correspondence between central banks' institutional settings[11] and the diffusion of green regulatory frameworks. Our analysis is carried out by considering the latest available UN Environment Inquiry Reports, World Bank Group IFC and central banks' official documents.

Regarding the diffusion of green prudential regulations, we distinguish among four categories, as reported in Figure 3: countries that adopted a mandatory regulation (highlighted in red), countries that developed a voluntary regulation (highlighted in yellow), countries that have both multiple and voluntary regulations (highlighted in orange) and finally countries in which there is an undergoing process of discussion about the implementation of such regulations (highlighted in blue). From this analysis, several interesting conclusions can be drawn. First, a clearly defined cluster of emerging economies located in the East Asia region (namely; China, India, Pakistan, Bangladesh, Vietnam, Indonesia) appears as the leader of the adopters of mandatory regulations. Other examples are Nigeria and Brazil, for which we report the adoption of both mandatory and voluntary regulations. Second, European countries, as well as other high-income countries (HICs) emerge instead as the "laggards", because, except from France[12], the adoption of a sustainable perspective in the financial regulation is still a topic of discussion at the policy level (see HLEG, 2018, for a recent analysis). In line with previous existing analyses (CISL and UNEP-FI, 2014; Dikau and Ryan-Collins, 2017), it is therefore evident that emerging countries are the most engaged in pursuing policies aimed at greening the banking sector. The rationale behind this evidence is twofold. First, central banks in emerging and low-income countries (LICs) have a larger spectrum of goals (and functions) than their HICs counterparts. Indeed, policy objectives usually explicitly include output growth, exchange rate stability and macroprudential supervision (Hahm et al., 2012; Ghosh et al., 2016;

related information.

[10]Alternative measures of "green" could be the environmental risk classification computed by Moody's (2018), or a low value resulting from a green stress test, or a labeling scheme as the one developed for green bonds (see Ehlers and Packer, 2017). Additional research, however, is needed to enhance the development of a common defined taxonomy of "green".

[11]See Appendix B for a detailed overview of macroprudential governance at country level.

[12] In 2013, the country set up an "Action plan for EU strategy" put forward by the Ministry of Ecology in order to embed social responsibility and responsible finance in the private and public sector as well as in the financial sector.

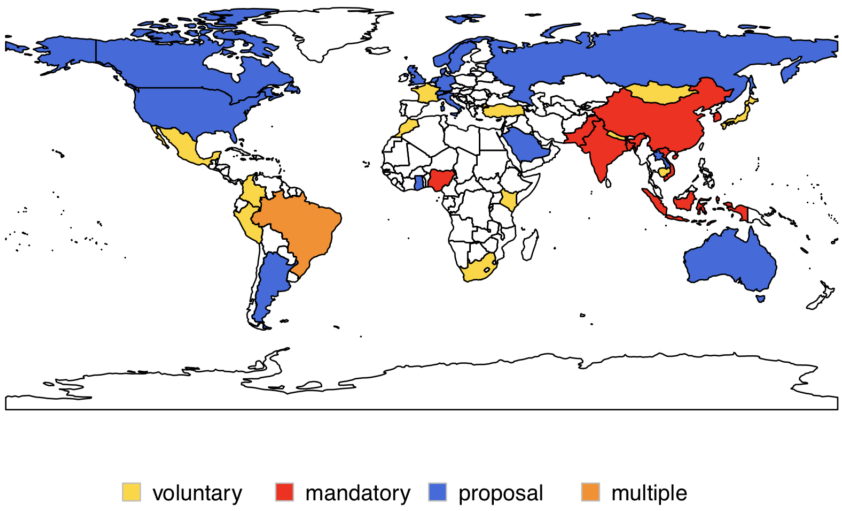

Figure 3: The diffusion of green prudential requirements; year: 2018.
Source: Authors' elaboration based on data retrieved from UN Environment Inquiry Reports (UNEP, 2018), World Bank Group - IFC publications (IFC, 2018) and central banks' official documents.

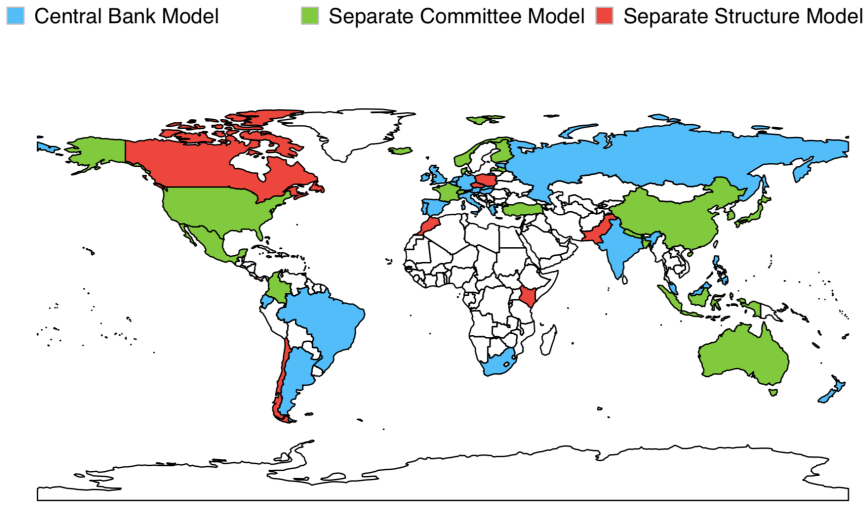

Figure 4: Institutional frameworks; selected Developing and OECD countries. Taxonomy based on Nier et al. (2011) and CGFS (2016).
Source: authors' elaboration based on data retrieved from latest available (2018) central banks' official and IMF documents. Further information on the dataset is available in Appendix B.

Chen et al., 2017). Second, LICs are more exposed to climate change; therefore they have to craft a response that needs to be more timely and effective in the very short run.

Regarding countries' institutional frameworks, we look at whether any correspondence could be drawn between the type of macroprudential governance (see Khan, 2017, for a recent overview) and the diffusion of the green financial regulation. In particular, we look at how the responsibility for macroprudential policies is associated with other institutions different than central banks, such as supervisors, governments or ministries. We identify three types of models and report them in Figure 4. In the first type, labelled as "Central Bank Model", macroprudential and monetary policies are considered under one roof. This implies that macroprudential policy is included in the mandate of the central bank, and the central bank itself is a designed macroprudential authority. A second type, labelled as "Separate Committee Model", is characterized by a partial integration, meaning that the central bank holds the financial stability mandate but is not the designed macroprudential authority. In particular, it is based on the existence of a separate committee that is either closely related to the central bank (i.e., the central bank chairs the committee), or operates independently (i.e., the central bank is a member of the committee but is not chairing). Usually, the former sees a passive role for the government or financial ministries, while the governmental involvement is more active in the latter. Finally, the third type, labelled as "Separate Structure Model", is characterized by no integration between the monetary and macroprudential mandates, implying that macroprudential policy is taken up by multiple agencies. In this case, there can be an engagement of the government, but this is a country-specific feature.

