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**Climate Change and the Role of Regulatory Capital:
A Stylized Framework for Policy Assessment¹**

Michael Holscher, David Ignell, Morgan Lewis, and Kevin Stiroh

October 18, 2022

Abstract

This paper presents a stylized, non-country-specific framework to assess conceptually how the financial risks of climate change could interact with a regulatory capital regime. We summarize core features of a capital regime such as expected and unexpected losses, regulatory ratios and risk-weighted assets, and minimum requirements and buffers, and then consider where climate-related risk drivers may be relevant. We show that when considering policy implications, it is critically important to be precise about how climate change may impact the loss-generating process for banks and to be clear about the specific policy objective. While climate change could potentially impact the regulatory capital regime in several ways, an internally coherent approach requires a strong link between specific assumptions and beliefs about how these financial risks may manifest as bank losses and what objectives regulators are pursuing. We conclude by identifying several potential research opportunities to better understand these complex issues and inform policy development.

¹ The views expressed in this paper reflect those of the authors only and not necessarily the Board of Governors of the Federal Reserve or the Federal Reserve Bank of New York. Holscher and Ignell are at the Federal Reserve Bank of New York. Lewis and Stiroh are at the Federal Reserve Board. We thank Ben Dennis, Chris Faint, Beverly Hirtle, Akos Horvath, Benjamin Kay, Missaka Warausawitharana and seminar participants at the Federal Reserve Board and the Federal Reserve Bank of New York for helpful comments on an earlier draft. All remaining deficiencies are our own.

I. Introduction

The financial risks of climate change are a topic of considerable focus for central banks and supervisory authorities focused on prudential risks and financial stability issues.² Prudential work to date has focused largely on supervisory issues and questions around the most appropriate risk management steps for supervised firms and supervisors. Supervisory guidance has been issued by several jurisdictions, including Bank of England (2019) and European Central Bank (ECB, 2020), principles have been issued by the Basel Committee on Banking Supervision (BCBS, 2022b), and draft frameworks have been proposed by the Office of the Comptroller of the Currency (2021) and Federal Deposit Insurance Corporation (2022).

A plausible hypothesis is that the physical and transition risks from climate change could change the distribution of potential losses that banks face. This raises a reasonable question: should the financial risks of climate change also be incorporated into the regulatory capital regime? Bank of England (2021b), the Basel Committee on Banking Supervision (BCBS, 2021d), the European Banking Authority (EBA, 2022b), and the European Commission (2021a, 2021b, 2021c) are all considering the potential implications of climate change for the regulatory framework including regulatory capital. IIF (2022) provides an overview of issues and challenges from the industry perspective.

This paper adds to this growing literature by presenting a stylized framework for assessing conceptually how the financial risks of climate change could be embedded into a regulatory capital regime. This is a stylized framework in the sense that we tried to capture the essential features of a regulatory capital regime, but we do not attempt to model or analyze the full complexity of the Basel framework (BCBS, 2022a) or the exact regime implemented in any particular jurisdiction. In addition, we don't explicitly consider interactions with other public policy tool as discussed by Lamperti et al. (2021). An obvious challenge from the regulatory perspective is to strike the right balance between including sufficient detail to develop policy-relevant conclusions, while maintaining sufficient simplicity for a tractable assessment.

We take an entirely positive approach that outlines a stylized framework to facilitate a systematic assessment of the potential linkages between climate change and regulatory capital, and do not take a normative position in terms of the appropriateness or efficacy of any particular policy. In addition, we examine these issues from a conceptual perspective and do not fully address empirical issues related to estimating climate-related impacts or the implications for calibrating changes to a capital regime. Rather, our approach is to highlight the conceptual links between specific assumptions and beliefs around how climate change could impact bank earnings, policy objectives, and the regulatory capital regime.

Our point of departure is that the primary purpose of capital is to absorb unexpected losses (BCBS (2005, 2010, 2022a), Federal Reserve (2022)). Within this context, we first consider key concepts and components of the regulatory capital regime such as expected and unexpected losses; regulatory ratios and risk-weighted assets; and minimum requirements and buffers. We then consider how climate

² See Network for Greening the Financial System (NGFS, 2021b) for a broad overview of supervisory issues and recent actions, Basel Committee on Banking Supervision (BCBS, 2021b, 2021c) for a discussion of the methodological challenges associated with identifying and measuring the financial risks of climate change, and Financial Stability Oversight Council (2021) and Financial Stability Board (2020) for a discussion of financial stability issues.

change could interact with and impact each component of this stylized regulatory capital regime to support a range of potential policy objectives in order to draw potential policy implications.

We conclude that understanding the potential implications of climate change for regulatory capital is a complicated exercise that requires clear views around both climate-related changes to the loss-generating process that drives potential losses for banks and the specific objectives of the different components of the capital regime. One needs to be precise about the nature of the loss-generating process and whether climate change creates expected or unexpected losses in order to draw internally consistent conclusions about the role of regulatory capital with respect to climate-related risks. For example, an increase in expected bank losses might be best addressed by forward-looking loan loss provisions and risk-based pricing, rather than capital. One also needs to be clear about which regulatory objective is being pursued in order to link the potential impact of climate change to the appropriate component of the capital framework. For example, climate change could have different implications for regulatory minimum or buffers depending on whether a safety and soundness or a financial stability objective is being pursued.

Consider the specific example where tipping points, financial sector amplifiers, and feedback effects amplify traditional cyclical forces and climate-related risk drivers so that the variance of potential losses for banks increase. Conceptually, this might suggest an increase in the required minimum capital ratio to maintain the same confidence level in terms of bank solvency. By contrast, if climate-related factors affect the relative riskiness of specific assets, it might be appropriate to consider the detailed mechanics of risk-weighting by asset class. As a third example, if one were concerned about how climate change could impact severity or duration of economic cycles, then it might be appropriate to reconsider the methods used to size the capital conservation or countercyclical capital buffers. By linking changes in the loss-generating process to specific policy objectives, one can better assess alternative policy options in an internally consistent manner.

We focus on the traditional role of capital as a loss-absorber and do not consider the use of the regulatory capital framework to promote other policy objectives. Some have discussed or are considering preferential treatment for sustainable activities or penalizing treatment for high-carbon activities in order to promote a transition to a low carbon economy.³ These seem to be distinct objectives compared to a traditional focus on bank resilience in the existing regulatory capital framework, and an important question for future work is how any potential incorporation of these broader policy objectives could impact the effectiveness of the traditional capital regime.

The remainder of the paper is organized as follows. Section II presents a simplified description of climate change and a stylized version of the capital framework. Section III considers how climate-related factors could impact the components of that framework, e.g., how the required minimum ratio is calibrated or how risk-weighted assets are calculated. Section IV discusses some of the key conceptual and practical issues associated with incorporating the financial risks of climate change into regulatory capital regime. Section V draws conclusions that may be relevant to policymakers considering potential changes to the regulatory capital regime.

³ See Center for American Progress (2021), I4CE (2021), European Banking Federation (2019), Hungarian Central Bank (2019, 2021), European Banking Authority (2022a), Lamperti et al. (2021), D’Orazio and Popoyan (2019), and People’s Bank of China (Gang, 2021).

II. Stylized Framework Linking Climate and Capital

This section begins with a brief description of climate change that is useful for developing the stylized framework around regulatory capital. We then introduce several foundational concepts such as the loss-generating process, defined as the combination of economic and financial factors that generate losses to a bank. These losses ultimately impact bank capital, which absorbs realized losses and allows a bank to continue to operate under a wide range of economic and financial outcomes. Note that we use the term “losses” broadly to refer to after-tax net income that is negative and thus depletes retained earnings and equity capital as in Kuritzkes and Schuermann (2008) and BCBS (2010). This broad interpretation of losses includes all factors that impact a bank’s profitability, e.g., credit losses, market losses, operational losses, and changes in bank revenue.

This stylized capital framework is not a complete representation of the international capital regime for internationally active banks outlined by the Basel framework (BCBS, 2022a) or in any particular jurisdiction. Rather, it is a stylized representation of the approach to risk-weighted capital that builds on the international framework to allow assessments of potential climate-related impacts in a coherent manner. We recognize that this approach does not capture all of the nuance and detail within the actual Basel capital framework, e.g., different definitions of capital such as common equity Tier 1 (CET1), Tier 1, or Total Capital requirements, risk-weighted vs. leverage ratio concepts, internal-ratings based vs. standardized approaches, conceptual differences between credit, market, and operational risks, or implementation differences across jurisdictions.⁴ Nonetheless, we believe this is a useful approach to simplify a complicated problem and to promote an orderly policy discussion.

a) Climate Change

Climate change reflects a complex set of relationships between physical events and human actions (Intergovernmental Panel on Climate Change, 2022). As a simplified, working definition for supervisory purposes, climate change refers to the long-term shifts in temperatures and weather patterns largely attributable to increased levels of atmospheric carbon dioxide produced by the burning of fossil fuels. These impacts can be both chronic (e.g., rising sea levels or higher mean temperatures) and acute (e.g., more frequent and more intense extreme weather events). Climate change depends on cumulative greenhouse gas emissions, which reflect a host of other factors such as the level and composition of global macroeconomic activity, climate policy choices such as carbon taxes or emissions trading systems, technological innovation, and consumer and investor preferences such as ESG investing trends or shifts to electric vehicles. Rudebusch (2019) provides a useful summary that describes these economic and financial impacts and linkages.

