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Anticipating the Unforeseen and Expecting the Unexpected: Effectiveness of Macro-Prudential Policies in Curbing the Impact of Stranded Assets in the Banking Sector

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Abstract: Banks are exposed to climate risks through stranded assets. This risk can be substantial in the banking sector, as it can spawn systemic risk. After the Great Recession, macro-prudential instruments effectively addressed systemic risk. However, climatic risks raise the research question of how feasible it is to address them by adopting macro-prudential instruments. The researchers, therefore, investigate how banks can respond to the risk posed by stranded assets through the framework of using macro-prudential instruments. A semi-systematic review of the related literature is carried out based on the researchers' aim to evaluate theory evidence in the effectiveness of macro-prudential instruments in addressing climate-related risks. The adaptability of macro-prudential instruments to address climatic risks and, by implication, systemic risk is demonstrated in the findings. The researchers develop a framework constituting climate transparency disclosures, climate capital requirement ratio, climate capital conservation, carbon countercyclical buffer and macro-prudential climate stress tests to mitigate the effects of climate risks in banking.

Keywords: capital adequacy; capital ratio; carbon countercyclical buffer; climate disclosures; climate risks; climate stress tests; macro-prudential instruments; risk weights; stranded assets; systemic risk

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1. Introduction

The burgeoning interest in climate-related risks is unquestionable. Their forms and related impacts are well documented. Countries, sectors and institutions have different exposures with varying magnitudes of negative consequences that disproportionately and profoundly impact economies. Banks are not spared, particularly through the significant role of intermediation, a process involving taking deposits and lending to those in need. Financial intermediation involves gathering money from surplus units to channel it to where it is needed (Ogunlokun and Liasu 2021). It ensures the availability of funding to deficient aspects of the economy (Bod'a and Zimková 2021). It is not difficult to see how climate risks can impact banks if one considers that asset stranding refers to "those investments which have already been made but which, at some time prior to the end of their economic life (as assumed at the investment decision point), are no longer able to earn an economic return" (International Energy Agency (IEA) 2013, p. 98). This risk to banks can also be seen through the lens of Harnett (2018) who described stranded assets as sunk costs, implying that they are a source of business risk to corporations. Since banks are subjected to capital regulation, bank losses resulting from climate damages can trigger lending limitations to affected and unaffected areas (Furukawa et al. 2020). Prices of assets can be negatively affected, leading to a deterioration in collateral values (Furukawa et al. 2020).

Financial institutions hold direct high-carbon exposures through investing in fossil-fuel companies. For European players, these exposures have been estimated as 1.3% for banks, 5% for pension funds and 4.4% for insurance companies, relative to their total assets (Battiston et al. 2017). If these investments were stranded, systemic losses could

be on the horizon. Different financial tools, including macro-prudential instruments, are available to deploy to curb these potential systemic losses. Macro-prudential policies aim to curb systemic risks (International Monetary Fund (2011)). In a nutshell, the macro-prudential policies aim to contain the chances of a crisis and mitigate the magnitude of losses (Cecchetti and Suarez 2021; Ma 2020; Tomuleasa 2015). Macro-prudential policies and their instruments effectively addressed systemic risks during the financial crisis. Since stranded assets can spawn systemic risks, it would be well-intended to reconfigure the same instruments to resolve and safeguard against systemic risks. The intended reconfigurations should not lead to other constraints in the financial system that could be counterproductive to mitigating systemic risks or to the overall goal of aiding the economies to grow.

Despite evidence of suggestions to calibrate macro-prudential instruments to encompass climate change (Campiglio et al. 2017), little is availed on how this should be carried out. Various strands of the literature offer discussions regarding the necessity of climatic voluntary full disclosures (Campiglio et al. 2017), mandatory full disclosures (TCFD 2017), and insufficient disclosures (Ilhan et al. 2020) without elaborating on the impact of these scenarios on the other macro-prudential instruments that are aimed at mitigating systemic risks. Other strands of the literature have looked at how the Basil III macro-prudential instrument could be calibrated (Batten et al. 2020) regarding climate stress testing, including Schoenmaker et al. (2015) concerning risk-weights assignments for climate-related exposures, and Bos and Gupta (2019) around the criticality of capital adequacy ratio in terms of bank performance amid climate risks as well as on the essentiality of the cyclical carbon buffer to mitigate losses. However, none of the aforementioned authors critiqued the performance of these instruments in the absence of mandatory full disclosures. There is an apparent lack of a coherent framework that connects the inputs and outputs of each reconfigured macro-prudential instrument, leading to a lack of justification of recalibration as well as demonstrable practicality of how climate change reconfigured macro-prudential instruments can be effectively employed. It would seem that all other reconfigured macro-prudential instruments involved in this study cannot be credible if mandatory full disclosures are not instituted. It is, therefore, difficult to locate a framework that captures the reconfiguration of existing Basel III macro-prudential tools to effectively address the potential harm of stranded assets to financial institutions, especially banks.

Consequently, this study endeavours to fill this gap by establishing and justifying the macro-prudential instruments as a framework that banks can reconfigure and use to mitigate the potential effects of stranded assets without spawning unintended consequences. Therefore, it should be prudent to note that while tightening and reconfiguring macro-prudential instruments is welcome, the same actions cannot be allowed to compromise economic growth (Cecchetti and Suarez 2021). The study's significance emanates from formulating a framework depicting the interconnectedness and interdependency of reconfigured macro-prudential instruments, not only to address aggressive lending towards assets that could be stranding but to mitigate financial instability from stranded assets.