From the comparison of the data summarized in Figure 3 and 4, we observe that the regulations are enforced by the central bank in Lebanon, China, Bangladesh and India, and by a supervisory department in Brazil. Similarly, the Reserve Bank of India has adopted a green macroprudential regulation approach because it considers explicitly the climate risk when assessing the financial and monetary stability of banks. The central bank of South Korea and Indonesia have followed a similar path (see Van Lerven and Ryan-Collins, 2018). However, it is not possible to recognize any direct relationship between the type of central bank mandate and the diffusion of green regulatory requirements.

Considering the differences between HICs and LICs, another interesting analysis is to investigate the relationship between the presence of climate-related regulations (defined as the macroprudential index (MPI) in Figure 5) and the country's GDP level. We consider countries' GDP (2016, constant 2010 million US$) and the green prudential requirements at work in the country[13]. From Figure 5, we observe that the majority of countries (both developed and emerging economies) are clustered in the MPI group labeled with the value of 2 (on the vertical axis), which corresponds to the case of countries where there is an

[13]For additional information on the list of countries and GPD levels, see the interactive map we developed, available at this link.

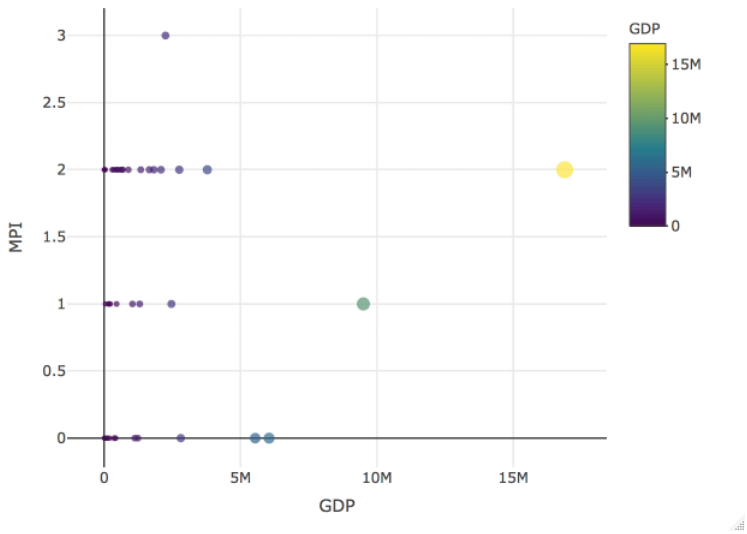

Figure 5: The diffusion of green prudential requirements defined as MPI (vertical axis) and countries' GDP (2016, constant 2010 million US$) (horizontal axis). On the vertical axis: 0 corresponds to the presence of voluntary requirements; 1 to the presence of mandatory regulation; 2 to undergoing discussion on the possibility to introduce green prudential regulations; 3 is an index for the case in which the country adopts both mandatory and voluntary regulations.
Source: authors' elaboration based on data retrieved from UNEP Inquiry Report, UN Environment Inquiry Reports, World Bank Group IFC and central banks' official documents and Countries' GDP data retrieved from the World Bank database. The interactive map is downloadable at the following link.

ongoing discussion on the possibility to introduce green prudential regulations. However, from this evidence, it is not possible to infer any negative correlation between GDP level and the green financial regulation diffusion as one would expect.

3 *Green* macroprudential tools: challenges and implications

The policy debate on the need to align climate and financial stability objectives is evolving intensively (HLEG, 2018; Gros et al., 2016; DNB, 2017). Recently, particular attention has been drawn by the proposal of the introduction of a "green supporting factor"(GSF), as well as the introduction of "differentiated reserve requirements"(DRR). In this section, we analyze the ongoing debate and a possible instrumental setup for financial regulation aimed at supporting the low-carbon transition. Additionally, we propose a classification

of macroprudential tools[14], as shown in Table 2[15]. Recognizing the possible redistributive effects of nowadays financial regulation on the low-carbon transition path, we analyze a possible synthesis of tools able to combine an objective to reallocate credit to the green sector while safeguarding financial stability. Furthermore, we discuss the challenges and implications deriving from their possible enforcement; a summarizing table is provided in Appendix C.

Intermediate Objective	***Category***	***Instrument***
Limit misaligned incentives, canalize credit to green sectors	Reserves Reserves of exposure	• Differentiated reserve requirement
Mitigate and prevent excessive credit growth and leverage	Capital Capital Capital	• CAR with GSF • Countrecylical capital buffer • Sectoral leverage ratio
Limit the concentration of certain exposures	Lending limits Lending limits	• Max(min) credit ceiling (floor) • Large exposures limit
Mitigate and prevent market illiquidity and maturity mismatch	Liquidity Liquidity	• Liquidity coverage ratio • Net stable funding ratio

Table 2: Classification of "green" macroprudential tools for green credit allocation.
Source: authors' elaboration.

Capital requirement. Recently, green supporting factors have been advocated to overcome the green finance gap. While the proponents highlight the capacity of GSF to incentivize the lending to green sectors and thus promoting sustainable investments (Dombrovskis, 2017; HLEG, 2018)[16], the opponents express their skepticism based on the previous experience of the small and medium enterprise (SME) supporting factor and because of the possible impact on bank stability (Matikainen, 2017; Finance Watch, 2018).

The combination of the minimum capital requirement with the "green supporting factor" (GSF) would allow for the *de-risking* of green assets[17]. As a consequence, banks

[14]See Claessens (2014); Cerutti et al. (2015) for more insights of the classification approaches in macroprudential instruments.