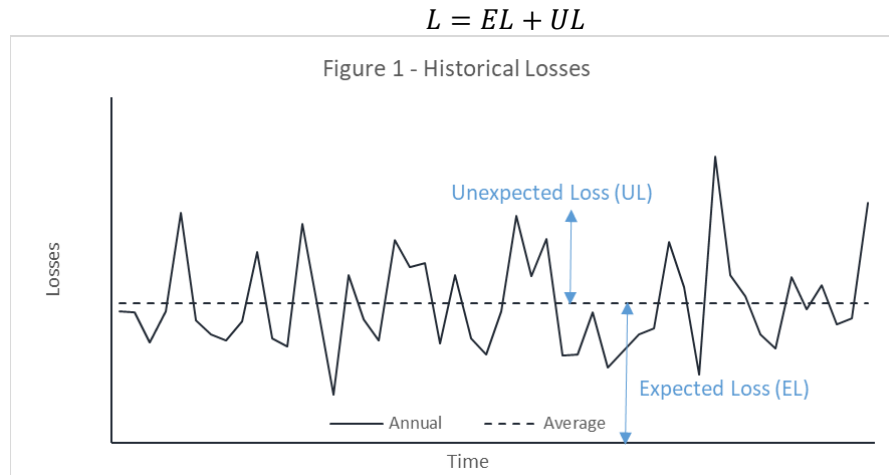
BCBS (2021b) follows a common supervisory approach that considers the impact of climate change in terms of physical risks and transition risks. Physical risks refer to the economic costs and financial losses resulting from acute events related to climate change, such as increasing severity and frequency of extreme weather events or chronic events like changes in precipitation, extreme weather variability, ocean acidification, rising sea levels, and rising temperatures. Transition risks refer to the risks related to the process of adjustment toward a low-carbon economy including climate policies, macroeconomic and sectoral outcomes, innovation, and changes to investor or consumer sentiment. Both are relevant for an assessment of potential losses and bank capital. Note that physical risks and

⁴ Greenwood et al. (2017) discuss the benefits a simple capital regime with a single requirement as a way to minimize distorting incentives.

transition risks are not independent and may interact in complex ways, e.g., stringent policy to raise the price of carbon may lead to lower physical risks over time, but increase transition risks in the short-term (NGFS, 2021a).

b) Loss-Generating Process

Bank losses vary over time depending on a number of factors related to macroeconomic factors, such as the business cycle or structure of interest rates, and to the idiosyncratic features of a bank's loan and securities portfolio or its business strategy. Figure 1 illustrates an indicative time series of losses where losses (L) in any year are either expected losses (EL) or unexpected losses (UL):



where total losses are the solid line, EL is the dashed line defined by the period average, and UL is the difference between realized losses and average losses. This could be a historical time series, for example.

We refer to the forces that impact bank losses as the “loss-generating process,” but we have a wider interpretation than credit losses on loans or mark-to-market losses on securities. One can think about this as net income, after taxes and distributions, so it is essentially retained earnings that add to or depletes bank capital. As such, it includes both income and expenses on the income statement on an enterprise-wide basis and would likely vary across the business cycle and due to structural changes in the economy.

c) Purpose of Capital

The purpose of bank capital is to absorb unexpected losses and allow a bank to continue to operate. For example, from a regulatory perspective, BCBS (2010, p1) states: “the regulatory minimum requirement is the amount of capital needed for a bank to be regarded as a viable going concern by creditors and counterparties” and the Federal Reserve Board (2022) states: “The primary function of capital is to support the bank's operations, act as a cushion to absorb unanticipated losses and declines in asset values that could otherwise cause a bank to fail, and provide protection to uninsured depositors and debt holders in the event of liquidation.” Greenwood et al. (2017) present a model of the purpose of equity capital and identify attributes of an effective, post-crisis capital regime, while Kress (2021) describes the history of regulatory capital from a legal perspective.

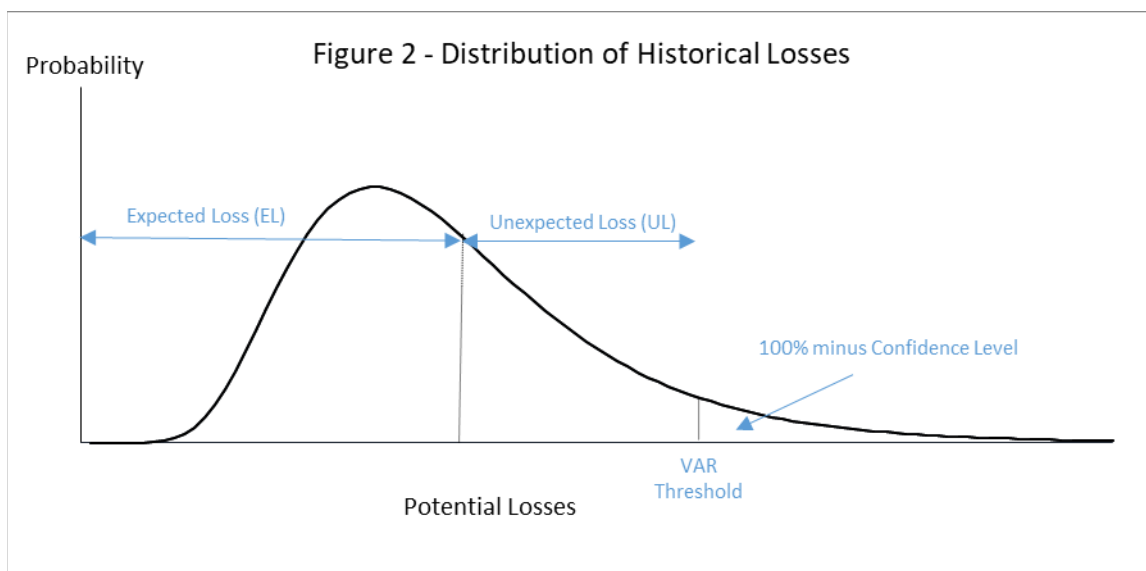
Heuristically, bank solvency and viability are determined by the composition of a bank balance sheet and variation income and losses relative to loss-absorbing capital. A bank remains solvent when

assets are greater than liabilities, which will occur when capital exceeds bank losses in a given year. A bank becomes insolvent when losses exceed capital and a bank cannot meet its debt obligations. As emphasized in BCBS (2010), minimum capital requirements are set at the level where creditors and counterparties view the bank as a viable going concern and will continue to do business with the bank even during periods of uncertainty. In general, regulators care about probability of bank failure because bank failures impose costs on society, e.g., fire-sales, credit crunches, excess risk-taking due to implicit guarantees.

A foundational point is that banks and regulators treat expected losses and unexpected losses differently (BCBS (2005, 2022a)). Expected losses are a normal cost of business that can be covered ex ante by appropriate risk-based pricing and through provisioning to build up reserves for expected credit losses. In the U.S., for example, loan provisions generally incorporate a forward-looking perspective that covers expected credit losses over the life of the assets.⁵ Market pricing, however, won't cover all unexpected losses due to information asymmetries that lead to well-known problems such as adverse selection. As a result, capital covers unexpected losses with a desired degree of confidence.

Consider the standard value-at-risk (VAR) framework, although other frameworks such as expected shortfall have the same implications (BCBS (2015, 2022a)). In this approach, capital levels are determined so that a bank remains solvent with a pre-specified, high-confidence level over a one-year horizon. Conversely, the bank is expected to become insolvent with a low probability over the one-year horizon in states of the world where losses are sufficiently high.

Figure 2 shows the frequency distribution of the losses depicted in the time series in Figure 1. Note that the indicative losses in Figure 1 and Figure 2 are represented as a skewed distribution with the potential for low-frequency, high-severity events, but other distributions are possible.