To this end, a semi-systematic review approach of the related literature was adopted. A semi-systematic review is a literature review based on a traceable literature search that hinges on a clearly defined method that includes criteria such as search items and databases (Mertz et al. 2016). According to Snyder (2019), systematic reviews are predicated on strict guidelines for executing the search and bringing the best in reflecting the aggregate meaning from several studies that can lead to policy formulation and implementation. The process entailed assessing progress to readjust macro-prudential instruments successfully employed under Basil III to curb risks from stranded assets. Suggestions, comments and exhortations were noted and used to formulate the framework. For effectiveness, the semi-systemic review was performed on articles selected using keywords associated with macro-prudential instruments and stranded assets such as macro-prudential instruments, stranded assets, Basel III, climate risks, climate risk regulation, climate (risk) weighted assets, stress testing, capital adequacy, and carbon countercyclical buffer. The implication of reconfiguring macro-prudential instruments requires comprehending the application

of Basil III macro-prudential instruments. Hence, the inclusion criteria of articles were based on articles published beginning in 2009 after the global financial crisis and as recently as 2022.

The outcomes of the semi-systematic review provide assurance, through the framework, of how stranded asset-induced systemic risk could be mitigated to improve financial stability. Furthermore, and fundamentally so, the pillar that strengthens the effectiveness of the studied macro-prudential instruments is the provision of mandatory full disclosures. The absence of mandatory full disclosures renders the effort of reconfiguration ineffective because the credibility of the impact of the instruments becomes questionable. The study proffers pragmatic ways of calibrating macro-prudential instruments to mitigate stranded asset-induced systemic risks. It contributes to theory by showing the interconnectedness and interdependency of reconfigured macro-prudential instruments. Additionally, the studies' necessity is anchored on the need for an urgent intervention that should be achieved by the deployment of all facets of the established framework comprising mandatory full disclosures, climate stress testing, climate capital adequacy ratio, climate risk weights and the countercyclical climate buffer, to optimise the prevention of losses from unanticipated asset devaluations and to guard against expected declines from identified future expected asset stranding.

This article commences with the introductory Section 1, followed by a review of the related literature in Section 2. Section 3 renders the materials and methods, whilst Section 4 furnishes the research results. Section 5 discusses the results, and Section 6 offers conclusions. Finally, Sections 7 and 8 dwell on managerial and practical implications, respectively.

2. Literature Review

In this section, the researchers commence by contextualising the term stranded assets.

2.1. What Are Stranded Assets?

The first strand of literature looks at the different versions of stranded assets. Kalin et al. (2019) indicated the numerous definitions of a stranded asset which are sector-dependent (for example, energy and utilities). Knuth (2017) positioned it in terms of magnitude, which is a fossil fuel energy sector composed of trillions of dollars that can shrink substantially. According to van der Ploeg and Rezai (2020), the definition should encompass workers with expertise in technology and countries which are fossil fuel export-driven. It can also be viewed as challenges (climate change, global markets) as in Ansari and Holz's (2020) definition, which broadly positions asset stranding as the decline and eventual curtailment of revenues from fossil fuels. Another definition stems from the discipline (accounting, economics, engineering), and the summary by (International Financial Reporting Standards (IFRS) (2022)) of obsolescence in assets resulting in negative income on the statement of financial position clarifies the definition. However, others have established different descriptions. Stranded assets pertain to unrecoverable investment costs once profitability falls below targeted levels (Cairns 2018).

Following van der Ploeg and Rezai (2020), four (4) types of stranding occur: There is stranded carbon emanating from fossil fuel reserves that should not be touched if temperatures should stay below 1.5 or 2 degrees Celsius. Then, there is stranded physical capital, which refers to infrastructure and capital invested in the fossil fuel industry that will become useless once the economy switches to renewable energy sources. The third type of stranding refers to a change in the valuation of assets once the unanticipated future changes become known. However, and finally, not all policy changes are known with certainty, and announcements today could be subject to doubt about their actual implementation leading to a change in the initial evaluation. By allocating investment capital to any of the aforementioned areas, banks can be affected if stranding occurs.

Banks can also be exposed to stranding through non-regulatory externalities. These are externalities that can also have a severe impact on their investments. Such investments

include real estate, which can be vulnerable to various lock-ins, drastically affecting the real estate market and leading to stranding. Citing Grabher (1993), Muldoon-Smith and Greenhalgh (2019) indicated the existence of three types of lock-ins:

1. Political lock-ins involve retention of the past means to the impediment of fresh inputs and policy initiatives.
2. Cognitive lock-in is associated with cultural acceptance, which can impede transformational ideas.
3. Functional lock-in hinges on the interconnectedness between previous building functions and worth, which opposes the embracement of exogenous change.
4. Amongst other core features, disruptive innovation has the potential to spawn stranded assets (Green and Newman 2017). However, they exhibit more risk reduction of a climatic nature, and current research points to increased environmental causes (Caldecott 2017). Regardless of the cause, sector, challenge or discipline, stranded assets are recognised as those prematurely written down, devaluated or converted to liabilities (Caldecott et al. 2013; Paun et al. 2015).

2.2. Challenges Presented by Stranded Assets to the Banking Sector

No country can be considered immune from physical risks; by implication, no bank can be regarded as immune. The challenges faced by financial service companies, particularly banks, could be substantial. Catastrophic events could inevitably trigger underinsurance, spawning a lending reduction (Garmaise and Moskowitz 2009). If major natural disasters cause disruptions in banking services, liquidity issues could become central. The financial system could find itself exposed to instability, prompting central bank involvement. (Batten 2018). Major banks, including the Bank of England, expressed concern regarding the financial dilemma resulting from the mispricing risk of stranded assets (Sen and Von Schickfus 2020). The prospect that insurance companies could take a flight from risks they deem uninsurable is high, a scenario that could also reduce collateral values (Batten 2018). Stranded assets' related causes could manifest in reduced output and employment, leading to increased default scenarios, a recipe for bank instability (Batten et al. 2020).