[15]The focus of the paper is mainly on lender-based measures. While the restriction on lenders influence the supply side of credit, the release of loan-to-value (LTVs), loan-to-income (LTIs), and debt-to-income (DTIs) mainly influences the demand for credit (Duca et al., 2018). Generally, the application LTV and DTI caps set a limit on the amount of lending to a particular customer based on the value of the asset is obtained (e.g., mortgage) or impose restrictions depending on the income of borrowers. In this way, asset-based macroprudential instruments boost the resilience of the banking sector directly by dropping the probability of default (PD) and the loss-given-default (LGD) of loans. Restrictive caps on borrowers could assist in transitioning to low-carbon economy if used to limit lending to targeted companies or sectors which are primarily involved carbon-intensive activities and are likely to have losses and become unprofitable shortly, given either new regulations or innovations in green technology.

[16]In particular, the vice-president of the European Commission responsible for financial regulation, Valdis Dombrovskis, in his speech in December of 2017 expressed the support of Commission to adjust banks capital requirements with sustainable finance goals proposing the introduction of a so-called a "Green Supporting Factor"(GSF).

[17]This is particularly relevant in a credit risk measurement mechanism of risk-weighted assets (RWA), because due to their longer pay-back period, green projects are usually assigned higher risks weights.

would be more incentivized to finance environmental-oriented projects and will include a possibility of calibrating the risk-weighted capital ratios so that low-carbon activities would exert a lower pressure on their balance sheet. The factor is applied on the denominator of banks' minimum capital requirement in the following way:

$$CAR^t_{green} = \frac{E_t}{RWA_t} = \frac{E_t}{\alpha_b L_t + (\alpha_g - \alpha_{GSF}) L^g_t} \geq \beta \tag{1}$$

where $\alpha_b L^b_t$ and $\alpha_g L^g_t$ are respectively the brown and the green risk weighted loans portfolios, E_t is the bank's capital, β is the CAR set by the policymaker. α_{GSF} is a mark-down on a green loan risk weight; it affects the capital requirement imposed on banks by altering the risk-weight of the asset depending on whether it is identified to be green or brown (HLEG, 2018; EBF, 2018)[18]. From this, it follows that if the bank is identified to be "brown", then $\alpha_{GSF} = 0$, otherwise $\alpha_{GSF} > 0$.

Building on the prototype of the SME supporting factor, the GSF aims at applying a cut-off factor on a risk weight for green lending (consequently committing less regulatory capital), thus incentivizing the exposures to credit toward the environmentally-aligned projects to accelerate the transition process[19]. The proposed mechanism implies that banks' ability to create credit is affected by indirectly adjusting the minimum capital adequacy requirement; i.e., the ratio of a bank's capital over its risk-weighted assets required by the regulator[20].

We find that, while the policy direction is right, the way it is approached can be prone to destabilizing effects for the banking sector. The effectiveness of such a tool is questioned because of two main issues. First, the financial regulatory response should focus on the transition path. This means not only investing more in green assets, but first and foremost moving the financial flows towards green sectors so that the zero-emission target can be achieved. Incentives created by regulatory intervention should have strong oversight on the materialization of possible risks along the transition process. Therefore, the stable position of regulatory capital based on the objective evaluation of associated risks is of paramount importance. In this respect, the introduction of a GSF in the current stance is fraught with loose regulatory capital requirement for green assets implying "less skin in the game" which underestimates the real financial risks (Schoenmaker and Van Tilburg, 2016; Matikainen et al., 2017; Van Lerven and Ryan-Collins, 2018). Bearing these caveats in mind, we think that this measure cannot be efficiently implemented until the more risk-sensitive approach is adopted regarding the establishment of a common taxonomy and disclosure standards for

[18]The distinction between green and brown is based on the criteria discussed in section 2.

[19]Related to this point, it is worth mentioning that there is no clear evidence for benefits on the application of SME supporting factor. For a more detailed discussion on these topics, see EBA (2016).

[20]While the effectiveness of capital requirements was highly debated in academic literature (Gauthier et al., 2012; Gersbach and Rochet, 2017), the potential of this tool to affect the lending capacity of financial institutions is supported by evidence (Aiyar et al., 2014; Budnik and Kleibl, 2018).

green assets, as well as mechanisms to transform climate exposures (measured by carbon intensity) into credit risk and an indicator of creditworthiness. Moreover, considering that high risk of carbon-intensive assets does not automatically make green assets safer, the implementation of a GFS should consider a targeted loan-loss reserve with enough capacity to absorb the risk that regulatory capital cannot backup. Second, 2DII (2018) points out that Green Supporting Factor would have an overall limited effect if compared to the SME supporting factor. Moreover, the introduction of the GSF to correct the mispricing of the assets is not justified by any empirical evidence (2DII, 2018).

Considering the arguments mentioned above, a stronger case in favor of a brown-penalizing factor (BPF) emerges. While the GSF would lower the capital requirement for green lending with no proved evidence that green is actually less risky (Moody's, 2018), the BPF with an add-on factor would require more prudential capital for carbon-intensive assets. Furthermore, if rising the capital is costly for a bank, being committed to holding assets containing high carbon risk will possibly push banks towards a more risk-sensitive attitude and, at the same time, lead them to hold more loss-absorbing capital for the emergence of a possible carbon bubble or a possible repricing of stranded assets. By adopting this definition of green capital requirement, policymakers would be more likely to avoid risk underestimation, providing consequently more robust and less risky regulatory capital framework for the bank itself.

Differentiated reserve requirements (DRR). Among the instruments that could be theoretically implemented to aligning soft carbon transition and financial stability objectives, differentiated "green" reserve requirements are drawing particular attention (Rozenberg et al., 2013; Campiglio, 2016; Volz, 2017)[21]. This instrument explicitly targets financial institutions actively involved in low-carbon transition process, via easing the reserve requirement (RR) for them. In other words, RRs may be reduced in proportion of the bank's lending to green sectors, thus subsidizing green credit. In contrast to the *harmonized RRs* that many central banks impose to commercial banks, the *green RR* would allow banks to hold fewer reserves against a "green" loan portfolio. By directly affecting the bank's money-creating ability, the green RR would align the profitability of their lending activities with the sustainability policy target.

A possible implementation of the DRR is suggested in the following, by pointing out that before its direct application, a calibration of a green factor (GF) is necessary. We consider the GF as a fraction of the overall loan portfolio which will allow us to distinguish between "green" and "brown" banks. The RR for a bank with a "brown" loan portfolio

[21]There is also evidence that some regulatory authorities already implemented it. An evident example is the Central Bank of Lebanon. Since 2010, it supports green credits by lowering the RR of commercial banks by an amount of 100-150% in the case in which bank's customer can provide a certificate of energy savings (see BDL, 2009, 2010).

is:

$$R_t = \sigma_{brown} * D_t \tag{2}$$

where σ_{brown} is a fraction of attracted deposits to be kept as a reserve, D_t is the stock of deposits hold by the bank at period t. The RR for a bank with a "green" loan portfolio will be:

$$R_t = \sigma_{green} * D_t \tag{3}$$

where $\sigma_{green} = \sigma_{brown} - \lambda$, $0 < \lambda \leq \sigma_{brown}$. λ is growing function of green exposures and its calibration depends on the country's characteristics (discussed below), the presence of other macroprudential instruments and the monetary policy stance.