⁵ See, for example, Financial Accounting Standards Board (2016). Loudis et al. (2021) describe the impact of a more forward-looking approach to loan loss provisioning (the Current Expect Credit Loss (CECL) approach) that includes estimates of lifetime losses on bank capital

The Value-at-Risk (VAR) Threshold is the level of potential losses associated with a given Confidence Level, e.g., 99.9% confidence level.⁶ Potential losses will be at or below the VAR Threshold with a probability equal to the chosen Confidence Level and potential losses will exceed the VAR Threshold with a probability of 100% minus Confidence Level. Desired capital is then defined as the difference between the VAR Threshold and expected losses in order to cover the chosen part of the loss distribution.

$$K = VAR\ Threshold - EL$$

In this VAR construct, unexpected losses are projected to be below capital and the bank to remain solvent with a probability equal to the Confidence Level. Unexpected losses are projected to be above capital and the bank to consequently become insolvent with a probability equal to 100% minus that Confidence Level.

d) Components of Capital

BCBS (2010, 2022a) define regulatory capital as consisting of two distinct components – minimums and buffers. We focus here on the regulatory components associated with a Pillar 1 approach and discuss Pillar 2 aspects in the following section. Generally speaking, minimum capital requirements refer to the capital necessary to cover unexpected losses with a pre-specified level of confidence as above so a bank remains viable, while buffers are additional capital that is built up outside of periods of stress and that can be drawn down as losses are incurred to ensure firms remain above the regulatory minimum or to support other regulatory objectives. The three most prominent forms of buffer capital requirements are:

- *Capital Conservation Buffer*: designed to ensure banks build up capital outside periods of stress to avoid breaching capital requirements throughout a significant sector-wide downturn (BCBS (2022a, p151)). In the U.S., the capital conservation buffer has been updated with the “stress capital buffer” methodology (Federal Reserve Board (2020a), Federal Reserve Board Staff (2020)).
- *Countercyclical Capital Buffer*: designed to ensure banking sector capital requirements reflect the macro-financial environment in which banks operate (BCBS (2022a, p155)). The U.S. has developed and implemented, but never triggered, the countercyclical capital buffer (Federal Reserve Board (2016, 2020b)).
- *Global Systemically Important Bank (GSIB) Buffer*: designed to increase resilience as a going concern to offset the greater impact that the distress or failure would have (BCBS (2013, 2022a, pp 170-172)). The GSIB approach has been implemented in the U.S. (Federal Reserve Board, (2015a, 2015b, 2021a)).

One can define required capital as the sum of the minimum plus all relevant buffers:

$$Capital = Minimum + Conservation\ Buffer + CounterCyclical\ Buffer + GSIB\ Buffer$$

⁶ As discussed above, market pricing would not support capital covering all potential unexpected losses. BCBS (2005), for example, acknowledges that the probability of losing the entire credit portfolio is highly unlikely and that holding capital against such a likelihood (i.e., VAR Threshold at 100%) would be economically inefficient.

The level of required capital can be rewritten as a combination of ratios determined by regulators and estimates of risk-weighted assets (RWA):

$$K = r * RWA + c * RWA + y * RWA + g * RWA$$

$$K = (r + c + y + g) * RWA$$

where K is the dollar value of capital, r is the minimum regulatory capital ratio, c is the capital conservation buffer ratio, y is countercyclical capital buffer ratio, and g is the GSIB surcharge ratio.

This representation in terms of relevant ratios and RWA provide a tractable approach to systematically assess how the financial risks of climate change might interact with the regulatory capital framework. Before turning to that description, it is useful to provide some additional detail on the calibration and derivation of each component as that will allow a more precise assessment of the link with the financial risks of climate change.

The minimum ratio, r , was calibrated by the BCBS based on a VAR-like framework using the historical distribution of annual net income in seven countries from a historical sample period ranging from 5 to 29 years following the financial crisis (BCBS, 2010). This approach leveraged the “return on risk-weighted assets” (RORWA) work of Kuritzkes and Schuermann (2008). The analysis focused on the tail (i.e., negative net income) of the distribution, specifically the 99th percentile. As above, the basic intuition is that the minimum capital requirement corresponds to a judgment about how far into the tail of the distribution of potential losses creditors and counterparties reasonably expect banks to self-insure with a certain level of confidence in order to remain a viable going concern.⁷ In general, the minimum requirement applies equally to all banks.

The capital conservation buffer ratio, c , was calibrated based on losses observed during historical stress periods, supplemented with results from supervisory stress tests performed in the aftermath of the 2008-2009 financial crisis, using the same RORWA approach as in BCBS (2010) and applicable to all banks. The U.S. stress capital buffer (SCB) regime extends the capital conservation concept by expressly linking the buffer calibration to the Federal Reserve’s annual supervisory stress test (Federal Reserve Board (2020a)). The SCB approach essentially created a forward-looking, bank-specific version of the capital conservation buffer that reflects bank-specific risks, while retaining the international buffer calibration as a floor.

The countercyclical capital buffer ratio, y , can be used to increase resilience of the banking sector when there appears to be build-up of system-wide risks (BCBS (2022a)), e.g., the ratio increases when aggregate risks are deemed to be elevated. The ratio is calibrated and implemented differently across jurisdictions. The countercyclical capital buffer is often viewed as a macroprudential tool because it increases overall resilience when risks are high and would be available to absorb losses when conditions deteriorate (Federal Reserve Board (2016)). The countercyclical capital buffer generally

⁷ The top-down approach in BCBS (2010) does not make a clear distinction between expected and unexpected. Rather, it focuses on the historical volatility of *realized* net income as a measure of potential capital needs, noting that the 99th percentile of the left tail (negative net income) is a reasonable proxy for the degree of shock market participants would expect banks to withstand. This figure is after provisions, so it would include the “expected loss” portion via net income in terms of credit risk. This measure also excludes *unrealized* losses in the mark-to-market available-for-sale portfolio, however, which directly lower capital but avoids retained earnings.

applies to a sub-set of large banks. Note that the Federal Reserve has not triggered the countercyclical capital buffer.

The GSIB buffer ratio, g , determines the additional capital requirements for systemically important banks due to the negative impact their distress or failure poses for the broader financial system. g is determined through a two-step process: (1) the measurement of a bank's systemic impact through an indicator-based approach and (2) the corresponding assignment of a higher loss absorbency (HLA) capital buffer requirement (BCBS, 2021f). Indicators reflecting cross-jurisdictional activity, size, interconnectedness, substitutability, and complexity were chosen to "reflect the different aspects of what generates negative externalities and makes a bank critical for the stability of the financial system (BCBS (2013), p5)." Based on the "expected impact" approach, the HLA requirement is calibrated so that a GSIB's probability of default (PD) is sufficiently reduced to offset the higher systemwide externalities in the event of default or distress.

Risk-weighted assets, RWA, are the final piece, and the most complex that form the foundation of the entire regulatory capital regime. Generally speaking, RWA are "intended to capture differences in risk across institutions (BCBS, 2010, p2)." The calculation of RWA is determined by a complicated set of approaches that differ across credit risk, market risk, and operational risk with additional details associated with different approaches within each risk category; BCBS (2022a) includes over 400 pages of documentation for credit risk alone. The basic idea, however, is straightforward: assets with higher risk receive a higher risk weighting so that capital increases with risk. In the context of incorporating climate-related risks into the RWA framework, we consider two specific challenges: heterogeneity and complexity across assets classes and the automatic response of some key risk indicators.

1. Heterogeneity and Complexity across Asset Classes

RWA measurement approaches vary considerably across asset classes so it is difficult to identify generally how climate-related impacts could impact the RWA methodology. Table 1 illustrates this variation across the exposure types and approaches in terms of risk measures (the metrics used to measure risk) and loss functions (the methodology used to translate into unexpected or stressed losses). This table is not exhaustive and is meant to provide an illustration in the variation with the Basel framework.

Table 1: Select Pillar 1 Risk Measures and Loss Functions

Approach	Exposure Type (non-exhaustive)	Indicative Risk Measures	Loss Functions for Stress or Unexpected Losses
Credit – Standardized	Corporate (banks, covered bonds, project finance, etc.)	External ratings	Defined in Regulation
	Real estate	LTV; underwriting	
	Other	Credit type, purpose, subordination, credit risk mitigation, etc.	
Credit - IRB	Corporate, sovereign, etc.,	PD, LGD, EAD, M	Defined in Regulation
Market - Standardized	Sensitivities based method	Price sensitivities by exposure type, maturity, etc.	Defined in Regulation
	Default risk charge	External ratings by issuer type (corporate, sovereign, etc.)	
	Residual risk add-on	Notional exposure	
Market – IMA	Modellable risk factors	Price sensitivities by exposure type, maturity, etc.*	Updated based on empirical observation*
	Non-modellable risk factors	Stress scenarios*	
	Default risk charge	PD, LGD, market correlations, etc.	Defined in Regulation
Operational	Operational Risk	Business Indicators	Defined in Regulation

*Unexpected loss measures are updated by banks with supervisory approval if realized losses exceed historical observations at a specified confidence level. Variables highlighted in red are more forward-looking indicators.