Furthermore, a cross-country effect could transpire in a severe increase in sovereign default risk (Batten et al. 2020). In addition, stranding can impact all stakeholders' asset values, profit margins for businesses, and default risk for banks (Scott et al. 2017). Consequently, default risks could trigger losses, a move that could lead to credit restrictions (Scott et al. 2017).

2.3. Proposals to Mitigate the Consequences of Stranded Assets

This section presents various proposals based on the related literature on macro-prudential instruments. A notable feature in the discourse on climate-related risks to the banking sector is the corresponding escalation in solution-oriented proposals to curb the potential effects. A more proactive option is to adapt macro-prudential regulations to consider climate-related financial risks. Therefore, macro-prudential policies are aimed at the aggregate financial markets and the ubiquitous economic risk factors (Galati and Moessner 2018). The instruments can be recalibrated to include climate considerations and incentivise financial institutions to expand lending to low-carbon activities (Campiglio et al. 2017). Transparency disclosures, capital requirement ratio, capital conservation, countercyclical buffer, and macro-prudential stress tests have become central in determining the soundness and stability of financial systems since 2008 (Acharya et al. 2014). The section commences with a discussion on the pertinence of full disclosures.

2.3.1. Full Disclosures of Climate Credit-Related Loans

Investors and other stakeholders have the right to know the extent of a bank's exposure to climate-related activities. According to Papandreou (2021), even though other reasons, such as ethical considerations, may exist regarding investors' interests, it is apparent that bank investors, including depositors, would be interested in their exposure to financial risk

stemming from banks' investments in climate-related projects. Furthermore, full disclosures could be the panacea towards a green economy (Papandreou 2021). It is in the spirit of disclosure that the Financial Stability Board (FSB) proposed an industry-wide disclosure that led to the formation of the Task Force on Climate Related Financial Disclosures (TCFD) in December 2015 underpinned by the four core elements related to governance, strategy, risk management and metrics (Papandreou 2021). The Task Force for Climate-related Financial Disclosures was mandated to develop voluntary disclosures that could promote more informed investment, credit and insurance underwriting decisions (Campiglio et al. 2017). However, the current levels of climate disclosures are insufficient (Ilhan et al. 2020). Gelles (2016), as cited by Christophers (2017), argued that there was a void in the SEC's 2010 disclosure guidance which reflected bare minimal risk disclosures. Ameli et al. (2020), citing Carney (2015), argue that the lack of transparency regarding who holds risky climate-related assets is evident. The effectiveness of climate-related disclosures, including those leading to the stranding of assets, is well accepted, resulting in other countries such as the United Kingdom and New Zealand making it mandatory (Bos and Gupta 2019).

When addressing climate and environmental risks, it is important to disclose them. For that reason, the Financial Stability Board's Task Force on Climate-related Financial Disclosures advocates for mandatory disclosures across all levels of financial institutions (TCFD 2017). Indeed, appropriate disclosures can result in full comprehension of the need to transition to a green economy. Resultantly, transparency regarding pricing risks and other options manifests in credible climate-related stress testing (Volz 2017).

Banks were accused of opaqueness in their debt levels. This led to the global financial crisis through profit generating amid questionable instruments (Bartlett 2012). Furthermore, non-disclosure of climate investments by banks could also spawn systemic risks. Therefore, a mechanism to confirm the accuracy of disclosure and to safeguard potential negative spill-overs should be instituted. Christophers (2017) voiced his concern over the aspect of voluntary disclosures. He put his weight towards mandatory disclosure as an effective tool. However, it is important to embrace the observation by Bartlett (2012) that the institutions whose subprime exposures were so opaque were the same institutions producing substantial quantities of mandatory disclosures. It is a stark reminder of the possibilities of interferences in climate reporting systems.

2.3.2. Stress Testing Climate Risks

Stress testing against climate risks is equivalent to assessing the resilience of financial institutions to unfavourable scenarios. For example, the ECB stress testing framework effectively evaluates climate scenarios' impact on banks' resilience over a 30-year time frame (Alogoskoufis et al. 2021). To effectively establish the resilience of financial institutions to systemic risk, Jung et al. (2021) developed a stress testing methodology termed CRISK. A financial institution will have an expected capital shortfall in a climate-stress setting. However, pinpointing scenarios that could spawn significant losses is the major challenge. To overcome the challenge, generating a scenario that could trigger significant financial losses is critical. However, determining the risk level hinders the ability to approximate the possibility of a new policy formulation (Battiston et al. 2017).

Nevertheless, results from such stress testing provide stakeholders with the much-needed risk exposure levels of financial institutions (Batten et al. 2020). Accordingly, Jung et al. (2021) employed stranded asset portfolio return for transition risk and estimated a time-varying climate beta. Their methodology demonstrates that the results of such stress testing would be questionable if the stranded asset portfolio is not fully disclosed, whether deliberately or due to skills deficiencies. Furthermore, the time-varying beta will likewise approximate accuracy only if estimated time frames to stranding are disclosed with a higher degree of accuracy (Jung et al. 2021). Consequently, the nexus between stress testing and disclosure becomes apparent. It is only through credible climate disclosures that commensurate stress testing results could also be deemed credible.