The practice of DRR is acceptable when there are precise and achievable targets in differentiation. Central banks and regulators of many countries had already a practice in the use of both multiple (depending on a banks size, type, and maturity of liability, currency, etc.) and differentiated (depending on the targeted sector) RRs to steer credit into specified financial institutions and areas of the economy[22]. Its implementation and efficiency depend on the policy frame it serves for (e.g.; monetary, macroprudential, microprudential) and country characteristics[23]. The latter has received a lot of attention in the literature, emphasizing the frequent use of the RR in developing countries attributing to both undeveloped financial markets (that may limit the efficiency of market-based instruments), and procyclical monetary policy that needs a hand from a countercyclical tool (Federico et al., 2014; Cordella et al., 2014; Cerutti et al., 2016)[24]. In particular, widespread use of RRs in developing countries originates from the procyclical behavior of the exchange rate over the business cycle. The latter in the presence of open capital flows impedes the smooth conduct of monetary policy and the use of interest rates as a counter-cyclical instrument. Thus in developing countries RRs were used countercyclically when concerns about the effects of interest rates on the exchange rate become paramount. In case of high income countries, instead, the efficiency of "green" RR can be questioned under the abundance of liquidity in the money market (due to quantitative easing, for example) and the capacity of the reserve ratio to act as a constraint on banks' reserve of exposures (see Campiglio, 2016).

From a policy perspective, the efficiency of the green RR walks hand in hand with the country's features. Considering that developing countries mostly use RRs in a coun-

[22]China offers a pertinent example of a country using multiple and DRRs as a regular policy tool (Fungáčová et al., 2016; Chang et al., 2018).

[23]We consider the RR to be a monetary policy tool when it is used to regulate market liquidity, macroprudential tool when it is used to corrected the business cycle and microprudential in the remaining cases.

[24]Note that RR initially was designed for monetary policy purpose but emphasized by Cordella et al. (2014) was intensively used by emerging markets as the countercyclical macroprudential instrument. In their analysis for the period of 1970-2011 Federico et al. (2014) find that 62% of the countries in their sample have followed an active RR policy in which 2/3 of developing countries against just 1/3 of developed countries. Moreover, authors note that after 2004 none of major developing countries were involved in active RR policy.

tercyclical manner (rising it in good times and lowering it in bad times) as substitutes to procyclical monetary policy, the "green" RR is expected to have ambiguous effect[25]. Indeed, although they are designed to stimulate green investments, RRs are still a form of liquidity requirement against the unexpected withdrawal of funds. Consequently, using the RR to subsidize direct credit can hinder liquidity management, thus bringing to a sub-optimal outcome (see Gray, 2011). Additionally, we point out that the use of "green" RR in developing countries characterized by "fear of capital inflows" and "fear of free falling" behavior, may induce policymakers not to raise interest rates in good times and use higher RRs to cool down the economy (as usually happens) which will bring distortions in either monetary policy conduct or the green loan flow. Hence in developing countries, more coordination is needed between the legal RR (which partially takes a role of monetary policy), exchange rate policy and green RR.

In the case of developed countries, the perspective is somewhat different: being passive users of RR both for monetary policy purposes, due to colossal CB balance sheet and excess liquidity in the market (see Campiglio, 2016, on this point) and for macroprudential stance (more focus on liquidity requirements under Basel III accord instead on reserve ratios), the efficiency of green RR can be found in use with a microprudential option[26]. The latter finds its application of targeting safety of soundness of individual financial institution that due to their specific size, activity and scale are intact by the harmonized requirements that align financial regulations with climate objectives.

Countercyclical capital buffer (CCyB). CCyBs are designed to reinforce financial institutions defenses against the build-up of systemic vulnerabilities and serve as a cushion during the contractionary phase of a credit cycle (Drehmann and Gambacorta, 2012; Jiménez et al., 2017; Popoyan et al., 2017). Its use is reported to have increased after the global financial crisis (Budnik and Kleibl, 2018), while the literature on its actual activation is scarce (BIS, 2018) and there is a lack of evidence about its effectiveness (Cerutti et al., 2017; BIS, 2017).

In this paper, we argue that it can be used to dampen the carbon cycle; as shown in Figure 6, building a buffer during periods of excessive carbon-intensive credit growth will increase the resilience during the upswing of the carbon cycle. In this way, CCyBs could play an important role in mitigating and preventing excessive credit growth and leverage related to carbon-intensive assets. The buffer add-on contains *ex-ante* the risk of carbon-intensive credit growth, therefore helping building buffers to absorb *ex-post* shocks to low-

[25]Many central banks in developing countries conduct procyclical monetary policy due to the need of either defending the local currency in bad times or not attracting more capital inflows in good times. Therefore, developing countries use RRs for stabilizing capital flows and the credit cycle when there are severe limits on the typical monetary policy ability to smooth the level of credit and/or economic activity (see Cordella et al., 2014).

[26]In fact, as highlighted by Federico et al. (2014), the majority of developed countries in their dataset have zero legal RRs.

carbon loans. Therefore, it can favor financial stability, by having a more direct impact on brown assets and by exerting an important signaling power in the financial market. However, to be effective, an adequate calibration and early activation are required. Beside level and timing issues, the implementation of the CCyB depends on how banks adjust their capital ratios (BIS, 2018). Additionally, we highlight that its effectiveness depends on the measure and indicators of climate-related systemic risk, which, as highlighted in previous sections, is a relevant topic of recent research agenda (see Battiston et al., 2017).