Each of these approaches then includes considerable complexity in terms of actual implementation. There are both quantitative elements (loan-to-value (LTV) ratios) and qualitative ones (underwriting assessments). As one specific example, BCBS (2019b) describes how RWA are estimated under the internal ratings-based (IRB) approach for corporate, sovereign and bank exposures via a VAR-like approach. Calibration is determined by asset-specific characteristics such as probability of default (PD), loss given default (LGD), risk-rating and maturity, and modeling assumptions such as correlation of returns (R):

$$\text{Correlation} = R = 0.12 \cdot \frac{(1 - e^{-50 \cdot PD})}{(1 - e^{-50})} + 0.24 \cdot \left[1 - \frac{(1 - e^{-50 \cdot PD})}{(1 - e^{-50})} \right]$$

$$\text{Maturity adjustment} = b = [0.11852 - 0.05478 \cdot \ln(PD)]^2$$

$$\text{Capital requirement} = K = \left[LGD \cdot N \left[\frac{G(PD)}{\sqrt{1-R}} + \sqrt{\frac{R}{1-R}} \cdot G(0.999) \right] - PD \cdot LGD \right] \cdot \frac{(1 + (M - 2.5) \cdot b)}{(1 - 1.5 \cdot b)}$$

$$RWA = K \cdot 12.5 \cdot EAD$$

2. Automatic Responses

Effective capital regimes should adapt dynamically to change in risks and some risk measures that determine RWA should naturally capture climate risks over time, e.g., market prices, credit ratings and bank internal risk estimates are all forward-looking measures to some extent and will all incorporate

at least some information about potential climate-related risks. The variables indicated in red in Table 1 are those most likely to naturally incorporate climate-related risks.

As a specific example, credit risk for real estate in the RWA framework depends primarily on underwriting standards and loan-to-value (LTV) ratios. To the extent that climate change affects the market values of specific properties in particular regions, this type of metric could adjust to incorporate climate-related risks.⁸ EBA (2022b), for example, points out that external credit assessments will likely integrate environmental risks over time and environmental risks may already be indirectly embedded in through forward-looking collateral values. As a counter example, Kress (2022) describes the implications of the U.S. regulatory capital system where regulators cannot rely on external credit ratings, which are one potentially dynamic risk measure.

It is difficult to know precisely, however, the extent to which climate-related risks are captured in RWA risk measures and the effectiveness of automatic adjustments is likely to vary across approaches. NGFS (2022), for example, suggests that risk differentials between green and brown assets (e.g., higher transition risk for “environmentally harmful” assets) could justify adjustment factors in the Pillar 1 capital requirement based on the greenness of the asset, although they do not report strong empirical evidence of a risk differential and conclude that Pillar 1 capital treatment would be a challenge at this point. Further, the calculations that translate risk measures into RWA based on historical stress or unexpected losses are largely static and based on a limited number of historical events. Future loss events in the presence of climate change could be more severe in their magnitude, duration, or distribution than currently assumed in RWA calculations. Scenario analysis could be a useful tool to help identify and estimate the differential impact of climate change across assets.

e) Pillar 2 Capital Requirements

The capital framework described above presents the capital requirements that apply equivalently across jurisdictions under the BCBS Pillar 1 regulatory framework. Beyond these requirements, banks are expected to develop their own internal capital adequacy processes that establish idiosyncratic capital levels above the regulatory minimum that are commensurate with their risk profile and control environment (BCBS, 2019a). This expectation is codified in the BCBS’ Pillar 2 approach, which places ultimate responsibility for ensuring adequate capital with bank management while supervisors review and evaluate banks’ assessment of capital needs relative to their risk. The Pillar 2 approach is principles-based, intended to be flexible and tailored to individual jurisdictions. Member jurisdictions have adopted heterogeneous approaches that differ according to each jurisdiction’s supervisory norms and practices, local banking environment, or supervised banks’ commercial and risk profiles. While differing in form, supervisory approaches are directionally similar.

Some have considered the incorporation of climate-related risk into Pillar 2 approaches (European Banking Federation (2017), D’Orazio and Popoyan (2019), and Bank of England (2021b)).⁹

⁸ Giglio et al. (2021) reviewed the empirical literature on the pricing of climate risks across asset classes including equities, fixed income, and real estate. Evidence is mixed that U.S. residential real estate valuations price higher perceived natural disaster risks in the aftermath of peril events (Bin and Polasky (2004), Donadelli, et. al. (2020), Hallstrom and Smith (2005), Kiel and Matheson (2018), Ortega and Taspinar (2018)) or for properties in higher risk-identified zones (Beltrán, et. al. (2018), Daniel, et. al (2009)).

⁹ FSB (2022) mentions the possibility of a “capital add-on” related to climate change, but it is not explicit if that is part of a Pillar 2 process.

One advantage of the Pillar 2 approach might be better targeting of heterogeneity in climate-related risk drivers on loss volatility within jurisdictional boundaries. For example, the spatial distribution of physical risks may render difficult a common classification of at-risk exposures across jurisdictions; in this sense, a Pillar 2 approach may enable greater targeting of material exposure at individual bank risk profiles to specific physical hazards. Conversely, if unexpected losses resulting from climate-related risk drivers are determined to be systemic and global in nature, a pure Pillar 2 approach may fail to internationally harmonize risk management approaches and create competitive implications. IIF (2022) argues that any Pillar 2 treatment could potentially lead to fragmentation across jurisdictions or hamper transition finance, and concludes that clarity and transparency are critical.

f) Other Users of Regulatory Capital

The discussion so far has focused on the traditional role of capital as a loss-absorber and has not considered the use of the regulatory capital framework to promote other policy objectives. European Banking Federation (2017), D’Orazio and Popoyan (2019), Thoma and Gibhart (2019), Center for American Progress (2021), I4CE (2021), IIF (2021), and Lamperti et al. (2021), for example, have discussed the use of risk weights to incentivize financial institutions to promote a transition to a low carbon economy. These proposals suggest incentivizing green investments and loans by lowering regulatory capital requirements for certain climate-friendly investments, known as “green-supporting factors,” or raising regulatory capital requirements for high carbon assets, known as “brown-penalizing factors.” The basic idea is that changes to risk weights could impact the marginal cost of financing for different activities and provide incentives to support the transition toward a low-carbon economy.

More specifically, European Banking Federation (2107) suggest lowering risk weights for green assets, after an empirical analysis, to incentivize financing. Thoma and Gibhardt (2019) conclude that brown-penalizing factors would be more effective than green-supporting factors due to the larger base of brown assets. Lamperti et al. (2021) consider a “green Basel II policy scheme” that excludes loans to green firms from banks’ capital as a way to relax the credit constraints on those firms. D’Orazio and Popoyan (2019) argue for a “markdown” on green loan risk weights in order to incentive the financing of low-carbon activities. By contrast, Bank of England (2021b) argues that the capital regime is an appropriate tool to deal with the consequences of climate change, but not the underlying causes of climate change.

A small number of central banks and supervisory authorities have implemented, or are considering implementing, preferential treatment for investments designated as “green.” The Hungarian Central Bank (2019, 2021) introduced preferential capital treatment for certain “green” assets, including corporate and municipal financing and housing loans, as part of a broader Green Program. In particular, the Hungarian Central Bank (2019) plans to “support the growth of green financial products” and ensure the financial system makes “significantly greater contributions to ecologically sustainable convergence and to the reduction of risks arising from climate change.”

The European Parliament and European Commission have mandated the European Banking Authority to assess whether a dedicated prudential treatment of exposures related to assets or activities associated substantially with environmental and/or social objectives would be justified. This directive, codified in EBA (2022a), instructs the EBA to assess “the potential effects of a dedicated prudential treatment of exposures related to assets and activities which are associated substantially with environmental and/or social objectives on financial stability and bank lending in the Union.” EBA

(2022b) concludes that “prudential regulations should reflect the risk profiles of exposures and should not be used for other policy purposes (p10).” In addition, EBA (2022b) outlines pros and cons of these types of adjustment factors from a prudential and public policy perspective.

Yi Gang, head of the People’s Bank of China (PBOC), reported that the PBOC is working to assess green assets and green products of commercial banks, and may consider risk weights associated with the green level of assets (Gang (2021)).

The case for green-supporting factors or brown-penalizing factors in this manner seems to rest on supervisors pursuing a broader set of objectives than the safety and soundness of individual firms. Stiroh (2022) discusses these issues through the lens of an ongoing discussion of “single materiality” vs. “double materiality” and the different mandates across supervisory authorities. In the U.S., for example, Federal Reserve (2021) states that the Federal Reserve works through its existing mandates and authorities to address the implications of climate change, particularly through the regulation and supervision of financial institutions and the stability of the broader financial system. The primary responsibility for addressing climate change itself rests with elected officials. By contrast, both the European Central Bank (European Union (2007)) and the Bank of England (Bank of England (1998), HM Treasury (2021)) have secondary mandates to support broader government objectives, which include ones related to sustainability. In cases where supervisory authorities have a broader mandate to support government policy or sustainability objectives, green-supporting factors and brown-penalizing factors that deviate from the specific risk implications for a given bank may be easier to justify conceptually. Note, however, that both Bank of England (2021) and EBA (2022) argue that the capital framework should remain focused on risks rather than be used for other objectives. Similarly, IIF (2022) argues against broader use of the capital framework.

