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Accounting for climate transition risk in banks' capital requirements

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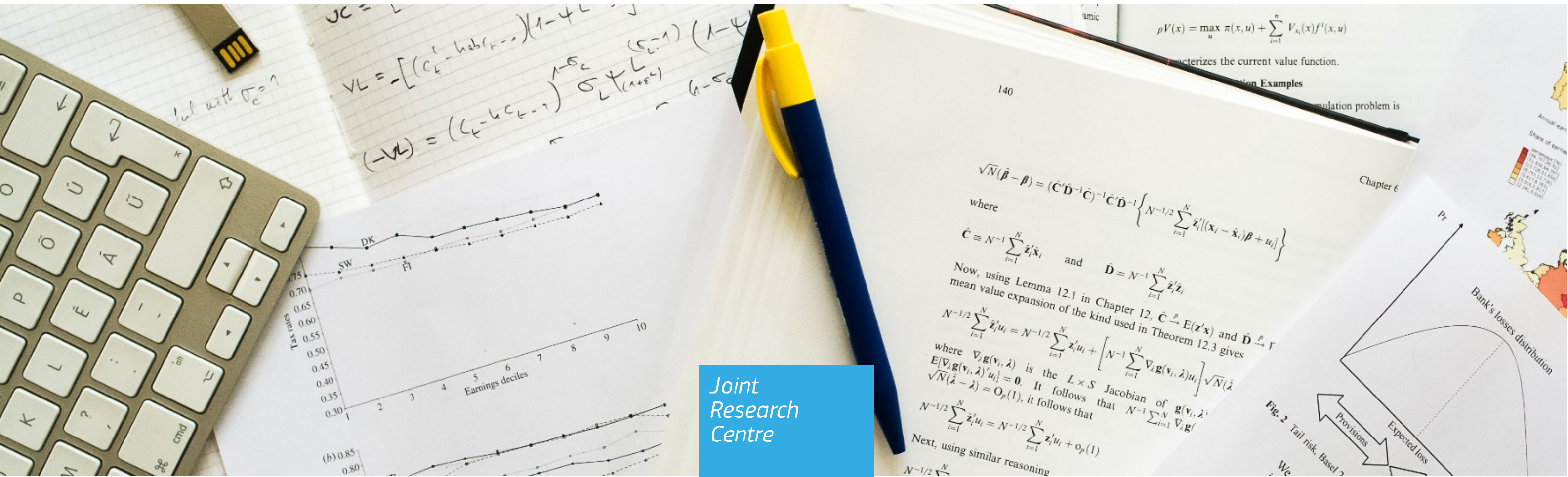

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Executive Summary

Climate change represents a major source of systemic risk, and has the potential to have serious consequences for the real economy and for the financial system. It is therefore of paramount importance to ensure that banks are well equipped to withstand potential impacts and that the financial system as a whole is resilient to these risks. The ability of banks to timely identify and manage climate-related financial risks and absorb financial losses potentially arising from them is ultimately key for financial stability. While individual banks are exposed to various degrees to climate-related risks, which justifies a micro supervisory approach, the systemic dimension of climate-related financial risks makes a macro-prudential framework also suitable to address the impact of climate change on the financial system.

Several policy initiatives are underway to raise awareness among financial institutions about the need to integrate climate-related risks in risk management processes, to make the regulatory and supervisory framework fit for purpose, and to develop suitable monitoring and assessment tools. The ultimate goal is to capture these risks in supervisory and policy decision-making processes, limit the further build-up of climate-related financial risks and enhance the resilience of individual banks and of the financial system as a whole. This paper contributes to this debate by assessing the potential impact on banks' balance sheets of climate-transition risk, i.e. those risks stemming from the financing of economic activities that will need to be abandoned in the low-carbon transition. These activities are for example related to fossil-fuels or particularly energy inefficient production processes and buildings. The risk is that relevant physical assets will become stranded and the associated investment will result in a financial loss. As a consequence, these financial assets become inherently riskier already before any relevant real-economy development actually takes place.

In this context, we establish a basis for calibrating relevant macro-prudential instruments, which could protect the banking system from such risks. In particular, we estimate the size of losses due to fossil-fuel and high-carbon assets when transition risks are material and not fully incorporated, under two main scenarios, namely: i) the case of a financial crisis triggered by climate-unrelated factors, under a static balance sheet assumption, where climate transition risk comes on top, and ii) the case of fire-sale dynamics triggered by a small depreciation of fossil-fuel and high-carbon assets, under a dynamic balance sheet assumption. In the first case, the analysis shows that additional bank losses directly related to transition risk would be concentrated in some countries. If fossil-fuel and high-carbon assets are indeed 15-25% more risky than reflected in current risk assessments, this could lead in some countries to increases in losses, up to 40%. In the second case, dynamics are introduced in the balance sheet as banks' portfolios

can become less exposed to transition risk by selling high-carbon assets or owing to a generalized greening of the economy. Results show that fire-sale dynamics, triggered by a very limited initial depreciation of fossil-fuel and high-carbon assets, could lead to significant losses for the EU banking system as a whole and to the default of a large number of institutions. This fire-sale process can be effectively tackled with the introduction of an extra capital buffer accounting for transition risk in banks' balance sheets, which based on current exposures should be around 0.5% of RWAs on average. However, as the economy becomes greener and banks' balance sheets become greener too, this capital buffer could be reduced.

Overall, our findings support the idea that banks that are financing high-carbon activities should be asked to increase their protection against the consequences they could face owing to the economy shifting to low-carbon, as losses could be sizeable and spill-over to the wider banking sector via systemic channels. We show that the consequences of a materialization of transition risks could be systemic and call for public intervention.

Accounting for climate transition risk in banks' capital requirements*

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Abstract

This paper uses a stylized simulation model to assess the potential impact of transition risk on banks' balance sheets and establishes a basis for calibrating relevant macro-prudential instruments. We show that even in the short run, a fire-sale mechanism could amplify an initially contained shock on high-carbon assets into a systemic crisis with significant losses for the EU banking sector. We calculate that an additional capital buffer of 0.5% RWA on average would be sufficient to protect the system. Moreover, under an orderly transition, the decrease in banks' transition risk exposure due to the greening of the economy would reduce the effect of a fire-sale by a factor of 10.