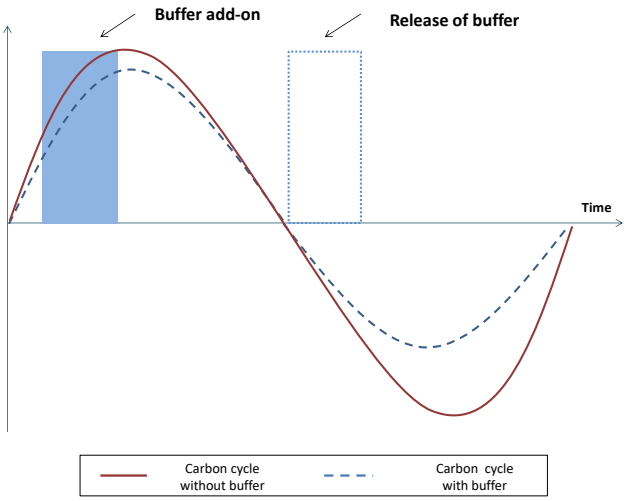

Figure 6: The buffer mechanism over the carbon cycle. Source: authors' elaboration.

Another way to approach the CCyB could be the application of a negative capital buffer (NCB). In this case, the "green" capital requirement can be considered an application of NCB on top of the minimum capital requirement if the bank's credit portfolio appears to be "green enough"[27]. Additionally, the NCB can be considered a compensation to certain banks for not being excessively exposed to carbon-intensive industry or for their active participation in the "green transformation". As in application of the GSF, a need of targeted loss reserve is needed with NCB to absorb uncovered residual risks.

Sectoral leverage ratio (SLR). While the leverage ratio in Basel III prevents excessive on- and off-balance sheet leverage by limiting banks' total assets to their equity (BIS, 2014), the SLR hereby proposed could limit a targeted group of assets.

The underlying logic can be expressed as follows:

$$LR_t^{Sector} = \frac{\text{Tier 1 Capital}}{\text{Exposures to carbon-intensive sector}} \geq \gamma. \tag{4}$$

[27]For a definition of the green features, we refer the reader to section 2.

where γ is the leverage ratio set by the regulator.

The relevance of the proposed SLR for financial stability depends on the extent to which highly leveraged financial institutions are exposed to carbon-intensive assets. For a better calibration of the leverage ratio, banks' exposure data and the level of carbon intensity of firms' resources should be adequately disclosed.

The impact the sectoral leverage ratio will have on banks' incentives is similar to the maximum credit floor (discussed below), but different regarding the balance sheet structure. Whereas the credit floor *caeteris paribus* will stabilize a predetermined fraction of the assets' portfolio to be allocated to a particular type of assets, in case of the SLR those assets will need to be backed-up by the bank's equity. Moreover, leverage ratio will serve as a backstop to a risk-based capital requirement, in order to avoid over-leveraging of a particular sector (BCBS, 2014).

Liquidity regulation. The current liquidity requirement imposed by Basel III is aimed at smoothing the maturity mismatch between assets and funding sources. The two primary metrics of liquidity are the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR) (see Hong et al., 2014; Aldasoro and Faia, 2016; Bai et al., 2018, for the efficiency of liquidity regulations). The former aims at "protecting" banks against short-term liquidity crises; the latter constraints banks to fund long-term assets with stable funding of at least a one-year maturity. However, they may have unintended consequences on green investment. First, LCR could reshuffle banks balance sheets toward highly-quality liquid assets (e.g., cash, sovereign and central bank bonds that has 0% risk weight, corporate bonds with high rating). Second, to meet the NSFR, banks will use long-term funds (that are usually more costly) to finance long-term assets, which implies that banks will cut the funding budget. In other words, banks will become more sensitive to temporal mismatches between assets and funding, and hence more reluctant to hold long-term assets (Liebreich and McCrone, 2013; Narbel, 2013; Spencer and Stevenson, 2013; Liebreich and McCrone, 2013). As a result, Basel III liquidity rules are likely to make long-term financing more expensive, which will particularly affect "patient" (i.e., long-term) green investments. Liquidity requirements will likely limit the amount of capital available for such financing.

Considering the issues raised above, we share the view expressed by EBF (2018), which proposes the introduction of a precise incentive mechanism for the LCR and the NSFR requirements to link the climate-related targets and the liquidity/maturity mismatch requirements in the existing macroprudential setup. The introduction of a lower required stable funding (RSF) factor (μ) is considered as promising, under certain conditions, to identify green exposures. We formalize it as follows:

$$NSFR_t = \frac{ASF_t}{RSF_t} = \frac{\sum_i^n \phi_{i,E} E_{i,t} + \sum_i^n \phi_{i,Liab} Liab_{i,t}}{\sum_j^m \phi_{j,B} B_{j,t} + \sum_j^m \phi_{j,G} G_{j,t}} \geq \eta,$$

where $\phi_{i,E}$ and $\phi_{i,Liab}$ stand for the available stable funding (ASF) factor while $\phi_{j,B}$ and $\phi_{j,G}$ are the required stable funding (RSF) factor for brown and green exposures, respectively. In particular, under this framework, green long-term finance should be considered as a category of promotional loans (both for NSFR and LCR) and treated with the reduced required stable funding (RSF) factor (i.e. $\phi_{j,G} = \phi_{j,B} - \mu < \phi_{j,B}, 0 < \mu < 1$).

Minimum credit floors and maximum credit ceilings. Although they were heavily criticized due to their non-market based nature, maximum credit limits have been widely used in advanced economies after the recent financial crisis to limit bank exposures to certain type of sectors' activities and loans' categories (see Lim et al., 2011; Van den End, 2016).

As emphasized by Volz (2017), they offer a very straightforward mechanism to channel investments to "green" projects. *Maximum credit ceilings* to certain carbon-intensive or polluting activities (sectors), or alternatively *minimum credit floors*, that requires banks to allocate a predefined fraction of their loans' portfolio to a "green" sector, are thus worth considering for the aim of closing the green finance gap. In contrast a maximum credit ceiling (Farahbaksh and Sensenbrenner, 1996), which creates incentives for banks to limit lending to less sustainable sectors, the minimum credit floor is a "hard" limit set by the regulatory authority. However, it may create possible market distortions without actually incentivizing green lending.

Large exposure limit. In the current regulatory application, large exposures limit is called to contain the maximum possible losses a bank could incur in the case of a failure of a single counterparty or a connected group, to a level that does not compromise the bank's solvency. In practice, the exposures limit can be the instrument that, except for a direct or indirect counterpart, based on a particular sector or even geographic area, actually limits the exposure to certain high-risk assets, and reduces lending by financial intermediaries accordingly. In a green finance context, the banks' exposures should be limited to carbon-intensive assets. This tool contains also an allocative feature very similar to credit ceilings. Schoenmaker and Van Tilburg (2016) find that credit limits are the most appropriate regulatory instrument to deal with material climate-related risks.

