Transition risk add-on: a simulation approach - Summary

Lorenzo van Cadsand

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Cllmate change poses significant risks to financial stability over long-term horizons through its impact on the drivers of classical financial risks. Climate risks represent a threat to current financial system because markets often fail to account for the long-term impacts intrinsic to such risks, which require an evaluation that incorporates a forward-looking analysis that often misaligns with the models currently used by most financial institutions. Academic literature broadly agrees that climate risk drivers can be categorized into two main types: physical, which arises directly from climate-related changes in weather and climate systems, and transition, which arises from the need to reduce CO_2 emissions through coordinated policies to facilitate the transition to a low-carbon economy and mitigate the physical risks associated with rising global temperatures. Both types of risk can significantly undermine the financial positions of households and firms by affecting their cash flows and asset values, ultimately impacting their credit risk.

This article focuses on disorderly transition risk, which can be triggered by factors such as delayed regulatory action, abrupt climate policies, or rapid technological advancements. These unanticipated shifts toward a low-carbon economy can significantly disrupt financial markets as investors and companies struggle to adapt their expectations and asset allocations. This could ultimately lead to a sharp revaluations of assets, particularly within carbon-intensive sectors where the risk of stranded assets becomes particularly acute. Stranded assets are investments or resources that can prematurely lose economic value due to external factors, often transforming from revenue sources into liabilities. In the context of climate finance, stranded assets are most commonly associated with fossil fuel reserves and related infrastructures, whose value can significantly vanish as the transition to a low-carbon economy accelerates. The direct impact on affected firms can be significant as reduced revenue from stranded assets and increasing compliance costs can strain cash flows, making it more challenging for firms to meet debt obligations and increasing their probability of default. This weakens firms' financial position, limiting their access to capital and potentially driving up their borrowing costs. Moreover, the loss in value of stranded assets directly diminishes the quality and quantity of available collateral, undermining firms' balance sheets and increasing lender exposure. Consequently, the cumulative effects of stranded assets, reduced cash flows, and degraded collateral quality can lead to market instability and potential financial contagion. This context highlights the potential for systemic risk, which regulators must manage. Regulators have, in fact, increasingly acknowledged that climate risks, both physical and transition related, can significantly impact banks' credit and market risks, ultimately affecting their capital adequacy. Recognizing this, numerous papers have been published in recent years to assess the degree to which climate risks should be integrated into the existing regulatory framework and to provide measures for dedicated capital buffers designed to cover climate risk exposures, thereby strengthening the resilience of the financial system.

This research aims to provide a measure of transition risk exposures, drawing upon the conceptual framework outlined by Gordy in the pioneering article "A risk-factor model foundation for ratings-based bank capital rules". In this seminal work, the author provided a measure of the capital charge necessary to account for concentration risk within a portfolio of (n) credit exposures, contingent upon the rating classes of the issuers involved and the number of exposures comprising the portfolio. Although Gordy's model did not explicitly account for climate-related exposures, which have only recently garnered significant attention, the fundamental principle of applying a risk measure to determine the capital buffers required to cover various risks remains pertinent. To incorporate climate exposures, I have assumed independence between the single systematic risk factor X included in Gordy's model and the introduction of a climate policy P.

The Climafin tool, developed by Battiston & Monasterolo, has been used to perform the climate evaluation. This method incorporates a transition shock into a closed-form expression that links financial valuation with transition risk. A set of issuers {1, .., j, .., n} is considered, each represented by a portfolio of fossil and renewable cash flows. Transition risks can affect these cash flows through various channels, including increasing research and development expenditures for new and alternative technologies, higher costs associated with the adoption of new practices and processes, declining demand for carbon-intensive products and services, rising production costs due to changes in input prices (e.g. for energy and water), and stricter output requirements (e.g. for carbon emissions and waste treatment). If not properly assessed, these changes can lead to lower-than-expected cash flows, potentially impairing a firm's ability to service and repay its debt, depending on its financial condition and its pre-shock technology mix. From an accounting perspective, the authors considered the issuers' balance sheet to consist solely of assets and liabilities. Liabilities are assumed to be constant, while assets are modeled as dependent on a transition shock $u_j(BP)$ and on an idiosyncratic shock $\eta_j(BP)$. Using a threshold model, a default condition dependent on both shocks is defined: the impact of climate shocks is to shift the distribution of the idiosyncratic shock (left/right), consequently shifting the default threshold (up/down) and the PD. The direction of these shifts is contingent upon the relative weight of low-carbon sectors within the current revenue composition. Moreover, by assuming a linear distribution for idiosyncratic shocks, we have been able to derive a linear expression for the financial adjustment induced by transition risk. This expression does not necessitate granular accounting information of individual issuers, as the sole data relevant for this analysis pertains to the Climate Policy Relevant Sectors of the exposures (specifically of the simulated energy sources corresponding to their revenues).