2.3.3. Risk Weights of Climate Exposures

The prevalence of a threat to financial stability has prompted the debate about including environmental considerations in macro-prudential instruments, which would inevitably include risk-weighted capital requirements (Campiglio et al. 2017). Resultantly, assets of a low-carbon nature would appear less risky on the books of banks. The unintended consequences should be prioritised (Campiglio et al. 2017). Similarly, Schoenmaker et al. (2015) proposed steeper risk weights for the broader category of carbon-intensive sectors. Ignoring credit rating agencies such as Standard and Poor (S&P) in their recognition of issuers' exposure to climate change results in under-assignment of risk weights to assets such as those of polluting companies such as Exxon and Chevron by regulators from the United States (Kress 2022). Instead, the United States allocates a flat risk weight to corporate assets despite the difference in the borrowers' risk profile, degenerating to a deviation from international standards (Kress 2022). By implication, risk weights are not being calibrated according to the impact's severity, which conflicts with the intended use of risk weights, culminating in the setting aside of lesser capital provisions. Lesser capital provisions are a source of systemic risks.

2.3.4. Climate Capital Adequacy Ratio

Dao and Nguyen (2020) established a statistically negative relationship between the capital adequacy ratio and banks' performance. Bos and Gupta (2019) believe that considerations of capital adequacy ratios and the inclusion of environmental aspects in measuring risk for risk-weighted capital requirements would be crucial. Capital requirements dependent upon carbon levels would inevitably lead to financing being directed towards low-carbon assets (Bos and Gupta 2019). In a widely referenced article, Gropp et al. (2019) noted that, in Europe, banks that were required to observe capital requirements were able to respond positively by improving their regulatory capital ratios significantly more than those that were not subjected to the same requirements. They (Gropp et al. 2019) further suggested that attaining higher capital adequacy resulted from a reduction in risk-weighted assets instead of an increase in capital levels, which could have been attributed to a reduction in outstanding loans. However, according to Campiglio et al. (2017), high-income economic regulators seem reluctant to use prudential regulations to support the low-carbon transition. Admittedly, financial risks due to issues such as stranded assets are widely recognised. However, that recognition is not supported by most central banks and regulators who do not consider it their mandate to justify adjusting prudential policies to direct finance towards low-carbon activities (Campiglio et al. 2017). Instead, the recognition and commensurate support could be rendered in circumstances where it is evident that these risks are material and are systematically higher for high-carbon activities (Campiglio et al. 2017). Regardless, considering the magnitude of potential losses, central banks cannot neglect their seeming obligation to adjust prudential instruments for adequate climate capital adequacy.

2.3.5. Climate Countercyclical Buffer

After the global recession, the Basil III regulatory framework introduced a new countercyclical buffer composed of equity between 0% to 2.5% of total capital to provide a countervailing force to credit bubbles (Edge and Liangb 2022; Rubio and Carrasco-Gallego 2016). The countercyclical buffer is more of a reserve set in anticipation of economic downturns and is to be utilised once a downturn has transpired with notable economic losses (Edge and Liangb 2022). Furthermore, unintended consequences manifesting as reduced economic credit supply should be kept in check (Edge and Liangb 2022). The same argument is put forward in this research, with the only difference stemming from the involvement of carbon-intensive credit growth. More capital should be reserved in times of wider economic carbon-intensive loan growth (Bos and Gupta 2019). Such an approach reduces the exposure of banks to carbon-intensive investments as well as ab-

sorbing the damage potentially coming from a devaluation of assets through stranding (Bos and Gupta 2019).

In summary, studies by Papandreou (2021) and Christophers (2017) voiced support for implementing mandatory full disclosures to mitigate stranded asset-induced financial instability. Furthermore, Jung et al. (2021) showed that effective stress testing of climate-related risks could improve banks' resilience and help mitigate financial crises. Meanwhile, studies by Campiglio et al. (2017) and Schoenmaker et al. (2015) confirmed the need for risk-weights stipulations based on the degree or level of climate risks. Finally, Bos and Gupta (2019) reflected on the capital adequacy ratio and concluded that low carbon-intensive projects would mean lower capital to be set aside by banks. Without focusing on the measure of the carbon countercyclical buffer, Bos and Gupta (2019) asserted the need for a buffer to be set aside for use in periods of losses due to climate risks. These conclusions mentioned above play a critical role in shaping the framework for effectively mitigating climate-induced systemic risks.

In the next section, the results are presented.

3. Results

The study results are presented following the order in which the macro-prudential instruments were presented in the reviewed literature.

3.1. Climate-Related Disclosures

When addressing climate and environmental risks, it is important to disclose them. However, inadequacy in disclosures is prevalent, as most of those institutions that are supposed to disclose are not doing so or, when they do disclose, they do not disclose fully (Ameli et al. 2020; Christophers 2017; Ilhan et al. 2020). Non-disclosure makes it difficult for regulators and other stakeholders to conduct climate-related stress tests. There seems to be a broader acceptance of the effectiveness of climate disclosures; however, the question of whether they should be considered mandatory or not arises. If the impacts of climate risks are as severe as the discourse reveals, then there should not be any inertia in mandatory disclosures across the globe. Christophers (2017), Ilhan et al. (2020) and TCFD (2017) believe that mandatory disclosures are the most appropriate means, not the end, for adequate risk mitigation since proper verifications of those disclosures are vital to avoid a repeat of a financial crisis stemming from hidden bank climate exposures. It is critical to observe that mandatory disclosures would aid in the transparency and management of the four core elements called for by Papandreou (2021) of governance (policy frameworks regarding the use of the instruments); strategy (formulation of goals to arrive at acceptable levels of stranding); risk management (monitoring of deviations from carbon-zero targets); and metrics (numeric and measurable values indicating progress or a lack of progress).