Keywords: Green transition risk, dynamic balance sheet, banking crisis.

J.E.L. classification: C15; G2; Q54.

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1 Introduction

Climate change, among many other consequences, represents a new source of financial systemic risk since its impacts have the potential to spread across the entire financial sector (see, e.g. European Systemic Risk Board, 2021; European Central Bank, 2021; Bank for International Settlements, 2021b; Bank for International Settlements, 2021a). In particular, the literature groups climate-related financial risks into two macro categories: a) physical risks, which arise from catastrophic events becoming more frequent and more severe; and b) transition risks, which arise from the transition to a low-carbon economy and the related changes in strategies, policies or investments. The ability of financial institutions to timely identify and manage both types of risks and absorb financial losses potentially arising from them is ultimately key for financial stability. Looking at the banking sector in particular, while individual banks are exposed to various degrees to climate-related risks, which justifies a micro-supervisory approach, the global dimension of climate-related financial risks makes a macro-prudential framework also suitable to address the impact of climate change on the financial system. Against this background, this paper provides quantitative evidence on the magnitude of climate transition risk for the European banking sector, by testing different scenarios, notably including that of a fire-sale on high-carbon assets. We show that in this case, even a very small depreciation on such assets could trigger uncontrolled market dynamics, ultimately leading to significant losses for the banking system as a whole. We also show that risks are concentrated in some countries. Finally, we calculate that should banks' assets become less exposed to transition risk, owing to an overall greening of the economy, a fire-sale would lead to reduced losses by an order of magnitude. Based on these results, we propose a calibration for relevant macro-prudential tools.

The proposal of using macro-prudential tools to address climate-related financial risks has received growing attention in the literature in recent years. Among others, Campiglio (2016) provides an early discussion about the use of macro-prudential regulation to reward banks financing low carbon activities. The paper analyses the role of differentiated reserve ratio requirements and capital requirements. D'Orazio and Popoyan (2019) provide a detailed overview of available macro-prudential tools, which could play an important role in leading the transition to a green economy. The paper focuses, among others, on the role of capital requirements.

However, the quantitative impacts and the effectiveness of introducing differentiated capital requirements to support financing to specific sectors of the economy are unclear. For example, one such measure was introduced in 2013 in the European Union, namely a capital discount for exposures to small and medium enterprises (SME), also known as 'SME supporting factor'. Based on an assessment performed by the European Banking Authority (2016), there is no evidence that this factor increased access to finance for smaller firms relative to larger firms. On the contrary, the study carried out by Dietsch et al. (2021) shows that the SME supporting factor had a positive impact on credit supply in France.

Recent studies investigate the effect of introducing a 'green supporting factor' (GSF) or a 'brown penalizing factor' (BPF), to discourage financing to environmentally harmful activities. These supporting and penalizing factors are modelled assuming a range of variation of 15%-25%, as the one used for the SME supporting factor. The policy justification for this particular range is provided by the EU Capital Requirement Regulation 2, which allows a capital reduction up to 23.81% for investments below €2.5 million and up to 15% for larger exposures. Dafermos and Nikolaidi (2021) examine the effect of a green/brown supporting/penalizing factor, which decrease/increase the risk weight on loans by 25 percentage points. The authors conclude that green differentiated capital requirements can be effective in mitigating global warming and the associated climate physical risks. This reduction is quantitatively small, but can be increased by introducing at the same time a brown penalizing factor. Thoma and Gibhardt (2019) estimate the potential impact of a GSF and compare it to that of a BPF, focusing on factors ranging from 15% to 25%. They find that a GSF would have a limited effect on overall capital requirements, namely savings of about 3-8 bn, depending on the breadth of the definition of green assets. An additional capital charges on brown assets would result in a €14-22 bn higher bank capitalization, by depending on the definition of brown assets. While a BPF could potentially reduce lending to environmentally harmful activities by up to 8%, the reduction in the cost of capital for green projects would likely be insufficient to make a difference. Dunz et al. (2021) assess the effectiveness of the introduction of a GSF and of a carbon tax as alternative policy levers to support the greening of the economy. They find that a GSF could contribute to scale up green investments only in the short term, while potentially increasing risks for financial stability.

Finally, Diluiso et al. (2021) argue that the integration of climate-related risks into the financial regulatory framework may lead to very different outcomes depending on the implemented scheme. In particular, in the case of a negative shock originating in the fossil sector, fossil penalizing capital requirements would significantly reduce the severity of a financial crisis, but also slow down the recovery.

This paper contributes to this debate by assessing the potential impact of transition risk on banks' balance sheets and establishing a basis for calibrating relevant macro-prudential instruments. In particular, we estimate the size of losses triggered by high carbon assets when transition risks are material and not fully incorporated. We do so by considering two main scenarios, namely: i) the case of a financial crisis triggered by climate-unrelated factors, under a static balance sheet assumption, where climate transition risk comes on top, and ii) the case of fire-sale dynamics triggered by a small depreciation of high-carbon assets, under a dynamic balance sheet assumption. In the first case, we quantify the additional bank losses due to climate risk, and show that they are concentrated in some countries. In the second case, dynamics are introduced in the balance sheet as banks' portfolios can become less exposed to transition risk by selling high-carbon assets or owing to a generalized greening of the economy. It should be noticed that, while the latter sub-scenario essentially corresponds to an orderly transition in the NGFS narrative (see, e.g. Network for Greening the Financial System, 2020, Network for Greening the Financial System, 2021), a fire-sale of high-carbon assets does not necessarily correspond to a disorderly transition, as market dynamics are much quicker than economic transitions. In other words, a fire-sale such as the one we model could unfold in the very short term, as it would be in fact much more related to investors' *expectations* on the green transition rather than to the actual progress of the transition process. Given its short-to-medium term focus, our model can be used as a climate-stress-testing tool.

The modelling approach includes several steps. First, the share of exposures to high-carbon activities is used to recalibrate the risk-weighted assets of banks, in order to reflect the increased riskiness of investing in harmful activities.[1] In particular, in line with the literature, high-carbon assets are assumed to be between 15% and 25% more risky than other assets. Second, the Systemic Model of Bank Originated Losses (SYMBOL, see De Lisa et al., 2011), i.e. a micro-simulation model based on individual bank balance sheet data, is used to generate crisis scenarios and derive the aggregated loss distribution for the banking sector.