An important question for future work is how incorporation of these broader policy objectives could impact the effectiveness of the traditional capital regime. The use of bank capital requirements to facilitate the flow of financial activities to specific non-risk objectives could sever the fundamental link between regulatory capital requirements and bank risk, reduce risk-related transparency for investors, and raises important questions about the legal mandate of supervisory authorities. For example, European Banking Federation (2017) cautions that capital levels should be maintained at sufficient levels to cope with the materialization of risks and Lamperti et al. (2021) warn that as a “green Basel II” approach allows greater financing to green firms, it also possibly increases the solvency risk of banks and the likelihood of banking crises. EBA (2022b) cautions that prudential treatment designed to redirect lending could have several unintended consequences, e.g., undermine credibility of prudential tools, lead to build up of financial risk in “green activities”, or impede the financing of transition activities. IIF (2021, 2022) argue that the capital framework should focus on resilience and system-wide alignment, but should not use prudential tools to steer the economy to a low-carbon footprint.

Moreover, there are important practical issues associated with developing a robust framework for assessing “green” vs. “brown” assets.¹⁰ We do not assess these issues directly, but highlight the importance of developing a sound theoretical foundation for evaluating these issues and potential trade-offs or synergies between the objectives.

¹⁰ NGFS (2020, 2022) explore whether measured risk differentials exist between green and non-green assets and reports inconclusive results due to methodological and data challenges.

III. Impact of Climate Change on the Regulatory Capital Regime

This section considers how climate change could impact the loss-generating process and the specific components of the capital framework. We begin with the assumption that capital is for unexpected losses and a working hypothesis that the physical and transition risks associated with climate change could change the distribution of potential losses that a bank faces.

This hypothesis is supported by a range of academic studies and policy papers. IPCC (2022) describes multiple impacts of climate change and Rudebusch (2019) describes the potential economic and financial linkages with climate change. Organization for Economic Cooperation and Development (OECD, 2021) draws on a wide range of expertise to highlight how the risk of future losses and damages will increase with climate change, focusing on three hazards: slow onset changes, extreme weather events and the potential for large scale non-linear changes within the climate system itself. Pindyck (2021) describes the fundamental uncertainties that link emissions to climate change (“climate sensitivity”) and that link climate change to economic impacts. Kiley (2021) reports evidence that rising temperatures will have substantially larger effects on downside risks to economic growth than on the central tendency of growth outcomes.

From a financial impact perspective, BCBS (2021b) describes climate risk drivers, transmission channels, and sources of variability that suggest the distribution of potential losses in the future might look different than the past due to a combination of new underlying shocks (e.g., change in the frequency or severity of severe weather events) or complex interaction of amplifiers and mitigants (e.g., the endogenous response of insurance that shifts who ultimately bears losses). FSB (2020) discusses how the financial system could amplify the effects of climate-related risks through, for example, feedback loops within the financial system or between the financial system and the real economy. Bolton et al. (2020) document both the high degree of uncertainty and nonlinearity associated with both physical and transition risks, and the distributional consequences of climate change between and within countries that could result a shift in the distribution of losses that banks face in the future. Miller and Dickau (2022) describe these potential links and the practical measurement challenges. As described next, it is critical to understand how economic and financial change impact the distribution of potential bank losses in order to determine the appropriate policy options.

In terms of the specific link between climate change and the capital framework, D’Orazio and Popoyan (2019) provide an overview of the three pillars of the Basel framework – Pillar 1 on regulation, Pillar 2 on supervision, and Pillar 3 on disclosure – and ways that the overall framework could include climate-related financial risks. Miller and Dickau (2022) explore the use of the large exposure regime as a complement to risk-based capital policies in a Pillar 1 context. Bank of England (2021b) discusses how potential climate-related gaps might manifest differently across the three pillars. EBA (2022b) provides a detailed assessment of the potential links across major risk stripes such as credit, market, and operational risk for different implementation approaches.

a) Changes in the Loss-Generating Process

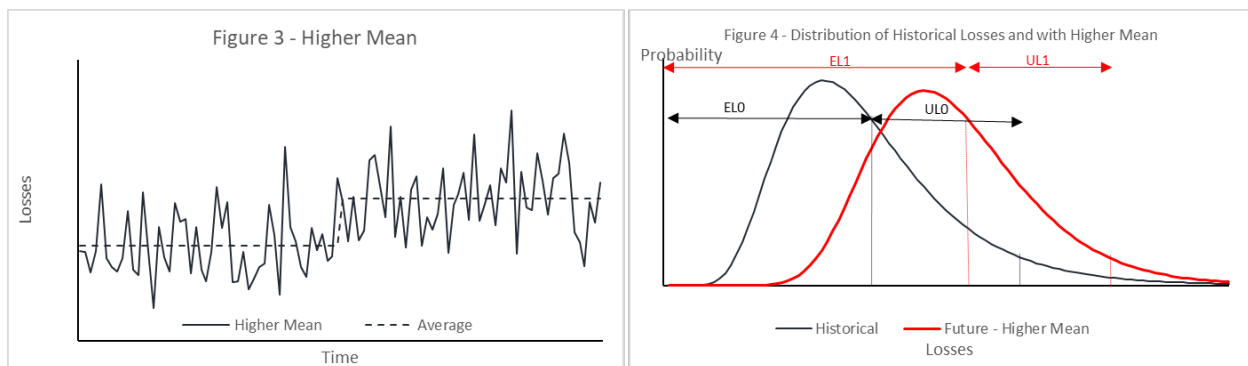
We begin with the VAR framework described above that shows the critical importance of precisely specifying the distribution of potential losses in order to draw the appropriate conclusions related to bank capital. To illustrate this point, we consider the ways that losses could change due to climate – higher mean losses, higher variance of losses, and higher mean and higher variance of losses. These changes in the log-generating process would reflect all climate-related impacts including the

direct impact of physical risks and transitions risks, and any indirect impact related to financial sector amplifiers and mitigants or the endogenous response of economic activity or policy changes. In all cases, for simplicity, we assume the distribution of losses shifts abruptly without transition and with certainty and perfect foresight. A useful extension would be to consider cases where the change in the distribution of losses occurs gradually and with uncertainty. This distinction between greater variance and uncertainty about changes in underlying distribution is critical, and we discuss later.

Understanding which of these is the most appropriate description of the impact of climate change is a difficult exercise, and it is ultimately an empirical one that will be revealed as we observe the impact. Nonetheless, we think this is a useful exercise to illustrate the need to have consistency between one's assumptions and beliefs about the impact of climate change and policy implications.

1. Case 1 – Higher Mean

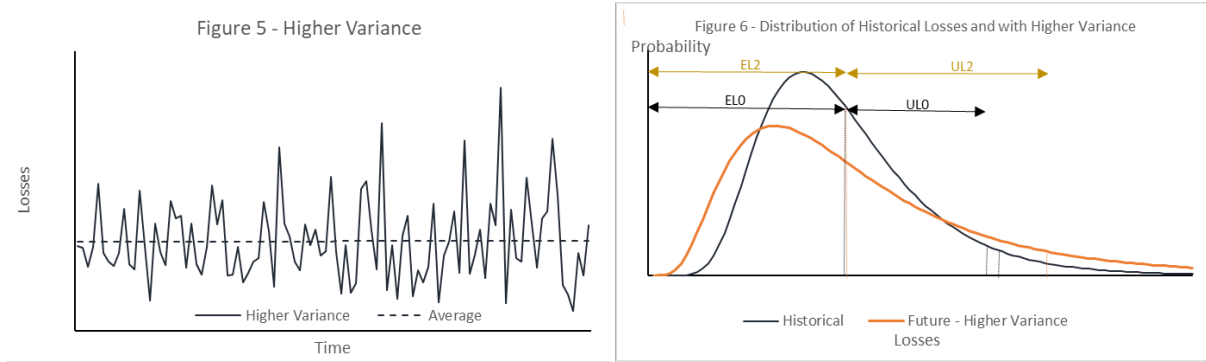
Climate change could increase average losses as physical and transition risks are realized. If these losses were independent of cyclical factors and predictable, this would effectively shift the distribution of future losses to the right as in Figure 3 and 4, where historical losses from the old distribution are shown from periods 1 through 50 and future losses from the new climate-impacted distribution are in periods 51 through 100.



In this case, expected losses increase, $EL0 < EL1$, while the variance of losses stays the same, $ULO = UL1$. In a banking context, this suggests that loan loss provisions and risk-based pricing would increase to cover the higher expected losses, but required capital would remain unchanged because unexpected losses have not changed.