3.2. Stress Testing of Climate Risks

While there is a variety of guidance on scenario-based climate adaptation frameworks, a careful analysis of the literature reviewed reveals that stress testing is widely accepted as effective in testing banks' resilience (Alogoskoufis et al. 2021; Jung et al. 2021). However, it is a very challenging proposition in climate-related scenarios if one considers the opaqueness of disclosures from the very institutions that should be stress tested. The researchers used Basel III liquidity stress testing to elucidate the difficulties in climate exposure testing. In liquidity stress testing, there is the following scenario:

$$\text{LCR} = \frac{\text{High Quality Liquid assets}}{\text{Total Cash Outflows}} \geq 1 \quad (1)$$

The LCR stipulates that banks should have enough high-quality liquid assets of Levels 1 and 2 assets relative to their expected net cash outflows (NCOF) (Fuhrer et al. 2017). Banks are mandated to keep a stock of unencumbered high-quality liquid assets (HQLA) to safeguard against liquidity constraints in the short term. The HQLA can speedily be sold

within 30 days to cover liabilities. Total net cash flows (TNCO) entail the total outflows anticipated within 30 days less the lesser of inflows or 75% of outflows. The effectiveness of stress testing liquidity lies in disclosing all the factors involved in the measurement and the specification of the 30-day time constraint. Therefore, to assess the full extent of the related impact on macroeconomic variables, a full disclosure of whether effects should be maintained (Batten et al. 2020), of the time constraints and of drop-offs relating to potential reductions in exposures based on loans being paid up is necessary. Not only should the focus be on outstanding loans reflecting climate risks, but the rate at which these loans are reduced based on payment instalments or early settlements should also take centre stage. This is linked to the TNCO. Such comprehensiveness in including all relevant factors mentioned above would make for effective climate stress testing. The likelihood of obtaining accuracy in stress testing, supported by Jung et al. (2021) stemming from time-linked full disclosure, is significant. Such accuracies will aid regulatory institutions such as ECB, whose other role is to evaluate the climate scenario's impact on banks (Alogoskoufis et al. 2021). The resilience of banks can better be measured and managed in the future, thereby contributing to much-needed financial stability.

3.3. Climate Risk-Weighted Assets

Based on the extensive literature reviewed, it is deduced that assigning low-risk weights to low-carbon-related projects is the preferred method. However, several challenges can minimise the effectiveness of this strategy. Critically, there is a gap in the literature reviewed on how the weights should be calibrated across the range of brown assets and those related to low carbon emissions. This is particularly pertinent given the various forms and types of assets and the potential causes of and envisaged time-horizon links to damages. Based on Breitenmoser et al. (2022) and Bos and Gupta (2019), assigning lower risk weights to low-carbon assets can induce capital flows to green-friendly assets and produce unintended consequences in the form of a green bubble. Not containing the green bubble can spawn a financial crisis. Based on the literature reviewed, it would seem appropriate that the riskiness of assets based on climate exposures cannot be uniform across the global banks and all loans. The standardised form, shown by an illustration, as used in Basel III in computing risk-weighted assets, should not apply. Table 1 depicts this standardisation for retail banking. All the figures utilised are for illustrative purposes only. The risk weights applied are standard across all asset classes and jurisdictions. Risk-weighted assets result from the asset's value and the risk weight assigned. Risk weights, therefore, turn the bank's risk exposure in each asset category into the required capital.

Table 1. Standardised risk weights.

	Year 1	Risk Weight	RWA
Assets			
Loans to customers			
Retail–Mortgage	500,000	40%	200,000
Retail–Consumer	500,000	100%	500,000
Property and Equipment	400,000	100%	400,000
Total Assets	1,400,000		1,100,000

Unlike in the above illustration and based on the literature reviewed, it would appear that effective categorisation of climate-related assets should be weighted based on the likelihood of stranding. Such categorisation should be based on causes such as technological developments, physical risks, the industrial sector (for example, mining or real estate), degree of exposure and estimated timelines. It is noted from the literature that what is likely to suffer from unexpected devaluations are the assets. Sometimes, estimating when a particular factor can take root is possible. Policy changes could be gradual or known well in advance, as could technological changes. Risk weights could increase due to the severity of the given factors, unlike in the Basel III setup, and the quality of underlying

assets in each category could induce variation. The most challenging aspect probably centres on physical risks from weather-related causes such as storms. Hence, each country or jurisdiction should have risk-weight computation based on its unique challenges and dominant factors. Table 2 provides a simple illustration of the differentiation in risk weights based on different scenarios. Again, the figures utilised are for illustrative purposes only.

Table 2. Multi-factor-based risk weights.

Country	Exposure $Billions	Sector	Physical Risk	Estimated Likelihood	Estimated Likelihood of New Policy	Estimated Timelines to Occur	CRW e.g.,
A	1000	Mining	Floods	Very high	1 year	1–2 years	100%
B	500	Mining	Floods	High	3 years	5–7 years	60%

Table 2 shows that the climate risk weights assigned to investments by banks in the mining sector in country A should be relatively higher than the one allocated to capital allocated to the mining sector by banks in jurisdiction B. A careful review of the literature, therefore, revealed that the presence of different levels of exposure to different types of causes allows for the assignment of different weights per region. Likewise, different degrees of concentration per region of different sectors, such as oil and gas and automobile manufacturing, to name but a few, necessitate the assignment of different weights per region. The benefit of this approach is that it addresses the criticality of under-assignment of risk weights since company and sector exposure is explicitly considered. In addition, issuer exposure is inherently addressed, and credit rating agencies' opinions and commensurate under-assignments (Kress 2022) are also inherently addressed. As a result, concerns of a flat risk weight and the allocation of lesser capital provisions, as suggested by Kress (2022), are invalid, and adequate capital provisions would become possible.