In the first scenario, we compare aggregate losses in the case of a crisis, comparable in magnitude to the global financial crisis, both assuming no transition risk and accounting for transition risk. We calculate that owing to transition risk, losses would be 8% higher at the aggregate EU level, but could increase by up to 40% in countries which are particularly exposed.

In the second scenario, to model second-round effects, based on the same model we check how many banks could fail only due to their particularly high exposure to transition risk in a business-as-usual setting (i.e. no crisis). We then assume that these bank defaults could trigger a fire-sale mechanism involving high-carbon assets, starting with an initially contained depreciation of these assets. The initial shock is

[1] Alessi et al. (2017)) show that fossil fuel companies are indeed riskier than their industrial peers, for example based on a Value-at-Risk assessment, and have become incrementally riskier after the Paris Agreement as well as during the COVID-19 pandemic.

amplified via second round effects, and eventually reaches a systemic scale, as further depreciations of high-carbon assets put under stress an increasingly larger number of banks, despite portfolio reallocations triggered by market developments. These dynamics only stop when a new equilibrium is reached, which happens, based on our results, after losing around 1% of total assets, i.e. €335-360 bn for the EU banking system as a whole.

Finally, we investigate under which conditions the introduction of additional capital requirements, accounting for transition risks faced by each bank, could effectively protect the system (see next section). We propose a calibration for such a measure that would be able to ensure that a fire-sale does not even start. Indeed, virtually no bank would fail due to its transition risk exposure thanks to the additional capital buffer and hence, no uncontrolled market dynamics would be triggered. We estimate that a capital buffer corresponding to 0.5% of risk-weighted-assets (RWA) on average would be adequate. However, such a policy measure could only be temporary, until the economy and, in turn, banks' balance sheet become green enough. In this respect, we calculate that in the event of a fire-sale, losses would be reduced by 90% by decreasing banks' exposure to transition risk by about one third to about a half, depending on whether risk reduction is quicker where risks are concentrated or is more homogeneous across banks, respectively.

The paper is organized as follows. The next section overviews relevant policy initiatives. Section 3 explains how the inputs to the model are derived, notably including estimates of augmented RWA accounting for climate transition risk. Section 4 provides an overview of the model and how it is used in the various scenarios. Results are presented in Section 5. Section 6 concludes.

2 Policy background

Several policy initiatives are underway to raise awareness among financial institutions about the need to integrate both climate risks in risk management processes, to make the regulatory and supervisory framework fit for purpose, and to develop suitable monitoring and assessment tools. The ultimate goal is to capture these risks in supervisory and policy decision-making processes, limit the further build-up of climate-related financial risks and enhance the resilience of individual banks and of the financial system as a whole. The policy framework is more advanced in relation to the monitoring and assessment of transition risks, but there is no doubt that also physical risks need to be addressed.

In its report on Environmental, Social and Governance (ESG) risk management and supervision the European Banking Authority (2021) provides guidance on how banks and supervisors should integrate these risks. The Basel Committee on Banking Supervision (2021) explores how climate-related financial risks can affect the banking system, concluding that 'traditional risk categories used by financial institutions and reflected in the Basel Framework can be used to capture climate-related financial risks'.

In July 2021 the European Commission launched its renewed Strategy for Financing the Transition to a Sustainable Economy (see European Commission, 2021a). Several of the main actions address the need for the financial system to identify and manage sustainability risks, including climate risk. In this context, a key issue relates to the ability of banks to absorb financial losses that may arise from exposures to companies and sectors negatively impacted by the transition. The strategy foresees potential amendments to banks' capital requirements as a means to enhance economic and financial resilience to sustainability risks.

The European Commission's proposal for a review of the Capital Requirements Directive (see European Commission, 2021b), published few months later, explicitly mentions the use of a systemic risk buffer to address risks related to climate change. Already back in 2018, in the Action Plan on Financing Sustainable Growth, the European Commission (2018) proposed a strategy to help channeling financial investments towards green activities. One of the suggestions was to investigate the possibility to use banks' capital requirements, the rationale being to align banks' investment decisions with sustainable finance goals. The Action Plan refers to the introduction of a green supporting factor (GSF) to reduce capital requirements for green investments, provided that they can safely be regarded as less risky than other investments.[2] The European Banking Federation (2017) as well is in favor of a GSF for certain assets classified as sustainable under the EU taxonomy.

This idea, however, has provoked a range of unfavorable reactions. It has mainly been challenged with the argument that *the extra risk of brown assets does not make green assets extra safe* (see Boot and Schoenmaker, 2017). Opponents to the GSF also claim that such a discount in capital charges reduces buffers needed by banks to face future losses (see Dankert et al., 2017).

Essentially, supervisors and macro-prudential authorities argue that under no circumstances, the need to make the financial sector contribute to the green transition should lead to an unjustified loosening of capital requirements, which have been increased after the global financial crisis to secure the resilience of banks and financial stability. On the contrary, the introduction of a brown penalizing factor (BPF) for fossil fuel intensive assets, reflecting the presence of a systematic and potentially systemic risk of brown assets, has been attracting growing attention. Not only this alternative would avoid the depletion of

[2] The speech of Vice-President Valdis Dombrovskis is available here.

capital buffers, including those needed to withstand additional losses linked to climate physical risks, but it would also discourage further investments in environmentally harmful activities, thereby contributing to favoring a shift towards green investments.[3] Moreover, if transition risks are material for certain asset categories and not fully incorporated, a BPF would also increase financial stability.

Finally, it should be noticed that any suitable macro-prudential capital buffer, be it a dedicated penalizing factor for high-carbon exposures or the systemic capital buffer itself, could potentially be used to protect the system, as long as it reflects the systemic nature of the risk. As concluded in a recent EBA discussion paper (see European Banking Authority, 2022), the Pillar 1 framework already includes tools that allow the inclusion of sustainability-related financial risks, including climate risks. In this respect, the results in this paper are relevant from a macro-prudential perspective; however, they can also be used in the context of Pillar 2 measures.