2. Case 2 – Higher Variance

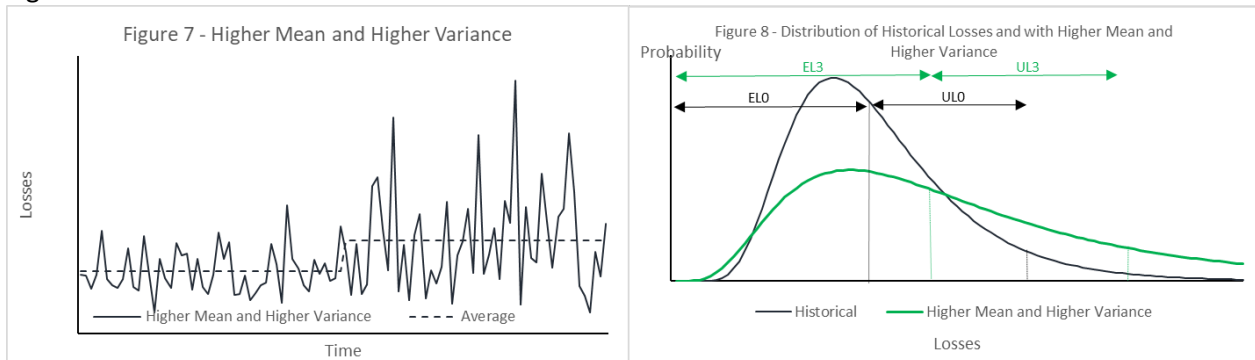
Climate change could increase the variance in losses without changing average losses, e.g., a change in the distribution of severe weather events that brings more volatility in terms of frequency and severity of economic impacts. Figures 5 and 6 illustrate the case where the mean is unchanged, but the variance of losses increase.



In this case, expected losses remain the same, $ELO = EL2$, but the variance of losses has increased, $UL2 > UL0$. In a banking context, reserves remain constant because expected losses are unchanged, but capital increases to reflect greater potential for higher unexpected losses. Given the increased potential for extreme unexpected losses, required capital must be higher to maintain the same confidence level around solvency.

3. Case 3 – Higher Mean and Higher Variance

Climate change could increase both the mean and the variance of bank losses. This could happen, for example, if losses related to the business cycle continue to be driven by the same underlying shocks and climate-related forces then bring additional losses as physical or transition risks are realized. Figures 7 and 8 illustrate the case where both the mean and the variance increase.



In this case, expected losses increase, $EL3 > ELO$, and the variance of losses has increased, $UL3 > UL0$. In a banking context, banks increase loan loss provisions to cover higher expected losses and required capital increases to cover heightened risk and the potential for greater unexpected losses.

It is useful to be more precise about what type of loss-generating process might generate this outcome. The simplest case is one where historical cycle losses are determined by business cycle or idiosyncratic factors as a random variable X , with a mean and variance illustrated in Figures 1 and 2. If climate-related losses reflect a new random variable, Y , with its own mean and variance, then expected losses in the future are determined as:

$$Expected\ Losses = E(X) + E(Y)$$

$$Variance\ of\ Losses = V(X) + V(Y) + 2\ cov(X, Y)$$

This simple example shows the importance of the correlation assumption between historical business cycle or idiosyncratic losses and climate-related losses, so the variance of total losses could theoretically increase or decrease. As a working hypothesis, it seems reasonable to assume that climate-related losses would be linked to business cycle and idiosyncratic losses, so the variance would increase. This could reflect the types of amplifiers described in BCBS (2021b), which could include interactions between different climate risk drivers (e.g., a physical shock and a carbon tax), the interaction between physical and transition risks (e.g., a series of severe weather events induces the relocation of economic activity), correlated physical shocks (e.g., the cumulative impact of severe weather events), financial feedback loops (e.g., changes in the pricing or availability of insurance), or self-reinforcing reductions in credit (e.g., lending falls in areas where physical shocks are realized).

This is analogous to the correlation assumption embedded in the Basel IRB approach for determining the risk-weighted asset for credit exposures (BCBS (2005, 2019b)). The intuition is that introducing additional risk can either have a diversifying impact or amplifying impact, depending on the correlation between the risk drivers.

4. Discussion

These illustrative examples show the critical importance of describing the loss-generating process when developing the conceptual link between climate change and bank capital. Following the fundamental theory of bank capital as a tool to absorb unexpected losses, climate change would need to impact unexpected losses through a higher variance in order to suggest a regulatory capital solution.

The obvious question is which of the three potential cases seems most appropriate for policy considerations given the distinctive characteristics of climate change including massive uncertainty about climate change and its economic impact, amplifiers and mitigants, non-linear relationships, and feedback effects described in BCBS (2021b, 2021c). These features are conceptually consistent with the idea that the variance of potential losses has increased, rather than just an increase in the mean. Similarly, Kiley (2021) concludes that climate change may make economic contractions more likely and more severe. It is ultimately an empirical question, however, and this paper doesn't take a stand on which is likely to be the most realistic description of potential bank losses in response to climate change. That is a critical area for further research and effective policy design.

A fundamental challenge, of course, is that we won't know with certainty in real-time how the loss-generating process that banks face will change, if at all. These illustrative examples were presented as one-time changes, but gradual shifts are much more likely as the impact of climate change grows and economies and financial markets adapt. Forward-looking scenario analysis such that performed by the European Central Bank (ECB, 2021), Autorite de Controle Prudentiel et de Resolution / Banque de France (ACPR, 2020), the Bank of Canada and Office of the Superintendent of Financial Institutions (2022), and the Bank of England (2021a, 2022) seems likely to be a valuable tool to better understand how the distribution of potential losses might shift and to distinguish expected from unexpected losses. Finally, even with a robust program of scenario analysis, policymakers will still need to make decisions without perfect information about these shifts, which raises important issues around robust policy design.

b) Changes in Capital Components

The next step is to consider how the financial risks of climate change could be captured in each specific component of the capital framework. Recall the simplified capital expression is:

$$K = (r + c + y + g) * RWA$$

where K is the required dollars of capital, r is the minimum capital ratio, c is the capital conservation buffer, y is the countercyclical capital buffer, g is the GSIB buffer ratio, and RWA is risk-weighted assets.

This framing raises a number of conceptual questions: should any climate-related impact be captured by increasing a required ratio or adjusting RWA ? By changing the minimum requirement or a buffer requirement? If a buffer requirement, which one? As stated in the prior section, these types of questions are most relevant in a world in which climate change increases the variance in the loss-generating process, which leads to higher unexpected losses. A final question is whether any desired changes would require a permanent policy change, a temporary policy change, or whether appropriate changes would be incorporated automatically as losses are realized and as firms update their capital-related parameters?

We consider the potential link between climate change these components in turn. Table 2 provides a summary of the key components and the assumptions required to link each to climate change. The remainder of the section discusses each in greater detail.

Table 2: Components of Capital Regime and Potential Link to Climate Change

	Policy Objective	Assumptions Needed for a Climate-Related Impact
Minimum	Ensures firm remains viable, with certain level of confidence	Increased unexpected losses for the bank as a whole
Capital Conservation Buffer	Cover stress losses to reduce probability that firm breaches the minimum	Increased stress losses for the bank as a whole
Countercyclical Capital Buffer	Protect against cyclical changes when risks are elevated	Changes in cyclical properties of bank losses
GSIB Buffer	Lower the probability of default (PD) to offset higher loss given default (LGD) for systemically important firms	Higher LGD of distress or failure of a GSIB
Risk-Weighted Assets	Reflect relative risk across asset classes	Changes in relative riskiness of specific assets

1. Minimum Ratio

The minimum ratio, r , reflects the required capital to cover unexpected losses with a certain level of confidence. If the entire distribution widens due to greater variance in future losses, as in Cases 2 and 3 above, one implication is to increase the required ratio. That is, more capital is needed to cover unexpected losses with the same level of confidence. The required minimum ratio effectively set the floor on capital for all banks, so this interpretation seems most consistent with a structural and permanent shift in the loss-generating process that impacts all asset classes and all banks.

While conceptually straightforward, implementation would require considerable empirical work to calibrate the impact. Basel (2010, p4) describes some of these calibration challenges, e.g., the historical loss data used to calibrate the minimum reflect outcomes under a different regulatory capital regime and the macroeconomic environment and bank behavior will likely be different in the future.

2. Capital Conservation Buffer

The capital conservation buffer ratio, c , reflects the amount of capital so that banks don't breach their minimum requirements with a certain degree of confidence. This is fundamentally linked to the idea of stressed losses, so calibration depends critically on the specification of potential stress losses. The Basel capital conservation buffer, for example, is calibrated on observations during historical stress periods and select stress testing outputs following the 2008-2009 financial crisis (BCBS (2010)), while the U.S. stress capital buffer is estimated on a forward-looking basis over a 13-quarter period (nine-quarter stress plus four-quarter loss provisions), subject to the Basel capital conservation buffer as a floor.