3.4. Capital Adequacy Ratio for Climate-Related Assets

Even though Basel III capital adequacy has effectively maintained the soundness and stability of banks, caution needs to be taken in their application to climate-related assets. It is revealed from the studied literature that the ratios can be manipulated in the sense that banks may not necessarily increase the absolute value of capital but can lower the risk-weighted assets and, by so doing, meet the adequacy ratios. Reducing risk-weighted carbon-intensive assets would seem ideal to mitigate the impact on banks from unanticipated declines or depreciation in asset values. There is a deep concern about the potential havoc to the economic well-being of nations as a result of the proportional reduction in loans. However, no clear-cut views exist on how the nexus between improved capital adequacy and a potential loan decline should be addressed. Once more, there seems to be a deafening gap in how the capital adequacy ratio should be constituted based on the already perceived constraints placed on banks in their lending businesses. Since there are already signs of discomfort in high-regulatory capital levels, increasing it would create further discomfort and likely strain banks' intermediation role. Based on the results on climate risk-weighted assets whereby it is discerned that jurisdictional computations should be instituted, it becomes logical to have a uniform regulatory ratio as in Basel III Tier 1 capital given by

$$\text{Tier 1} = \frac{\text{Shareholder Equity}}{\text{Risk} - \text{weighted Assets}} \tag{2}$$

The model changes to the one that takes into account climate credit risk:

$$\text{Climate Tier 1} = \frac{\text{Shareholder Equity}}{\text{Climate Risk} - \text{weighted Assets}} \tag{3}$$

To elucidate the above explanation, the following illustrative calculations for banks A and B (for convenience purposes) are displayed in Table 3.

Table 3. Capital adequacy calculation for climate risks.

	Capital	**Bank A**	**Bank B**
Common Equity Tier 1 (CET1)	Common equity (Billion dollars)	200	200
	Retained earnings (Billions)	250	250
	CET 1	457	450
Tier 2	Revaluation reserve	20	20
	Total Tier 1 + Tier 2	657	657
CET1		Bank A	Bank B
Total CRWA	1000 × 100% 500 × 60%	1000	300
Total CRWA X 7%		70	21
CET 1		457	450

In Table 3, the exposures or credit risk assets of 1000 and 500 have been extended from Table 2, representing the total assets exposed to climate risk for banks A and B, respectively. Applying the minimum risk weight of 7% yields credit risk-weighted assets of 70 and 21, respectively. It can be observed from Table 3 that the total CET 1 capital of 457 and 450 are more than sufficient to meet the 7% (assuming regulators recommend the same minimum of 7% of climate risk assets as in Basel III) since the minimum should be 70 and 21, respectively. Therefore, applying the capital adequacy ratio in climate-related assets is feasible and practical to allow banks to set aside capital for unexpected losses from stranded assets. The implication is that when justifiable and correctly determined capital adequacy is used, the financial system should witness greater good bank performance and fewer bank failures due to the statistical significance between capital adequacy and bank performance observed by Dao and Nguyen (2020). Once banks' performance in the wake of stranded assets reflects soundness, it is possible for central banks and regulators to consider their mandate to set policies aimed at directing finance towards low-carbon activities. Such developments, which will contrast the prevailing status quo regarding the lack of willpower by central banks to adjust mandates (Campiglio et al. 2017), could see a more stable financial system that is not shaken by the risk of stranded assets.

3.5. The Carbon Countercyclical Capital Buffer

What appears as very crucial in the literature reviewed is the suggestion that a cyclical carbon buffer should be instituted to provide a countervailing force to absorb burgeoning losses during a prolonged downturn due to carbon-intensive loans while maintaining credit extension to the economy. Just as in the Basil III countercyclical buffer, the hope is that the carbon countercyclical capital buffer moderates credit extension to the economy when credit and asset developments (as in stranded assets) point to a rise in systemic risk. This moderation would require the accumulation of the carbon countercyclical capital buffer. This system ensures a balanced approach in carbon-intensive credit exposures during upward trends of the carbon-intensive credit cycle and provides a buffer for damage control should stranding take effect.

The gap in the literature shows up in the lack of specifications of the range and, most critically, of the link between the buffer and the factors such as the perceived time frames of occurrence of asset devaluations that are short-, medium- or long-term, bearing in mind that when referring to the stranding of assets in particular, the key factor is in its unanticipated occurrence. The literature shows that the biggest challenge in using the Basel III methodology of maintaining a range such as 0–2.5% is that anticipating the unforeseen and expecting the unexpected will always leave the banks at the mercy of stranded assets. The unexpected element in stranding means this risk has some profound and permanent characteristics.

Consequently, a zero-percent countercyclical buffer cannot be viable and can be characterised as a recipe for disaster. The unexpected nature of stranding means that any continued granting of capital to projects that may get stranded implies that banks should always

have a cyclical climate buffer of greater than 0% in readiness for the unexpected economic downturn. A greater than 0% buffer would imply that current and future multi-trillion-dollar losses due to the devaluation of fossil fuel resources and in the particular global geography of properties rendered useless due to stranding (Knuth 2017) would be covered through the buffer. Since stranding is already happening, the buffers should be released after adequate stress testing materialises, and losses are incurred (Edge and Liangb 2022) while maintaining the flow of credit to the economy. Ultimately, confidence in the banking system is sustained, and crises that result from a lack of confidence in the capacity of the banking system as a whole to mitigate stranded asset risks can be avoided.