The necessity to assess and limit the size of large exposures in banks' balance sheets (concerning their capital) has long been recognized by the Basel Committee on Banking Supervision (BIS, 2014). As it is designed, large exposures regulation aims at limiting the maximum loss a bank could face in the event of a sudden counterparty failure to a level that does not endanger the bank's solvency. While applying for low-carbon transition

purposes, this limit could, on the one hand, limit banks' overexposed position towards carbon-intensive assets; on the other hand, act in a macroprudential manner to safeguard them from transition and systemic risks.

The implementation of large exposure limits for carbon-intensive activities implies a high effort on disclosing and reporting every large exposure connected to a single, group or interconnected carbon-intensive firms. The first step suggests a precise definition of large exposures to the carbon-intensive sector[28]. The second step suggests a constraint for large exposure limit to a single counter-party, or a group of connected counter-parties, not to be higher than a certain percentage of bank's available eligible capital base at all times.

4 Green macroprudential regulation and monetary policy: beyond a dichotomous relationship?

The awareness about climate-related financial risks has been growing in the past years (Carney, 2015; Gros et al., 2016; Draghi, 2017; Campiglio et al., 2018) and the decision about whether to incorporate them in the mandate of central banks has been highly debated (Schotten et al., 2016; DNB, 2017; HLEG, 2018). In our view, two alternative perspectives can be distinguished. A first one sees the possibility to include a sustainability objective in the central bank policy function[29], while a second view is more critical about the expansion of policy objectives. Regarding the critiques that could be raised, multiple criteria can be considered. A first one directly relates to the technical difficulties to satisfy the Tinbergen principle, according to which "for each policy objective, at least one policy instrument is needed" (Tinbergen, 1939, 1952). Therefore, according to this perspective, by including a *sustainable finance* objective, a new set of policy instruments should be considered by policymakers. A second critique emphasizes the risks of overstretching the central bank mandate, which could consequently become less clear and too broad, thus undermining the independence of the authority (Eichengreen et al., 2011).

[28]For example, large exposures to carbon-intensive sectors could be defined as exposures to clients or groups of connected clients where the value of it is equal, or exceeds, 8% of the eligible capital of the bank. The ratio of exposures to eligible capital to indicate the large exposure could be calibrated considering the country characteristics, the concentration of carbon-intensive firms, the presence of other stringent requirements, etc.

[29]In the EU, this would be supported by Article 3 (3)of the *Lisbon Treaty On European Union* which defines the objectives of the Union and possible additional objectives (beyond price stability) of the European System of Central Banks, as described in Article 127 (1): "*The primary objective of the European System of Central Banks (hereinafter referred to as "the ESCB") shall be to maintain price stability. Without prejudice to the objective of price stability, the ESCB shall support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union as laid down in Article 3 of the Treaty on European Union. The ESCB shall act in accordance with the principle of an open market economy with free competition, favouring an efficient allocation of resources, and in compliance with the principles set out in Article 119.*".

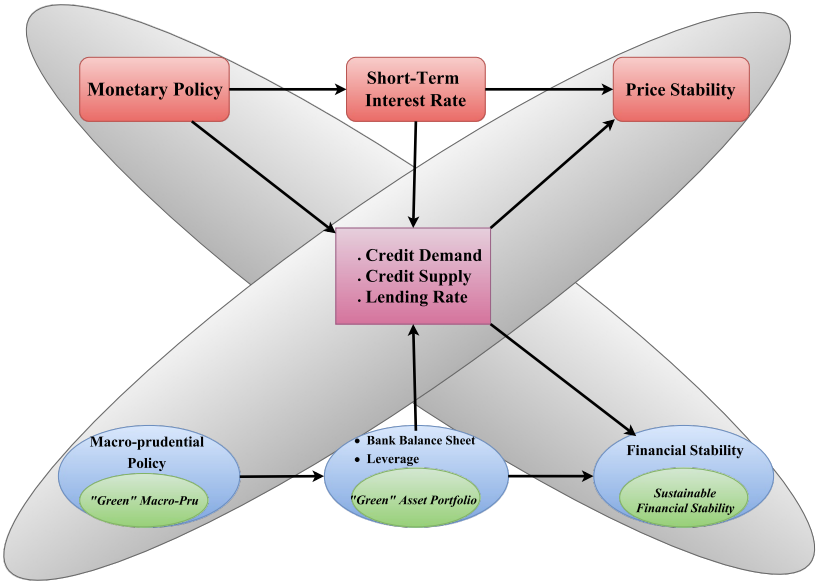

Figure 7: Monetary and macroprudential policies interactions in presence of climate-related financial risks. Source: authors' elaboration.

According to us, the climate-related financial risks being material to financial stability and the need to fill the green finance gap, urge for the development of a "synthesis" between monetary and green macroprudential policymaking. We maintain that the inclusion of a sustainable finance objective in the policy function can be undertaken without violating the Tinbergen principle, as the green macroprudential policy can be considered as an "offspring" of the more general macroprudential policy. As a result, in this proposed green policy framework, monetary policy could be concerned with the primary objective of price stability, while macroprudential policy - enriched with the greened tools - should be concerned with financial stability, hence reaching also the sustainability objective. Issues regarding the mismatch between the number of instruments and the number of objectives therefore do not arise[30]. The interaction and the transmission mechanism as implied by this approach are summarized in Figure 7, in which we envisage the possibility of tensions between the two. Indeed, in order to achieve its principal objective, i.e., limit systemic distress in financial institutions also due to climate risks, (an already greened) macroprudential policy will, directly or indirectly, affect assets and liabilities compositions

[30] Additionally, we emphasize that the Committee on International Economic and Policy Reform (Eichengreen et al., 2011) called for the Tinbergen separation principle to be retired. The Committee pointed out that, rather than having one instrument devoted to one objective, the macro stabilization policy must be conceived as an optimization problem where monetary and regulatory policies are jointly used to achieve monetary and macroprudential objectives.

of intermediaries, therein sharing with monetary policy some similarities. For example, both policies have allocative effects on the demand and supply side of credit via suspending/bringing forward spending over time (Jiménez et al., 2014; Altunbas et al., 2014), and affecting the leverage and funding cost of financial intermediaries (Adrian and Liang, 2016; Borio and Zhu, 2012). At the same time, it is acknowledged that macroprudential tools can have adverse effects on monetary policy (Igan and Kang, 2011; Farhi and Tirole, 2012; IMF, 2011).