On a practical level, capital absorbs losses from any potential shock, so one practical consideration is how a climate-related calibration compares to other estimates of stressed losses or the current capital conservation buffer floor. If projections of climate-related impacts are less than those already incorporated in the calibration, then the capital conservation ratio may be adequately sized. One would need to increase the capital conservation ratio only if climate-related effects lead to stress losses that are bigger than the currently-estimated impact within the relevant horizon.

One key question is whether climate-related factors exacerbate shocks or sensitivities in a way that changes the potential impact in periods of stress. If climate change impacts the depth or duration of recessions, for example, then the capital conservation buffer ratio could change to reflect that. Furthermore, such factors could also impact the appropriate calibration of other buffer requirements described below, which were also informed by historical stress losses and are implemented as extensions of the capital conservation buffer.

3. Countercyclical Capital Buffer

The countercyclical capital buffer ratio, s , is designed to protect against cyclical forces that reflect periods when risk may be elevated above normal levels. Generally, this has been tied to cyclical financial vulnerabilities based on drivers such as the provision of credit and debt accumulation. This type of cyclical phenomenon seems different from the secular impact of climate change.

One can ask, however, whether climate change could exacerbate the business cycle or change the dynamics of credit and financial cycles. For example, stranded assets or bubbles in emerging sectors could bring different forms of financial risks, firms focused on transitioning to a low-carbon economy might be less resilient to shocks, or a low-carbon economy that is less dependent on oil could exhibit different business cycle patterns, all of which could alter cyclical dynamics for the economy. If cyclical dynamics shift, then it may be appropriate to adjust the size or duration of the countercyclical capital buffer. Understanding these potential interactions seems like another fruitful area of future research.

An alternative interpretation is financial risks could be elevated during the transition to a low-carbon economy, but could normalize over time, which could suggest some type of medium-run buffer would be appropriate. We discuss this idea in more detail below.

4. GSIB Buffer

The GSIB buffer ratio, g , is based on the goal of offsetting the externalities of distress or failure by lowering the probability of default for certain banks deemed to be systemically important. In this context, climate risks would need to change the sources or magnitude of the systemic externalities in distress or default to warrant changes to the GSIB buffer framework. That is, climate change would need to make distress or failure of a GSIB more costly to other parts of the financial sector.

One might consider, for example, whether the failure of a large bank could lead to disproportionately large credit contraction externalities during an energy transition when other parts of the economy or financial sector are adjusting. In principle, the GSIB indicator-based measurement approach could be modified to reflect any potential changes in the sources of default-related externalities due to climate change. Careful work would be needed to develop the conceptual framework, identify alternative systemic risk indicators that might reflect these externalities linked to climate change, and to determine the appropriate calibration in order to warrant incorporation to the current GSIB framework.

5. Risk-Weighted Assets

Risk-weighted assets are designed to capture the relative riskiness of different assets on a bank's balance sheet. As discussed in BCBS (2021b, 2021c), the impact of both the physical and transition risks of climate change are likely to be heterogenous across sectors, regions, and asset classes. Adjusting risk weights to reflect the relative riskiness of specific assets seems appropriate if there is an empirically-driven approach for calibration of the risks that the bank faces. As discussed above, the Basel regime for developing risk-weights is incredibly complex with considerable variation across asset classes and within asset classes. Rather than performing a complete assessment, we offer several observations.

One, changing risk-weights is fundamentally about improving measures of relative risk, rather than overall amounts of capital required to lower the probability of failure. This suggests the need for careful assessment of the combined impact of any change to required ratios and methods for determining risk weights. Two, changes to risk-weights have implications beyond the minimum amount of capital held by banks. As discussed above, the capital conservation buffer, the countercyclical capital buffer, and the GSIB buffer all link back RWA to scale the impact on the actual amount of capital banks are required to maintain. Three, as discussed above the Basel framework incorporates a wide range of factors including some forward-looking estimates (e.g., PD of an obligor or market prices) and some fixed parameters (e.g., structure of the correlation assumption). As such, some of these factors will adjust automatically as climate-related risks manifest, while others would require active steps to update the framework. Disentangling these impacts requires careful work on an asset class-specific basis. Four, one could envision incorporating new, climate-related risk metrics into existing models of PD or LGD in order to improve estimates of relative riskiness. Again, this is fundamentally about measuring relative risks as accurately as possible across asset classes, which is the foundation of any risk-based capital regime.

IV. Conceptual and Practical Issues

We conclude with a discussion of several conceptual and practical issues associated with the interaction between climate change and the regulatory capital regime. These issues are relevant for all aspects of the topics discuss above.

a) Uncertainty

A fundamental challenge is that the impact of climate change on the economy and financial sector is subject to enormous uncertainty (BCBS (2021b, 2021c) and IPCC(2022)) and policymakers won't know how or if the loss-generating process is evolving with certainty. Bolton et al. (2020) conclude that this type of uncertainty requires an “epistemological break” that shifts focus from traditional, backward-looking assessments to forward-looking approaches grounded in scenario analysis. In the context of the earlier discussion, one can think about uncertainty around the bank loss-generating process – will the process change? If so, will the change look like Case 1, Case 2, or Case 3? Or something else entirely? When will this shift occur? And when will policymakers know with sufficient conviction that the shift has occurred to motivate changes to the capital regime?

The stylized examples presented above are obviously a simplification, and it will be difficult to understand in real time how this process is evolving. The challenge for policymakers is to develop policies that are robust to this uncertainty and the most likely to ensure resiliency across a range of possible future outcomes. European Union (2017) and Chenet et al. (2021) discuss an application of the “precautionary principle” to climate-related policy, where policymakers put greater weight on avoiding catastrophic outcomes. In the case of adaptive regulatory arbitrage, Greenwood et al (2017) argue for an “incomplete contracting approach” where regulators adapt as firms respond to the regime. Similarly, optimal design might include flexibility to respond to changing conditions and updated views on the underlying loss distribution. Policymakers will need to consider the relative costs of errors in both directions when assessing optimal design in a world of deep uncertainty and complexity.

b) Time Horizon

Capital is intended to absorb future unexpected losses and is generally calibrated over a one-year horizon. BCBS (2010) notes that a one-year horizon was used in calibrating minimum capital requirements in part for practical reasons related to data availability.¹¹ One year time horizons are also embedded in certain risk measures that determine RWA, such as PD estimates, although there is some flexibility in many risk measures to incorporate assumptions on the impact of loss drivers like climate-related risks over longer time horizons, e.g., external ratings or market prices.

From a conceptual perspective, a relatively short-term capital planning horizon incorporates the ability of banks to take action over time to reduce exposures, mitigate losses and raise additional capital if needed. As physical risks become more likely over time, they will naturally be captured in the rolling one-year planning horizon. In addition, estimates of probabilities of default (PD) or loss-given-default (LGD) in the determination of credit-related RWA may have different horizon assumptions.

The long-term nature of climate-related risks and the uncertainty around when those risks will materialize raise questions around whether the capital regime should consider longer horizons. One could consider whether a bank's strategic and capital planning processes should extend beyond the traditional one-year horizon due to the wide-reaching impact of climate change, potential adjustment costs during an extended transition, and the implications for a bank's funding profile. One could also consider the use of forward-looking scenario analysis, in addition to historically-estimated losses. A

¹¹ BCBS (2010) states that the focus on a one-year horizon was in part because annual data are in many cases more readily accessible than data over other horizons and because one year is “somewhat of a standard horizon in capital analysis.” However, the paper notes we do not know with any certainty that market participants focus on solvency at a one-year horizon.

forward-looking approach is already embedded in some techniques presently in use such as the stress capital buffer in the U.S. and the SREP Pillar 2 capital charges in the E.U.

These difficult questions require views on the probability of climate-related shocks, changes in the timing and duration of the loss-generating process, and the opportunity cost of capital, and any proposal should be assessed against the practical and conceptual underpinnings of the current regime. This is another area that would benefit from future study. For example, one could consider how incorporation of a different time horizon for capital planning would impact each component of the capital regime in Table 2.

c) Interaction between Minimum Calibration and RWA Calculation

A practical channel is that changes in the distribution of potential losses could impact both the required ratios that determine the minimum levels of capital and the calculation of RWAs that reflect relative riskiness. The appropriate policy response depends on assumptions about the drivers and correlation of losses across different assets. Greenwood et al. (2017), building on Gordy (2003), discuss the technical assumptions needed for the aggregate amount of capital to be a sufficient statistic for bank risk of default, e.g., a single systematic risk factor and diversification of all idiosyncratic risks.