Our framework is constituted as follows:

1. Mandatory, and not voluntary, disclosures of climate risks are necessary for full risk mitigation.
2. However, it appears as if mandatory disclosures are only a means to adequate risk mitigation and not the end since proper verifications of those disclosures are vital to avoid a repeat of a financial crisis that could stem from hidden bank climate exposures.
3. The effectiveness of climate stress tests cannot be attained without fully disclosing all loans (assets) linked to climate risks.
4. Regarding stranded assets, effective risk-weighting for climate-related assets should be based on the likelihood of stranding based on causes such as technological developments, weather patterns, industrial sector, degree of exposure and estimated timelines of occurrence. Hence, each jurisdiction should have its computation based on the abovementioned factors.
5. Since there are already signs of discomfort in high levels of regulatory capital, increasing regulatory capital has the potential to strain the intermediation role of banks. Jurisdictional computation of risk-weighted assets would allow for a more pragmatic regulatory capital ratio, as in Basel III Tier 1 capital, to be applied globally.
6. Anticipating the unforeseen and expecting the unexpected will always leave the banks at the mercy of stranded assets. Therefore, a zero-percent countercyclical buffer cannot be viable and is a source of a financial disaster. Consequently, banks should always have a cyclical climate buffer greater than 0% in readiness for an unexpected economic downturn.

4. Discussion

The documented results demonstrate the interconnectedness and interdependency of the calibrated macro-prudential instruments within the framework for effectively mitigating financial instability. Firstly, mandatory full disclosures will lead to reliable stress testing since all information necessary to execute stress testing is provided. Secondly, the resulting stress testing based on mandatory disclosures leads to the logical and reasonable assignment of risk weights. The possibility of different geographic concentration and scale of stranded assets evidences this. Risk weights are then reasonably assigned by incorporating the full disclosure and the degree of concentration. Once risk weights are assigned, the required capital adequacy would have merit since all components ranging from mandatory disclosures, adequate stress testing and logic in risk-weight categorisation would have been properly incorporated. Lastly, the reasonableness in determining capital adequacy would be built on a better determination of a carbon countercyclical buffer. Due to current and future stranding, the carbon countercyclical buffer cannot be set at 0%. The sequel mentioned above is the essence of the framework and demonstrates its capacity to aid in financial stability by addressing systemic risk stemming from stranded assets. An expanded and detailed discussion is provided as follows:

Due to the enormity of climate risks, investors' interest in exposures should be considered. Bartlett (2012) provides a caveat to this consideration in that disclosures should not be opaque. Opaqueness and non-disclosure make it difficult for stakeholders to conduct climate stress tests. Hence, the results show that mandatory disclosures should be instituted, but caution should be considered in their full disclosure status to avoid systemic

risks. On stress testing, the results show that all climate-related factors, including but not limited to full disclosure of all loans (assets) and time constraints, should be considered in stress testing. Of significance should be the inclusion of drop-offs relating to potential reductions in exposures based on loans being paid up and the rate at which loans are reduced based on payment instalments. Early settlements should also be included to make stress testing more credible. This is in tandem with an assertion by Batten et al. (2020) that including such information in stress testing could help financial market participants assess the climate-related risk exposure of particular institutions. In assigning risk weights, the results highlighted the pertinence of jurisdiction-based flexibility since climate-related scenarios differ across geographic boundaries. Some factors or sectors may not even be present in other regions. Hence, arriving at the results, the study leveraged Schoenmaker et al.'s (2015) discussion that higher risk weights can effectively be assigned where carbon-intensive assets are detected. However, in assigning lower risks to low carbon-intensive assets, caution should be taken to avoid the unintended consequences of a green bubble which can spawn other systemic risks. Bos and Gupta (2019) supported the inclusion of climate risks into risk weights.

The resultant jurisdictional risk weights should give rise to capital adequacy by simply diving the commensurate risk-weighted assets into shareholder equity to arrive at a climate Tier 1 capital ratio. Hence, the required capital adequacy can be set at a uniform percentage. Finally, the cyclical capital buffer can be calibrated to a cyclical carbon buffer. However, the possibility of unexpected devaluations of assets would require that the minimum never be set at 0%. This requirement can be deduced from Bos and Gupta's (2019) appeal for a carbon countercyclical capital buffer from financial institutions for potential losses emanating from periods of excessive financing of carbon-intensive projects. This entails increased capital reservation during periods of carbon-intensive credit extensions for the wider economy. Again, however, that buffer cannot be set at 0% because of the inevitable stranding of assets.

5. Materials and Methods

The study's methodological approach was based on a semi-systematic review approach of the literature based on the researchers' aim to evaluate theory evidence in the ability of reconfigured macro-prudential instruments in mitigating climate-related risks. Besides the aim of overviewing a topic, a semi-systematic review traces the dynamics and progress of research in a specific research category (Snyder 2019). Based on the study's aims, search terms were used to access relevant articles from Google Scholar and the University of South Africa library database. Macro-prudential policies and instruments used to address the global financial crisis of 2009 formed the basis of the search criteria. This approach equates to what Booth (2016) describes as an enlightened action plan for getting to a sample specimen. In addition, the search criteria considered climate risks and articles related to stranded assets and their likely influence on financial instability.

Furthermore, Basil III, a regulatory framework which played a critical role in ensuring the soundness and stability of the financial sector, was also considered for the evaluation of theory evidence. The relationship between Basil III regulation and the macro-prudential instruments formulated to address the global financial crisis was of particular interest. This was considered pertinent since the study's main objective was to reconfigure those macro-prudential instruments meant for correcting the ills of the financial crisis and recalibrate them to address the potential ills posed by stranded assets. Hence, the search used terms constituting keywords: macro-prudential instruments, stranded assets, Basel III, climate risks, climate risk regulation, climate (risk) weighted assets, stress testing, capital adequacy, and carbon countercyclical buffer. From the study's main objective to selecting search terms, it was important to be transparent and reflect a well-formulated research strategy for a meaningful presentation of results (Snyder 2019). Since Basel III was a part of applying macro-prudential regulations, the articles used ranged from those published after the financial crisis (2009) to as recently as 2022. Hence, the inclusion criteria were based on articles published after the formulation of Basil III in 2009 to the year 2022; any

related articles prior to 2009 were excluded. All articles were written in English. This comprehensiveness allows for mitigating the dangers of excluding relevant literature and including relevant literature (Bahlas et al. 2021). Initially, 150 abstracts were read based on search terms. Of the 150 abstracts, 68 were selected as the most relevant. Upon reading the full texts of the 68 articles, 35 articles were included in the study since they were the most appropriate for achieving the aims and objectives of the study.