This methodology has been adopted considering a portfolio of (n) Zero Coupon Bond to ensure that transition loss, denoted as $\Delta v_j(BP)$, is defined within the interval [-1,1] for each exposure, consistent with the variable loss U_i defined in Gordy. Recognizing the challenges associated with obtaining precise sectorial information for available issuers and consequently the difficulties in executing CPRS mapping, I have opted for a Monte Carlo simulation approach. By this simulation I have randomly modeled the technology mixes of the (n) issuers across (m) simulations to associate to each issuer a transition shock $u_j(BP)$, computed as weighted average of the longitudinal variations in corresponding outputs across different IAM trajectories with regards to the LIMITSBaseline scenario B. By means of such methodology, I have generated an empirical distribution of (m) "Transition Risk Portfolio Loss Ratio" (TRL) for a portfolio of (n) issuers by aggregating individual transition losses $\Delta v_j(BP)$ of single exposures, dependent on the transition shocks. This variable is constructed analogously to the "Portfolio Loss Ratio" introduced by Gordy, wherein the exposure A_j is replaced by the face value of a ZCB and the loss U_j is replaced by $\Delta v_j(BP)$. I have then applied a Value-at-Risk measure to this empirical distribution to determine a capital buffer for transition risk, where the convergence of the empirical q-th quantile to the population quantile is ensured by the application of the Law of Large Numbers (LLN), which establishes the convergence of such measure for i.i.d. data with a large number of simulations. In light of the independence assumption between the systemic risk factor (X) and the introduction of a climate policy (P), total economic capital has then been defined as the sum of the granularity add-on and the transition risk add-on. The transition risk term is different from zero solely in the event of a specific climate policy (P) being implemented. Otherwise, the economic capital reduces to the granularity add-on.

Given the forward-looking nature of transition risk, this research relies on projections derived from climate models, rather than historical trends. Consequently, the analysis required the integration of forward-looking projections from the LIMITS database to incorporate the potential impacts of policy adoption and to facilitate the assessment of risks arising from anticipated policy shifts through $u_j(BP)$. This model has been applied to various technology mixes (e), modeled by the weights randomly assigned to the energy variables associated with each issuer (j) under different models and scenarios:

- Models: WITCH and REMIND.
- Scenarios: LIMITS450, LIMITS500, LIMITSPledges, OilIndependence, EnergyIndependence. These scenarios represent potential pathways identified by the scientific community for reducing GHG emissions and limiting global temperature rise to below 2 degrees Celsius compared to pre-industrial levels. The first two scenarios, Energy Independence and Oil Independence, focus on energy trade restrictions between regions. LIMITS450 and LIMITS500 represent climate policies that set specific emission targets for countries to be achieved through coordinated action.

In light of the absence of real data in this approach, the primary result of my analysis is to provide a measure that facilitates a comparison between the different models and scenarios developed by the scientific community for possible climate policies and to realize a capital charge that is comparable by magnitude and methodology to the one related to concentration risk. Nevertheless, it should be noted that the same approach could be applied to real data, considering an empirical distribution of transition portfolio losses generated across a multitude of scenarios and financial models.

The granularity add-on has been computed utilizing the same distributions and stylized values for key parameters developed by Gordy. Therefore, the values obtained for this capital charge are similar to those obtained by the author in his article. Subsequently, a climate policy P was introduced in accordance with the aforementioned set of scenarios, and the climate valuation was executed on different degrees of greenness, expressed by underlying energy categories (that can be linked to fossil or renewable energy sources). These were established by pre-establishing the weights assigned to the energy categories for the simulations.

This approach has been executed across 10.000 simulations on a portfolio comprising 100 ZCBs and considering a VaR applied at a 99.5 confidence level. Particularly, I considered both a portfolio composed of issuers originating from all regions and regional portfolios, to compare the discrepancies induced by transition risk associated with investing in different areas. We run our model on three different technology mixes to reflect possible investment choices available to financial actors:

1. Green: the portfolio consists solely of issuers operating exclusively with renewable energy sources.
2. Fossil: the portfolio includes issuers operating exclusively with fossil energy sources.
3. Mix: the portfolio comprises issuers operating with a balanced energy mix, utilizing 50% renewable energy sources and 50% fossil energy sources (25% primary energy and 25% secondary energy).

For all technology mix I have assigned a maximum of 3 IAM energy variables for category (primary energy — fossil, secondary energy — electricity — fossil, secondary energy — electricity — renewable). The results demonstrate that for most regions the introduction of a climate policy, particularly those targeting significant reductions in CO_2 emissions, results in a substantial adjustment to required economic capital. Furthermore, I demonstrate that transition risk add-on decreases as the "greenness" of the technology mix increases and decreases over considered time frames (spanning from 2030 to 2050). For a green portfolio, as expected, the add-on exhibits negative values across most scenarios. This suggests that, even in the 99.5 percentile worst-case scenario, investing in a renewable-based portfolio may reduce the economic capital requirement for a financial institution. Conversely, both mixed and fossil fuel-based portfolios demonstrate positive transition risk add-ons, implying an increase in economic capital requirements.

The model discussed in this research demonstrates clear potential for significant improvement. Indeed, potential enhancements to our model could involve integrating the data underlying the granularity add-on values through the use of parameters and distributions calibrated to the specific financial context of each region. Such a development would enable the calculation of the total economic capital segmented by the regional origin of the investments. Furthermore, both the assumptions related to the uniform distribution of idiosyncratic shocks and to the independence between systemic risk factor X and the introduction of a climate policy could be relaxed in order to develop more complex models. In conclusion, potential enhancements could also be related to the adoption of climate shocks other than those based on CPRS and forward-looking projections introduced by Battiston and Monasterolo, or to the development of more complex threshold models to describe the default events of the issuers involved in the analysis.