We distinguish two possible scenarios. On one side, if the above described monetary-macroprudential dichotomy is in place, issues of coordination may arise (Smets et al., 2014; Malovaná and Frait, 2017; Mester, 2017). On the other side, if the interaction between the "two spheres" is very intense, there is a broader scope for coordination, but policymakers should be warned about the risk of the so-called "push-me-pull-you" behavior (Wadhwani, 2010). Additionally, when the sustainable financial stability is included in the policy objectives, then reputation and time-inconsistency issue may arise as well (see Dalla Pellegrina et al., 2013; Ueda and Valencia, 2014).

Considering the coordination concerns between the greened macroprudential and monetary policy, we try to shed light on the possible institutional arrangements, and the needed degree of a coordination effort, between the two[31]. First of all, we maintain that it is of paramount importance that the designed "green" macroprudential authority has a clear-defined mandate, independence, adequate resources, as well as powers, to delineate the oversight boundaries (Krishnamurti and Lee, 2014). In this, the country-specific factors, and the already existing position of the microprudential authority (who is responsible for the safeness and soundness of individual financial institutions), are important to dictate the choice of the type of macroprudential governance. It follows that two alternative institutional models are possible: either the "green" macroprudential authority is positioned within the central bank as a committee of the board (green central bank model), or it works "out of it" (separated model), as a member of representative agencies that involve the central bank as a leading player[32].

In the case of emerging and developing countries, usually equipped with a bank-centric financial systems (see Dikau and Ryan-Collins, 2017; Campiglio et al., 2018, for recent overviews), where central banks are responsible for both micro and macroprudential oversight (Masciandaro and Volpicella, 2016; Cerutti et al., 2017), the choice of the *green central bank model*; i.e. having the prudential authority in the central bank's structure, seems a natural choice. Instead, in many of advanced countries, where neither designed macroprudential authority nor the microprudential supervision is in central bank's hands

[31]It is worth emphasizing that we do not look at the coordination issues between green macroprudential and macroprudential policy in general, considering the former as a part of the latter as already explained in the previous paragraph.

[32]In both models of "green" macroprudential policy we consider central banks as a critical player considering the questions of accountability and its expertise to deal with systemic risks.

(e.g., Australia, Japan), the *separated model* of green macroprudential oversight is more likely to be implemented. The latter presumes a committee of representative agencies (including a central bank), that shares the "green" macroprudential mandate. This model will require a higher level of coordination and cooperation between the central bank and the macroprudential authority, since the division of the "green" macroprudential mandate among several authorities may complicate the decision-making, weaken accountability and increase the risk of an inaction bias.

Accounting for the issues discussed so far, we claim that the leading position of central banks in a committee of representative agencies could smooth the coordination problem. Moreover, for a green macroprudential authority to work efficiently, independence from both political and financial markets' influences should be granted. The latter explains our position suggesting to grant a central bank a leading role (in both the above-discussed models). Nevertheless, this does not imply that the model where the "green" macroprudential authority is under the same roof with the central bank does not have shortcomings. In many jurisdictions, the independence of central banks is indeed not granted; hence the balancing between different policy mechanisms will be needed.

5 Conclusions

"*On rèsiste á l'invasion des armèes, on ne rèsiste pas á l'invasion des idèes.*"
Victor Hugo, Histoire d'un Crime

By looking at the current financial framework, financial risks related to physical and transition risks do not seem to be adequately considered, neither by financial institutions, nor by regulators and markets. The attention is usually devoted to the causal relation that goes from the green transition process to the financial sector, while the effects of monetary and macroprudential policies on the so-called green structural change are often overlooked. Taking into account the climate-related financial risks and the need to fill the green finance gap, in the paper we argue that monetary and prudential authorities can play a potential important role in leading the transition to a low-carbon economy.

To support our claim, we have reviewed the existing and potential prudential approaches to incentivize the decarbonization of banks' balance sheets and promote green investments and discussed their pros & cons in channeling the financial flows to sustain smooth carbon transition while reducing the systemic risk and the procyclicality of the the financial sector. Moreover, we have reviewed official central banks documents to provide an up-to-date mapping of green prudential regulations and tools currently available at the OECD, developing countries and EU level. Finally, we suggest possible institutional arrangements between a green macroprudential and monetary policies, which is crucial for the achievement of the green structural change.

Considering both the theoretical underpinnings of central banks' models and the effects of the development of green prudential instruments, we claim that, by acknowledging price stability, financial stability and green financial stability as complementary policy objective, central banks and financial regulatory authorities can profitably contribute to the low-carbon transition process. If we adopt this view, then the proposed approach is consistent with the Tinbergen principle and two policy tools are then needed to achieve the objectives; namely, the interest rate for price stability and green macroprudential tools for climate-related financial stability. Although the empirical evidence on the effectiveness of the standard macroprudential tools is still scarce, and the quantitative approach is of limited guidance for the calibration of green macroprudential tools, we still endorse the important role these instruments could play, especially in the case of the environmental-oriented mandate.

From the analysis carried out in the paper, an interesting heterogeneous picture emerges regarding the adoption of green macroprudential tools. While many developing countries (i.e., China, India, Brazil, Bangladesh among others) are adopting mandatory prudential instruments to channel credit towards green sectors, developed countries seem to lag behind by staying still satisfied by "all talk, no walk" strategy. Moreover, while analyzing the green macroprudential tools that are under discussion (mainly in EU), we found that while the direction of the policy intervention is right, the way it is designed is prone to destabilizing effects for the financial sector. In particular, in the case of the establishment of a minimum capital requirement with GSF, we suggest that a better alternative is either adopting a more risk-sensitive capital requirement with the GSF based on a common taxonomy and disclosure standards for green assets combining with targeted loan-loss reserve or implementation, or opt for a BPF. Additionally, regarding the efficient application of DRR as a possible green macroprudential instrument, we it as a policy more suitable for developing countries rather than HICs, where the legal RRs are close to zero. However, it can hinder liquidity management bringing to a suboptimal outcome and complicate the conduct of monetary policy; hence, a strong coordination issue arises.

Bearing these caveats in mind, we see a potential in the modification of the current harmonized Basel III financial regulatory setup to align climate and financial stability objectives. Accordingly, we suggest a strategy of greening Basel III via the adoption of a countercyclical (or negative) capital buffer along the carbon cycle, a sectoral leverage requirement which targets exposers toward a specific green sector, a liquidity regulation to dampen the short-termism in financial intermediation, minimum (maximum) credit floors (ceilings) and large exposure limit to constrain an intermediary exposures to brown sectors.