Additionally, the 35 articles included 5 articles that were referenced from the initial 68 selected. A combination of descriptive information, the conceptualisation of ideas, and effects and findings were extracted from the reviewed articles. To keep with the traditions of reliability, a search was performed to ensure the extractions included all themes relevant to effectively addressing climatic risks using macro-prudential instruments. As employed by Mertz et al. (2017), the synthesis was based on the most relevant interpretation of what was described in mechanisms to reconfigure macro-prudential instruments and to build an effective framework to mitigate stranded asset-induced financial instability. The extractions were used to improve the theories of climate risk mitigation using macro-prudential instruments and to make them more effective by leveraging Basil III strategies. Illustrative examples were also provided to clarify the impact of adaptions of the instruments on climate risk.

6. Conclusions

Based on a semi-systemic literature review, this study supplied a framework in a form that is suitable for guidance in the adoption and execution of macro-prudential instruments in mitigating the effects of climate risks in the banking world. Even though the framework is a collection of individual macro-prudential instruments that are reconfigured to address climate risks, its novelty and uniqueness emanate from their interconnectedness and interdependency. It is, therefore, apparent that all the other instruments would not be credible if they were not based on the first fundamental principle of mandatory and full disclosure. Results of stress testing that are not based on full disclosures cannot be trusted by investors. Doubts will be triggered regarding the adequacy of capital requirements if they are hinged on disclosures that cannot be relied upon. Risk weights cannot be fully and reasonably assigned if the concentration levels of climate risks are not fully disclosed.

Studies such as those by Christophers (2017) and Ilhan et al. (2020) attest to the need for full, standardised voluntary and mandatory disclosures that can enhance market discipline but do not connect to the effectiveness of other reconfigured macro-prudential instruments as a result of such disclosures. However, Christophers (2017) found that full disclosures' effectiveness lies in giving investors confidence about an institution's capital adequacy. This study transcends the aspect of capital adequacy by looking at the climate capital adequacy ratio as an instrument to measure and give credibility to the adequacy of capital. Likewise, Jung et al. (2021) concluded that stress testing effectively establishes the resilience of banks but fell short in connecting that effectiveness to mandatory full disclosures or linking it to the effective assignment of risk weights. Finally, stranding is a reality and, if disclosed fully, renders the carbon countercyclical buffer impossible at a zero-percent minimum. Even though Knuth (2017) established that the magnitude of losses attributed to stranding carries a substantial risk to investors, he did not extend the argument to incorporate the analytical usefulness of macro-prudential instruments such as the climate–carbon cyclical buffer for banks in their investment role. Since stranding is already happening, the buffers should be released after identifying devaluation losses. Hence, the zero-percent minimum should be rectified. Furthermore, the study significantly incorporated the overarching principle that unintended consequences should be mitigated. Therefore, the involvement of all stakeholders, particularly regulatory bodies and central bankers, in climate actions must be carefully designed to avoid unintended consequences that can further trigger more systemic risks.

Consequently, this study proffers pragmatic ways of calibrating macro-prudential instruments to mitigate stranded asset-induced systemic risks and contributes to theory by

showing the interconnectedness and interdependency of reconfigured macro-prudential instruments. Additionally, the study's necessity is anchored in the need for an urgent intervention that should be achieved by deploying all facets of the established frameworks to optimise the prevention of losses from unanticipated asset devaluations and to guard against expected declines from identified current and future expected asset stranding. This interconnectedness and interdependency, which commences with mandatory full disclosures of stranded assets, enhance the capability of financial institutions to curb financial instability. However, there are limitations to the study, as shown below.

The study's limitations are two-fold: firstly, it does not provide an analytical background of how mandatory disclosures could be regarded or ascertained as full disclosures. Secondly, just like the case where mandatory disclosures were ubiquitous, although accompanied by opaqueness in subprime exposures (Bartlett 2012), the current study does not attempt to bridge this grey area between mandatory full disclosures and opaque exposure to stranded assets. Such a matching principle could give more credibility to the framework established in this study and mitigate further financial instability triggered by stranding. This can be an area that calls for input from further studies.

7. Managerial Implications

Based on the findings, authorities, regulators and other policymakers, including central banks, must strive for mandatory full disclosures of climate exposures of banks. Concurrently, it behoves bankers to embrace the call for mandatory disclosures if there is nothing to hide regarding exposure to climate risks. These concurrent actions by authorities and bank management will pave the way for confidence building in the banking world in addressing systemic risks by reconfiguring the aforementioned macro-prudential instruments. Moreover, since the stranding of assets is already taking place presently, and devaluation losses are evident, the deployment of the framework should not be delayed.

8. Practical and Social Implications

Immediate framework deployment would likely mitigate systemic risks in the banking sector. Consequently, the potential of bank instability induced by inappropriate handling of stranded assets would be mitigated. A financial crisis with its drastic consequences, such as loss of income, slow economic growth and unemployment due to bank closures or even bailouts, could be prevented. Furthermore, authorities' and bank management's adoption of the framework implies mitigating climate risks in general and channelling resources towards green initiatives to benefit all stakeholders.

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