3 Data and other model inputs

Individual banks' balance sheet data, consolidated at the level of the banking group, is sourced from Orbis BankFocus. In particular, we use Total Assets (TA), Risk Weighted Assets (RWA) and Total Regulatory Capital (K).[4] The final data set covers nearly 461 EU banks located in the EU27, including commercial and cooperative banks, saving institutions, and real estate & mortgage banks. They account for around 89% of the total assets in the EU banking system. The data refers to 2020.

Together with balance sheet data, a key input to the model is the size of high carbon and fossil-fuel-related assets in bank's balance sheets, whose share is used to re-calibrate banks' RWA so as to reflect the increased riskiness of financing harmful activities. In particular, we adjust the calculation of RWA by assuming fossil-fuel-related assets to be between 15% and 25% more risky than other assets. We assume an increased riskiness of 25% (β_1) for securities and corporate loans financing high-carbon and fossil-fuel-related activities (FFA) while we assume an increased riskiness of 15% (β_2) for mortgages financing particularly energy inefficient buildings.[5]. Formally, the augmented RWA accounting for transition risk (RWA_{tr}) are derived for each bank as follows:

$$RWA_{tr} = (\beta_1 \phi_{1,c} + \beta_2 \phi_{2,c})RWA + (1 - \phi_{1,c} - \phi_{2,c})RWA,$$

[3] Grantham Institute: "Green doesn't mean risk-free: why we should be cautious about a green supporting factor in the EU", available here.

[4] See Table 1 in Appendix A for descriptive statistics on the representativeness of the sample by country.

[5] Chamberlin and Evain (2021) apply a penalizing factor of 25% to assets directly related to fossil fuels, and a lower penalizing factor of 10% to a broader set of assets including also assets financing energy-intensive manufacturing activities.

where ($\phi_{1,c}$) represents the country-specific share of FFA in banks' balance sheet, while ($\phi_{2,c}$) represents the share of mortgages financing highly inefficient properties.

To obtain estimates of the ($\phi_{i,c}$) shares, we start from estimates based on Alessi and Battiston (2021), namely for the transition risk exposure of national banking systems through equities ($TE_{e,c}$), through bonds ($TE_{b,c}$) and through mortgages ($TE_{m,c}$)).[6] Using breakdowns of domestic and cross border intra euro-area positions provided by the ECB,[7] we derive the share of equity (E), bonds (B), mortgages (M) and corporate loans (C) in banks' balance sheets at the country level, to which we apply the coefficients above.[8] For countries outside the euro zone, which are not included in the reference paper above, we adapt results from Alessi et al. (2019).

$$\phi_{1,c} = TE_{e,c} \cdot E_c + TE_{b,c} \cdot (B_c + C_c),$$

$$\phi_{2,c} = 0.7 \cdot M_c.$$

Figure 1 shows the distribution densities for the share of assets exposed to transition risk. The mean and median values correspond to 1.7% and 6%, respectively, when mortgages are not considered as FFA, while they are both around 14% when mortgages are included as FFA. Figure 2 shows how accounting for transition risk increases the size of RWA by between 1% and 2% for most of the banks, with a smaller fraction facing increases up to 8%.

Figure 1: Share of assets exposed to transition risk

[6]As transition risk exposure coefficient for mortgages we use the coefficient proposed for real estate activities, i.e. 70%.

[7]Series: 4. Domestic and cross-border positions of euro area MFIs (excluding the Eurosystem) and 2.2.1 Loans to households and non-financial corporations (EUR billions; not seasonally adjusted; outstanding amounts at end of period).

[8]We use $TE_{b,c}$ also for corporate loans as a specific exposure coefficient for loans is not available.

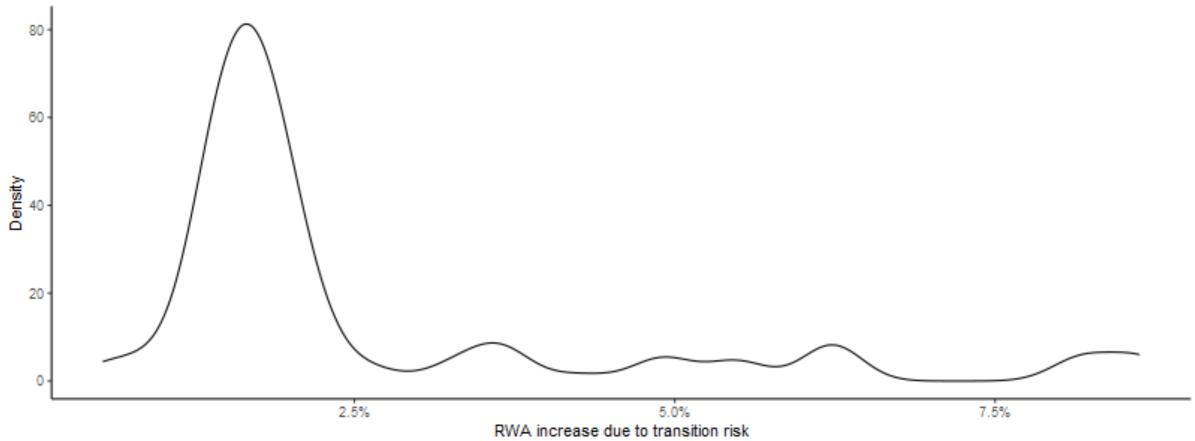


Figure 2: Distribution of increases in RWA due to exposure to transition risk

4 Modelling framework

4.1 Simulation model

The modelling strategy is based on the Systemic Model of Banking Originated Losses (SYMBOL, see De Lisa et al., 2011). The model, based on bank level data, essentially simulates banking crisis scenarios where individual banks may default based on their actual capital (K) and on the probability of default attached to their portfolio (PD).

The bank's portfolio PD is derived by inverting the Basel formula, which expresses minimum capital requirements as a function of the PD of a bank's portfolio and its RWA. Bank-specific PDs are then used to generate unexpected losses for individual banks via a Monte Carlo simulation, where randomness is introduced by sampling the underlying shocks. Failure of any individual bank is determined by the size of the losses, compared to the actual regulatory capital available to absorb them.[9] Some of the model iterations, most likely those where the sampled shock is larger, will result in at least one bank defaulting.