Additionally, we point out that, because of the variety of institutional arrangements and forms of cooperation among central banks, commercial banks and government that can be distinguished theoretically, there does not exist a "one size-fits-all" approach to

greening the financial system. There could a potentially high number of approaches; indeed, path-dependencies and the peculiarity of national institutional frameworks (North, 1990, 1994) play a crucial role in the process of change that is needed to achieve a more sustainable economy. This implies some degree of experimentation left for policymakers and regulators, in an attempt to strike a balance between "boldness and realism" (Borio, 2011). Enlarging monetary authorities' mandates implies coordination, reputation and time inconsistency issues as well as the risk to attribute overly-ambitious goals to central banks. We think, however, that the window of opportunity offered by the proposed green policy framework to tackle climate change cannot be missed. As the financial crisis has lead to the build up of instruments to ensure the system's resilience against financial instability (Lombardi and Siklos, 2016), we envisage a similar dynamic for the development of green prudential instruments to tame financial risks related to physical and transitions risks and contribute to increase the financial resources to be devoted to green investments.

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A Macroprudential tools under Basel II and Basel III

BASEL II		
Pillar I	**Pillar II**	**Pillar III**
Minimum capital requirement	***Supervisory review***	***Market discipline***
Minimum standards for management of capital: • Credit risk • Operational risk • Market risk	- Capital adequacy strategies - Evaluation internal models - Level of capital charge - Proactive monitoring of capital levels and ensuing remedial action	Risk management: • credit • operational • market
BASEL III		
Pillar I	**Pillar II**	**Pillar III**
Enhanced minimum capital & liquidity requirements	***Enhanced supervisory review***	***Enhanced risk disclosure & market discipline***
Additional tools: - Liquidity coverage ratio (LCR) - Net Stable Funding Ratio (NSFR) - Leverage ratio - Capital conservation buffers - Countercyclical capital buffers - Enhanced loss absorption clause - Quality and level of capital - Securitization - Trading risk - Counterparty credit risk	*Additional tools:* - ICAAP - Supervisory review Evaluation process - Stress tests	*Additional tools:* - Regulatory capital components - Regulatory capital ratios - Securitisation exposures

Table 3: Overview and comparison of the 3 Pillars framework of Basel II (upper panel) and Basel III (lower panel).
Source: Authors' elaboration.

B Macroprudential governance

Country	*CB has a financial stability mandate*	*CB is a prudential authority*	*CB chairs the Financial Stability Committee (if any)*
		OECD Countries	
Austria	✓	✗	✗
Australia	✓	✗	✓
Belgium	✓	✓	-
Canada	✗	∼	✗
Czech Republic	✓	✓	-
Denmark	✓	✗	✓
Estonia	✓	✓	✗
Finland	✓	✗	-
France	✓	✗	✗
Germany	✓	✓	✗
Greece	✓	✓	-
Hungary	✓	✓	-
Iceland	✓	✗	✗
Ireland	✓	✓	✓
Israel	✓	✓	-
Italy	✓	✓	✗
Japan	✓	✗	✗
Latvia	✓	✗	✓
Luxembourg	✓	✗	✗
Netherlands	✓	✓	✓
New Zealand	✓	✓	-
Norway	✓	✗	✗
Poland	✗	✗	✓
Portugal	✓	✓	-
Slovak Republic	✓	✓	-
Slovenia	✓	✓	✓
South Korea	✓	✓	✓
Spain	✓	✓	✗
Sweden	✗	✗	✗
Switzerland	✓	✗	✓
United Kingdom	✓	✓	✓
United States	∼	✗	✗

Note: The table is constructed on a base of data gathered by authors form CB and IMF sources. *Legend*: ✓: YES; ✗; NO ∼: Somewhat; -: non available.

Country	*CB has a financial stability mandate*	*CB is a prudential authority*	*CB chairs the Financial Stability Committee (if any)*
		Developing Countries	
Argentina	✓	✓	-
Bangladesh	✓	∼	-
Brazil	✗	✓	✗(Rotating members)
Chile	✓	✗	✗(MOF)
China	✓	✗	✓
Colombia	✗	✗	✗(MOF)
Ecuador	✗	✓	-
India	✓	✓	✗(MOF)
Indonesia	✓	✗	✗(MOF)
Kenya	✗	✗	-
Lebanon	✓	✗	-
Malaysia	✓	✓	✓
Mexico	✓	✗	✓(CB and MOF)
Mongolia	✗	✗	-
Morocco	✗	✗	-
Nepal	✓	✗	-
Pakistan	✗	✗	-
Philippines	✓	✓	-
Russia	✓	✓	✗(I deputy PM)
South Africa	✓	✓	✓
Turkey	✓	✗	✗(MOF)

Note: The table is constructed on a base of data gathered by authors form CB and IMF sources. *Legend*: ✓: YES; ✗; NO ∼: Somewhat; -: non available.MOF -Ministry of Finance, CB - Central Bank, PR - Prudential Authority

C Green macroprudential tools: policy implications

Tool	Pros	Cons	Alternative Proposals
DRR	Canalizing exposures to green sectors	1.Suboptimal for liquidity management 2. Non universality	A. Activation of DRR on the base of country characteristics, policy stance and goal
CAR-GSF	Favours green investments by incentivizing the presence of green loans in banks' portfolios	1. Underestimates risks connected with green loans 2. Undermines the resilience of the financial system	A. Increase risk weights for brown loans (Schoenmaker and Van Tilburg, 2016) B. Brown penalising factor: set a higher CAR for banks with brown assets (2DII, 2018)
CCyB	1. Favors financial stability 2. Mitigates excessive "brown" credit growth 3. Prevents excessive leverage related to "brown" credit 4. Signalling power	1. Depends on the measure of the climate-related system risk 2. Depends on the adopted indicators of systemic risk 3. Requires adequate calibration 4. Requires early activation	A.Negative Capital Buffer (NCB) B. Construction of buffer through carbon-cycle
NSFR	1. Favors financial stability 2. Reduces maturity mismatch between assets and funding sources	Favors short-term/brown assets	Lower RSF (EBF, 2018)
SLR	1. Limit exposure of a bank to brown assets 2. Limits over-leveraging	1. Relies on appropriate disclosure of bank's exposure 2. Possible spillover effects to non-targeted sectors	
Minimum credit floors	Allocates a defined fraction of loans to green sector	1. Possible market distorsions 2. Low incentives for green lending	
Maximum credit ceilings	Limits lending to non-sustainable sectors		

Table 4: Green macroprudential instruments: overview of their policy implications and alternative measures.
Source: authors' elaboration.