From a policy perspective, changes to regulatory minimums to account for climate-related risks would reflect risk that affects all asset classes simultaneously and proportionally, while changes to RWAs would target relative differences in risks across assets. Changes to the minimum requirement can be viewed as a blunter tool than changes to the risk weights for a particular asset and would require a different type of assessment with a potentially higher burden of proof. A relevant policy design conclusion from Greenwood et al. (2017) is that in an efficient capital regime all banks should face the same risk weights for the same type of activities. Finally, it would be inappropriate to account for the same climate-related risk in both the calibration of a minimum capital ratio and the RWA calculation. These are challenging questions, particularly given the deep uncertainty and forward-looking nature of the risks that could manifest differently across assets and geographies.

d) Time-Varying Climate Buffer

In a world where the financial impact of climate change varies over time, e.g., at different points along a given transition path, it could be appropriate to consider whether a capital buffer could be introduced that allows for dynamic targeting of temporal shifts in unexpected losses. Bolton et al. (2020), for example, suggest that climate-related stress tests could lead to a systemic capital buffer and European Systemic Board (ERSB, 2016) raises the potential of climate-related system buffers to protect against the impact of a “hard landing.” European Commission (2021c) suggests that the “systemic risk buffer” in Europe is used to address various kinds of systemic risk, which may include risks related to climate change.

D’Orazio and Popoyan (2019) argue that the countercyclical capital buffer can be used to support “financial stability in the transition process from the high-carbon to the low-carbon economy as it is meant to help banks to lean against the build-up phase of the carbon-intensive credit cycle.” They propose increasing the buffer during periods of “excessive carbon-intensive credit growth” to both restrain ex ante credit to carbon-intensive firms and to build ex post resilience to carbon shocks. Similarly, FSB (2022) raises the possibility of a “climate capital buffer” to reflect the structural changes associated with a transition a low carbon economy. This could be structured, for example, as a

temporary buffer with triggers for additional capital when uncertainty is high such as during a transition to a low-carbon economy. Alternatively, it could be linked to measures of uninsured losses from physical hazards. Of course, both would face significant implementation and calibration challenges. Finally, one could also consider the macroprudential implications of changes to buffers or relative risk-weights in terms of credit provision through a transition to a low-carbon economy.

e) Interaction between Capital Framework and Accounting Standards

This paper has largely focused on the conceptual interaction of unexpected losses from climate change with the regulatory capital framework, but climate risks may also reasonably manifest as expected losses, i.e., a shift in the loss distribution, as in Cases 1 and 3 in Section III.a above. As noted, increases in expected losses should typically be reflected as an increase in loan loss provisions and fair values of assets, which are defined by accounting standards. This naturally leads to questions about how potential climate risks are captured within accounting frameworks and how this might interact with their incorporation into the regulatory capital framework, adding to on-going discussions of the evolving interaction among these frameworks generally.¹²

In addition to considering how climate risks might be reflected in the recognition and measurement of lifetime expected credit losses, one can also consider the implications for credit impairment or the fair value measurement of financial instruments. IFRS (2020) provides a non-exhaustive discussion of how climate-related impacts might be reflected in financial statements and related disclosures. An investigation of the accounting-regulatory capital interaction is outside the scope of this paper, and a practical analysis of climate-related risks under existing accounting standards, and its implications for bank capital, could be a useful next step.

f) Frequency of Updating

A final consideration is the pace at which climate risks are likely to materialize relative to the appropriate frequency at which minimum capital requirements can be adjusted in order to maintain a stable level of capital relative to risk over time. In an optimal world, capital requirements would adjust concurrently with changes in risk; however, given the high degree of uncertainty in predicting the timing and magnitude of climate-related impacts, ensuring capital requirements remain commensurate with bank portfolio risk may be a challenge.

One must consider the tradeoffs in recalibrating capital requirements on a dynamic, frequent, and forward-looking basis versus recalibrating gradually over time and on a lagged basis. There is potential error in either approach: the former could result in capital requirements that are improperly calibrated based on imprecise estimates of future impacts, while the latter may result in capital levels that are temporarily insufficient if climate risks increase rapidly. The costs and benefits of these two approaches is a potential area for further study.

V. Conclusions

This paper provides a stylized model of the international regulatory capital regime to help develop understanding of the potential impact of climate change from a capital perspective. Our

¹² For example, BCBS (2016b) discusses the policy interaction between the adoption of expected credit loss provision models and the regulatory treatment of these accounting provisions under the Basel III regulatory capital framework.

primary conclusion is that while climate change has the potential to impact the regulatory capital regime in many ways, one needs to be precise about the underlying assumptions and beliefs about how the loss-generating process may change in order to make the appropriate policy assessment. Moreover, the regulatory capital regime itself encompasses several distinct components and policy objectives related to bank resilience and financial stability, so it is important to tie any policy changes to a specific policy objective.

Our analysis begins with the foundational view that the purpose of bank capital is to absorb unexpected losses with a certain degree of confidence. This implies that one might consider an increase in the required capital ratio if, for example, climate-related drivers increase the variance in the distribution of potential losses for a bank. This could reflect a world where tipping points, amplifiers and feedback effect create a link between traditional cyclical forces and climate-related risk drivers. By contrast, if climate-related factors affect the relative riskiness of specific asset types, it might be appropriate to consider the detailed mechanics of the risk-weighting function, which requires a careful assessment about those change would automatically flow through as higher risk-weights or whether in some cases more proactive changes to fixed parameters are needed. If one believed that climate change would impact the severity or duration of economic cycles, then it might be appropriate to reconsider the sizing and methods for the capital conservation or countercyclical capital buffer. Finally, changes to the GSIB buffer would require an assessment of how climate change could increase the externalities associated with the distress or failure of a systemically important bank.

These possible links from climate to the regulatory capital regime follow the logic of regulatory capital in a stylized, conceptual sense. Actual implementation entails additional challenges from several perspectives. In contrast to the illustrative cases presented here, one will not know for sure how or even if the loss-generating process for banks is shifting in real time. Policymakers will need to make informed judgments based on partial assessments and imperfect data as climate-related effects are realized and the economy evolves. Moreover, the complexity and heterogeneity within the Basel capital regime, particularly the determination of risk-weighted assets, suggest a long, detailed process of technical assessment and adjustment on an asset-by-asset basis.

The challenge of policy-making uncertainty is pervasive and not unique to climate change, of course, but the unprecedented nature of the potential economic transition and myriad ways that physical risks might materialize make this a first-order concern in this context. This is clearly an area where more empirical research is needed to determine how the loss-generating process may be evolving and whether changes are best characterized as affecting expected losses vs. unexpected losses and involving temporary shifts vs. permanent shifts. Both of these dimensions have clear implications for optimal policy design.

A final conceptual challenge is one of relative judgment across the many risks that banks face. Climate-related financial risks are not the only forces that might be shifting the potential losses that internationally active banks face. Cyber threats, fintech competition, and ongoing financial innovation all have the potential to introduce new risks and change the distribution of bank losses in the future. To justify substantive changes to a capital regime, one would need to believe that climate-related risk drivers are more likely to lead to more substantive changes in the potential losses. Moreover, one would need to consider the broader implications for the financial sector if, for example, changes to the bank capital regime simply shift financial activity outside of the regulatory perimeter.

We end with a several observations about areas where future research could be particularly valuable to help policymakers work through these difficult issues. One obvious area is continued empirical work on how the physical and transition risks associated with climate change impact the loss-generating process for banks. This is central for informed assessment of policy options and the calibration of any desired potential changes to the regulatory capital regime. Climate-related scenario analysis seems like a useful tool to help understand the range of potential impacts. Insights from this work would help inform our ability to distinguish expected losses from unexpected losses, ensure the appropriate treatment from an accounting perspective, and develop robust risk-weights that accurately represent the differential impact across assets.

A related question is around the development of robust policy action. Given the deep uncertainty about climate change itself and the potential economic impacts, it seems useful to consider how to develop robust policy options that reflect the reality that it will be impossible to know precisely how ongoing climate change is impacting bank performance in real time.

A second area of potential research relates to the link between climate change and cyclical dynamics. Theoretical and empirical work, for example, could assess whether climate change and the related financial amplifiers and mitigants are likely to change the severity or duration of the business cycles, and whether those changes are likely to be temporary through a transition period or more long-lasting. This assessment is critical for the entire capital regime, and particular for discussions of potential changes to the capital conservation and countercyclical capital buffers.

A third question is whether climate-related changes impact the systemic externalities of distress or failure of large financial firms, which is essential for discussions of the GSIB buffer. Increased risks to a given firm should be captured through the appropriate regulatory minimum ratio and appropriately-calibrated risk-weighted assets, but one could assess how climate change amplifies the impact of distress of failure on other financial firms or financial markets more broadly. This would require incorporating climate-related factors into models of financial stability that expressly include externalities and interconnections among firms.

A final question, particularly relevant in jurisdictions where the supervisory authority has a legal mandate that including supporting a transition to a low carbon economy, is the potential interaction of the traditional risk mitigation objective of bank capital requirements with that broader objective. Using the bank regulatory capital regime for the broader objective could sever the fundamental link between regulatory capital requirements and bank risk and reduce risk-related transparency for investors. Understanding potential trade-offs or complementarities between these two objectives would be an interesting question for future work for jurisdictions with the legal mandate to pursue both objectives.

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