The output of the Monte Carlo simulation is an $I \times J$ matrix of unexpected losses $(\mathrm{GL})_{ij}$, obtained as follows:

$$GL_{ij} = LGD \cdot N[\sqrt{\frac{1}{1-R_i}}N^{-1}PD_i + \sqrt{\frac{R_i}{1-R_i}}N^{-1}\alpha_{ij}],$$

where $i = 1, \ldots, I$ refers to the banks in the sample, $j = 1, \ldots, J = 200,000$ denotes the model iteration, R_i is the correlation among exposures in the portfolio, LGD is the loss given default equal to 0.45 as per

[9] See Benczur et al. (2017) for details.

regulation, and $N^{-1}(\alpha_{ij})$ are correlated normal random shocks. The α_{ij} shocks are correlated as they are defined as the sum of a common shock Z_j and a bank-specific shock W_{ij}, as follows:

$$N^{-1}(\alpha_{ij}) = l \cdot Z_j + \sqrt{1-l^2} \cdot W_{ij},$$

where l are the loadings, W_{ij} are the idiosyncratic shocks, and Z_j is a common shock which might be linked, for example, with overall economic developments. The standard version of the model, which is used in this paper, sets l so as to yield a fixed correlation of 0.5 across the α_{ij}.[10] The shocks Z_j and W_{ij} are drawn from a standardized Normal distribution.

In each iteration, the following two components are summed up for each bank: i) losses that cannot be absorbed by capital, and ii) recapitalizations needed to bring the banks back to a viability status, i.e. a regulatory capital ratio at 8% of RWAs. From here on, we then define as *losses* for each bank and each iteration, the unexpected losses in excess of capital plus recapitalization needs, as follows:

$$ExLR_{ji} = \max(GL_{ji} - K_i + 8\% RWA_i, 0).$$

Excess losses plus recapitalization needs for individual banks yield the following aggregate loss distribution for each iteration:

$$L_j = \sum_{i=1}^{I} ExLR_{ij}. \tag{1}$$

Depending on the banks in scope, the aggregate distribution can be at the country or EU level. Like for individual bank losses, each point in the distribution (i.e. each iteration) is associated to a different level of distress.

4.2 A crisis not triggered by transition risk

This application of the model presented above aims to assess the impact of transition risk during a systemic banking crisis which is *not* triggered by climate transition risk. We do so by comparing the following two situations:

1. There is no transition risk and actual RWA properly reflect the level of risk;

[10] See Di Girolamo et al. (2017) for a discussion on a more sophisticated correlation structure.

2. Transition risk is introduced by keeping regulatory capital constant, while adjusting RWA to reflect the exposure of banks to high carbon and fossil-fuel-related assets and their increased riskiness (see Figure 2).

We focus on the (very) right tail of the loss distribution, which is associated to a severe, but plausible, banking crisis. Technically, this part of the distribution corresponds to values of Z_j which are farther than 3 standard deviations from the mean.[11] This corresponds to the following iterations $\widetilde{j}$:

$$\widetilde{j} = \{j \text{ such that } Z_j > \mathbb{E}(Z_j) + 3\text{std}(Z_j)\}.$$

Systemic losses (SL) are then computed by taking the expected value of bank losses on the selected iterations, which corresponds to the Expected Shortfall concept:

$$SL \quad = \quad \mathbb{E}_j[(L)_j \mid j \text{ in } \widetilde{j}]. \tag{2}$$

By comparing systemic conditional losses with and without transition risk one can derive how much additional capital banks should hold to reach an adequate level of protection in the face of a crisis, considering transition risks as material.

4.3 Transition risk as a trigger of a crisis

In this second application of the model, we investigate whether transition risk could be the trigger of a crisis. In particular, we apply SYMBOL to identify those banks that could fail due to a materialization of transition risk but would not fail otherwise. Then, we model a mechanism whereby, owing to these initial defaults, a sell-off of high-carbon and fossil-fuel-related assets takes place. A depreciation of these assets, in turn, puts more banks under stress. The fire-sale continues until the system reaches a new equilibrium, i.e. no more banks default.

In the first step, based on the loss distribution, we identify those banks that given the same shocks default in case 2 above (i.e. when transition risk is introduced), but do not default in case 1 above (i.e. in the absence of transition risk). Formally, these correspond to the banks and iterations satisfying the following condition:

[11] As Z_j may be seen as a negative economic shock, this calibration is representative of a recession comparable to those due to the global financial crisis and the Covid pandemic.

$$\begin{cases} ExLR_{ij} & = 0 \text{ without transition risk,} \\ ExLR_{ij} & > 0 \text{ with transition risk.} \end{cases}$$

The systemic loss due to transition risk is computed as in Eq. 2, considering only iterations satisfying the above condition. This is a first order systemic loss, as so far no amplification mechanisms are considered.

In the second step, we introduce dynamic features in the model, namely: i) a dynamic balance sheet, i.e. the possibility for banks to reallocate their portfolios; and ii) a depreciation of FFA (see Section 3). In particular, we assume that bank failures may trigger a sequence of fire-sale on FFA, which is reflected on the one hand, in a lower share of FFA on banks balance sheets, and on the other hand, in lower market prices for those assets.[12] The fire-sale mechanism is modelled as follows. We assume that the initial sell-off of assets exposed to transition risk only leads to a very limited depreciation of such assets, corresponding to $\delta = 0.3\%$.[13] If any additional bank defaults, this triggers a further sell-off.

The size of the depreciation at each round of the fire-sale can be modeled in different ways. We focus on two alternatives, namely linking the depreciation size to the number of banks defaulting (Option 1), and assuming exponential dynamics (Option 2). With respect to option 1, it is reasonable to assume a sharper depreciation if the number of bank defaulting at each round increases, and a milder depreciation when bank defaults start to decrease. Formally, at each round of the fire-sale r the size of depreciation is proportional to the number of failing banks in previous round (Option 1):

$$\delta_{t_r} = \begin{cases} 0.003 \text{ if } t_r = 1 \\ \max\left(\frac{D_{t_r-1} - D_{t_r-2}}{D_{t_r-2}}, 0.003\right) \text{ if } t_r > 1 \text{ and } D_{t_r-1} > 0, \end{cases}$$

where D is the number of defaults. The sequence stops when no more banks fail. As for Option 2, the exponential depreciation is modelled as follows:

$$\delta_{t_r} = 0.003 * \exp t_r.$$

[12] We do not include mortagages, as such assets are not subject to mark-to-market accounting.

[13] For $\delta = 0.3\%$, a fire sale is triggered under any plausible value for the size of the initial sell-off (i.e. θ, see below). Focussing on the benchmark exercise where $\theta = 0.05$, a depreciation of $\delta = 0.15\%$ would be enough to trigger a fire-sale, while the overall result of the modelling exercise in terms of losses would not change.

Finally, while triggering further defaults among banks in the system, the fire-sale also implies changes in banks' balance sheets, as the share of FFA decreases. Formally, we assume that when the fire-sale starts, together with a depreciation of FFA their share in banks' balance sheets also decreases by a percentage θ:

$$FFA_{t_r} = \begin{cases} FFA_{t_r} * (1-\theta) \text{ if } t_r = 0 \\ FFA_{t_r - 1} * (1-\delta_{t_r}) \text{ if } t_r > 0. \end{cases}$$

In the benchmark exercise we assume $\theta = 0.05$, i.e. banks sell off 5% of their high-carbon assets in period 0 of the fire-sale, and also test values of $\theta \in \{0.1, 0.2, 0.3, 0.4, 0.5, 0.6\}$. With respect to subsequent periods, it becomes increasingly difficult to sell assets that are subject to a fire-sale, hence we assume for simplicity that the share of FFA does not significantly change. However, it would be possible to use any suitable functional form.

5 Results

5.1 A crisis not triggered by transition risk

In a crisis situation, not triggered by transition-related factors, aggregate bank losses for the EU27 increase by 8% when including the transition risk faced by financial institutions as a consequence of the exposure to high carbon activities. In fact, losses increase proportionally more in the case of crises of a lower severity. For example, in the case of a crisis due to GDP growth below its mean by 1 standard deviation (as opposed to 3 standard deviations, which is the benchmark case), losses would increase by 12% owing to transition risk.

Even though transition risks seem to bring about contained, though not irrelevant, additional financial losses, our results uncover that a few countries would be affected particularly strongly. Indeed, Figure 3 shows that the situation is quite heterogeneous across jurisdictions, with some countries subject to very mild (or almost zero) impacts and others where losses can increase substantially with respect to the baseline of no transition risk. This is the case in particular for five countries, where the increase in overall losses is around 20%, and up to 40% in one case. This finding reflects the large variability in the exposure to high-carbon and fossil-fuel-related assets across Member States, and the associated high concentration of transition risks. This finding also calls for a more decisive reduction of the exposure to transition risk in particular countries.

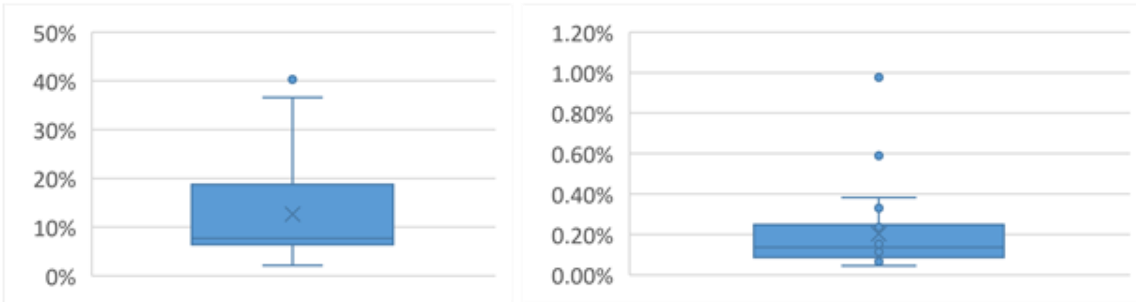


Figure 3: Loss increases in percentage terms (left panel) and losses as share of TA (right panel)

5.2 Transition risk as a trigger of a crisis

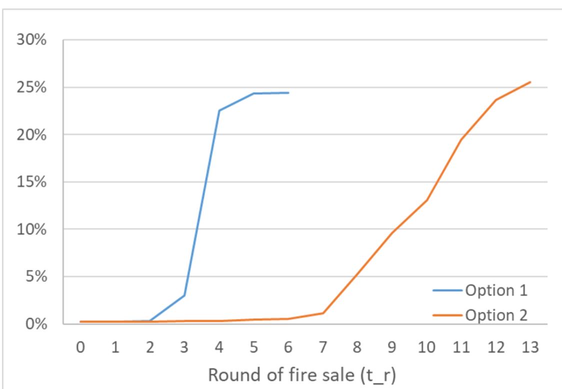
Based on the SYMBOL simulation, in a business-as-usual (i.e. no crisis) scenario around 20% of the banks could fail should transition risks materialize, with one or two actually failing in each Monte Carlo iteration. Furthermore, we calculate that should a small depreciation of such assets follow, this would trigger additional bank defaults. Indeed, some other, particularly exposed financial institutions would suffer substantial second-round losses due to the depreciation of high-carbon assets. The first panel in Figure 4 shows the cumulative share of bank at risk over the total number of banks in the sample, at each period of the fire-sale , corresponding to different depreciation paths. For both considered paths, the fire-sale stops only after around 25% of the banks fail. In reality, this would not happen, as bank recovery mechanisms and troubled assets purchase programs would be triggered way before such a large number of banks becomes insolvent. Therefore, these results show that should such a crisis break out, we should be prepared to use public finances to avoid systemic consequences of this magnitude. Based on our simulation, 30% of all banks would be immune from the risk of defaulting due to a fire-sale.

Looking at aggregate financial losses, Figure 4 shows their evolution as percentage of Total Assets, under different paths for the progressive depreciation of high-carbon assets. Numbers suggest that, given the small size of the banks defaulting in the first phases of the fire-sale, losses for the banking system as a whole would be initially very contained. However, the dynamics would then become exponential. By rescaling the results we obtain based on our sample to the whole population of EU banks, we calculate that losses would initially remain under €1 bn for some periods but then start to sharply increase under all paths.

Hence, it is at the latest at this point that a backstop could still manage the crisis with limited recourse to public finances. Going forward, the extra risk of holding harmful assets could lead to on average losses corresponding to 1% of total assets, i.e. around 335-360 bn for the EU banking sector as a whole. It should be noted that the distribution of additional losses at the bank level is highly skewed to the left, with a relatively limited number of cases leading to disproportionately large losses. The risk is thus not only potentially large but also highly unpredictable in nature, owing to the large variance of the loss distribution.

Appendix B shows results for alternative values of the parameter θ. Clearly, the higher the share of FFA that banks manage to sell-off at the beginning of the fire-sale, the lower the overall losses they will suffer. However, it would be difficult to defend a parametrization corresponding to banks being able to shed a large portion of their FFA, in a context where all financial market participants are trying to do the same.

Based on these results, an extra capital buffer proportional to the transition risk faced by each institution would succeed in protecting the system, as all banks would be adequately protected and hence, a fire-sale would not even start. An extra capital buffer of around 0.5% of RWA on average, or 3% of existing capital, would be sufficient. However, Figure 5 shows that banks where transition risks are concentrated would need to set aside more capital, up to 4.5% of RWA in very extreme cases.



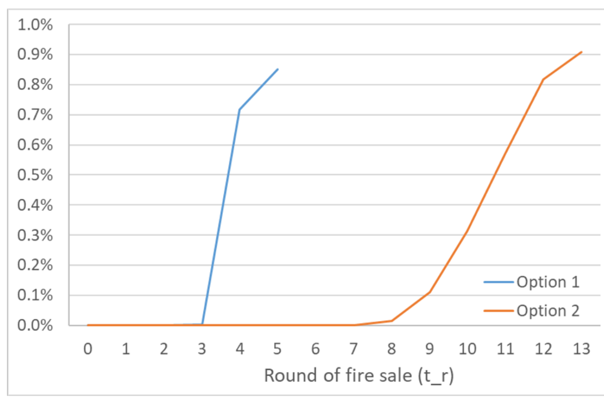


Figure 4: Evolution of the fire-sale in terms of cumulative share of banks at default (left panel) and cumulative share of bank losses as share of TA (right panel), under two alternative depreciation paths.

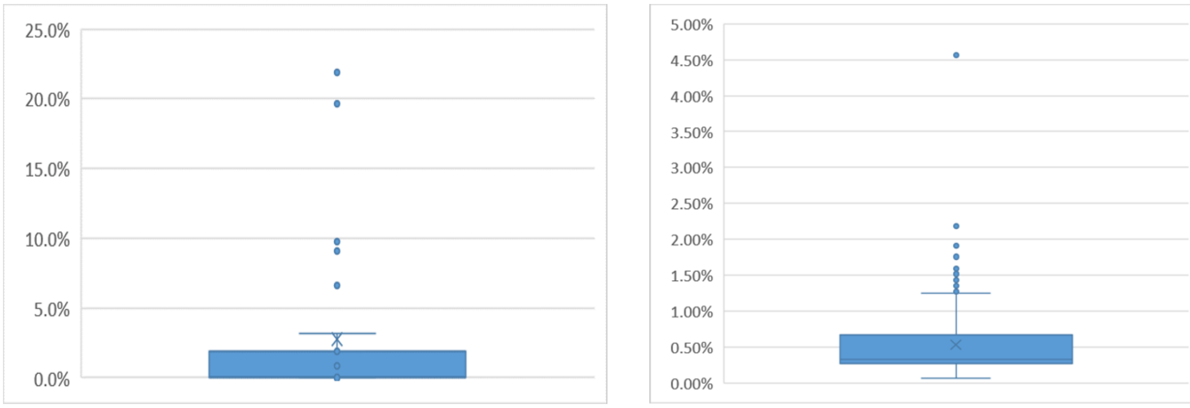


Figure 5: Distribution of bank losses after a fire-sale as share of TA (left panel) and of additional capital needed to offset transition risk as share of RWAs (right panel).

5.3 Losses under an orderly transition

This section explores the impacts of a fire-sale as described in Section 4.3 in a context where an orderly reduction in transition exposures has taken place before the financial crisis breaks out. The reduction in transition-risk exposure takes place as the weight of fossil-fuel and high-carbon activities decreases in the economy as a whole. In turn, financial assets funding companies and activities become also greener. It should be emphasized that no shedding of high-carbon assets needs to take place in an orderly transition, as assets themselves become greener in line with the firms they finance.

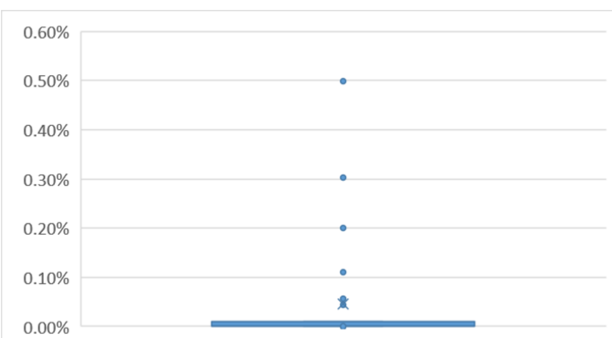
Of course, an orderly transition is an economic and societal process that by definition takes place over a rather extended period of time. Hence, this modelling experiment is not a stress test, given that a substantial greening of the economy can only materialize in the medium to long term. Rather, it should be intended as an assessment of the reduction in systemic risk due to the reduction in transition risk, which would be brought about by the green transition.

We consider that greening can happen in two alternative ways, notably either by decreasing risk concentration or not. To investigate the case in which risk concentration decreases, we test a situation where the economy has become sufficiently green for banks to only be exposed to transition risk for maximum 5% of their total assets. Indeed, based on the results in the previous section, we know that banks whose share of fossil fuel assets is higher than 5% are much more likely to get in trouble in a fire-sale. Given the high concentration of transition risk characterizing the status quo (see Section 3), assuming that all banks reach the same low exposure to transition risks amounts to assuming that banks that are more exposed green their balance sheet quicker than less exposed banks. In turn, this means that countries whose economies currently rely more heavily on fossil fuels and where production processes are less energy efficient, put more efforts in transitioning compared to others and/or that banks that are more exposed to brown assets take a more active role in steering the transition.

We show that a substantial greening of the economy would indeed be quite effective in reducing the negative impact of disorderly market dynamics. Notably, given a much greener economy, losses from a fire-sale of FFA would be reduced by a factor of 10 compared to today.

In the case of a greener economy and much less exposed banks, the additional capital requirements needed to completely offset residual transition risks for the EU banking sector would be less demanding compared to the status quo, i.e. around 0.4% of RWA on average (or 2% of existing capital), and up to 2% of RWA for the most exposed banks (see Figure 6). This means that the level of extra capital required to protect the system could gradually decrease over time, provided that the green transition gains traction.

Finally, we explore the alternative situation, whereby the economy becomes greener due to a uniform reduction in the exposure to transition risk across banks. This implies that risk concentration remains high, though the overall level of risk exposure decreases. In this case, a comparable loss reduction to the previous case, i.e. larger than 90%, would be achieved if all banks would almost halve their FFA. More precisely, aggregate FFA would need to decrease to 1.5% of TA from the current 2.7%. Interestingly, a slightly smaller reduction, to 1.6% of TA, would only reduce losses by 60%. The overall greening effort is smaller in the case of a reduction of risk concentration, as FFA in the system as a whole need to be reduced from 2.7% to 1.8%, as opposed to 1.5%. In other words, reducing transition risk where it is concentrated is a more effective strategy to reduce systemic risk.[14]



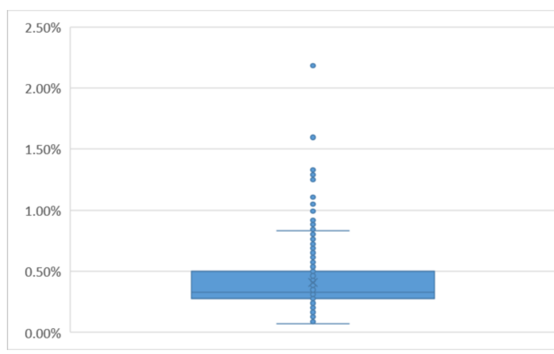


Figure 6: Distribution in case of an orderly transition of bank losses after a fire-sale as share of TA (left panel) and of additional capital needed to offset transition risk as share of RWAs (right panel).

[14]Detailed results are available upon request.

6 Conclusions

In this paper we propose a methodology to assess the potential bank losses associated with transition risk. We show how, if fossil-fuel and high-carbon assets are indeed 15-25% more risky than reflected in current risk assessments, this could lead in some countries to significant (up to 40%) increases in losses in a static systemic financial crisis scenario.

Moreover, we calculate that even in a business-as-usual scenario few banks could default should transition risks materialize. We show that, should these losses trigger disorderly market adjustments, fire-sale dynamics could lead to significant losses for the EU banking system as a whole and to the default of a large number of institutions. This fire-sale process can be effectively tackled with the introduction of an extra capital buffer accounting for transition risk in banks' balance sheets, which based on current exposures should be around 0.5% of RWAs on average. However, as the economy becomes greener and banks' balance sheets become less exposed to high-carbon assets, this capital buffer could be reduced as the risk of a fire-sale becomes lower, as well as the associated potential losses.

Overall, our findings support the idea that banks that are financing high carbon activities should be asked to increase their protection against the consequences they could face owing to the economy shifting to low-carbon, as losses could be sizeable and spill-over to the wider banking sector via systemic channels. We show that the consequences of a materialization of transition risks could be systemic and call for public intervention. Further research could investigate more in detail the impact of transition-risk-related financial crises for public finances.

Appendices

A Data inputs

Table 1: Sample descriptive statistics

	N banks	TA, bn€	RWAs, bn€	K, bn€
AT	26	651	290	56
BE	14	1,138	388	78
BG	9	48	25	6
CY	9	48	22	4
CZ	12	247	91	21
DE	19	5,888	2,036	357
DK	22	1,095	259	61
EE	7	40	16	5
ES	44	3,883	1,496	248
FI	20	861	265	55
FR	100	12,550	3,120	588
GR	6	293	167	25
HR	7	65	36	8
HU	14	143	77	15
IE	8	575	233	46
IT	43	3,119	1,102	207
LT	4	28	9	2
LU	8	218	81	17
LV	9	20	8	2
MT	4	23	9	2
NL	14	2,169	679	148
PL	14	361	208	39
PT	14	366	176	39
RO	8	76	38	9
SE	14	994	257	58
SI	7	40	24	4
SK	5	71	39	6

B Transition risk as a trigger of a crisis under alternative levels of initial disinvestment

Table 2: Fire sales losses for Option 1, under alternative values of the parameter θ

θ	0	1	2	3	4	5	6	7	8	9
0.1	0%	0%	0%	0%	0.47%	0.77%	0.78%	0.78%	0.78%	0.78%
0.2	0%	0%	0%	0%	0.16%	0.63%	0.65%	0.65%	0.65%	0.65%
0.3	0%	0%	0%	0%	0.06%	0.47%	0.5%	0.5%	0.5%	0.5%
0.4	0%	0%	0%	0%	0.01%	0.27%	0.33%	0.33%	0.33%	0.33%
0.5	0%	0%	0%	0%	0%	0.11%	0.19%	0.19%	0.19%	0.19%
0.6	0%	0%	0%	0%	0%	0%	0.01%	0.04%	0.06%	0.06%

Table 3: Fire sales losses for Option 2, under alternative values of the parameter θ

θ	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0.1	0%	0%	0%	0%	0%	0%	0%	0%	0.01%	0.09%	0.28%	0.52%	0.75%	0.84%
0.2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.06%	0.21%	0.43%	0.63%	0.7%
0.3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	0.15%	0.33%	0.51%	0.57%
0.4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.01%	0.09%	0.24%	0.39%	0.44%
0.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.04%	0.15%	0.27%	0.31%
0.6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.01%	0.07%	0.15%	0.19%

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