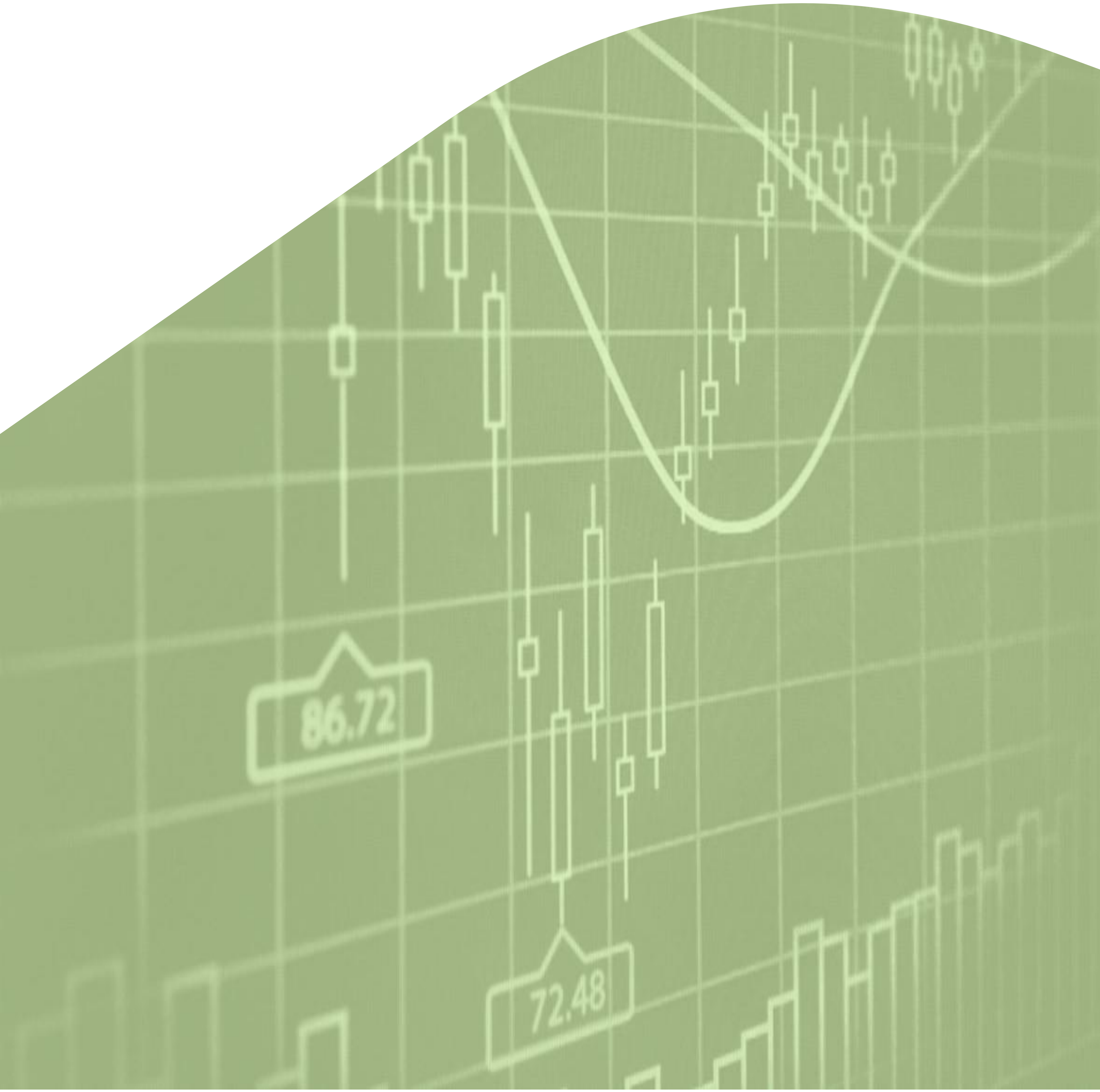
19 December 2023
ESMA50-524821-3073

ESMA TRV Risk Analysis

Sustainable Finance

Dynamic modelling of climate-related shocks in the fund sector



ESMA Report on Trends, Risks and Vulnerabilities Risk Analysis

ISBN 978-92-95235-03-8, DOI 10.2856/403241, EK-02-23-265-EN-N

European Securities and Markets Authority (ESMA)
Economics, Financial Stability and Risk Department
201-203 Rue de Bercy
FR-75012 Paris
risk.analysis@esma.europa.eu
ESMA - 201-203 rue de Bercy - CS 80910 - 75589 Paris Cedex 12 - France - www.esma.europa.eu
Cover photo: Image Microsoft 365

Sustainable Finance

Dynamic modelling of climate-related shocks in the fund sector

Contact: alexander.harris@esma.europa.eu[1]

Summary

Identifying vulnerabilities of the investment fund sector in climate stress scenarios is of vital importance given the sector's size in the financial system and its crucial role financing the green transition. In line with recent ESMA mandates in this regard, this article outlines a first approach to dynamically modelling the impact of asset price shocks from adverse scenarios involving climate-related risks. A given set of asset price shocks is the core input to the model, which comprises static impacts – the immediate price impact on funds' direct and indirect asset holdings – plus dynamic impacts, such as inflows and outflows by investors and portfolio rebalancing by managers. The present analysis focuses on the direction and sequencing of dynamic impacts, showing that dynamic responses can exacerbate falls in total fund assets due to outflows following an initial shock. Portfolio rebalancing, in contrast, only affects the sensitivity of fund valuations to subsequent shocks. The article concludes by discussing the sensitivity of the results and possibilities for further research.

[1] This article was written by Adrien Amzallag, Alexander Harris and Paul Reiche.

Introduction

The investment fund sector, with assets under management (AuM) of over EUR 60tn globally and EUR 17tn in the EEA, is a key component of the financial system.[2] Its exposure to climate-related repricing shocks has implications for financial stability, especially as such shocks could arise during adverse macroeconomic conditions. At the same time, the sector's crucial role in financing economic activity and the green transition may be limited by climate shocks. The task of identifying vulnerabilities in the investment fund sector to climate-related shocks is therefore of major importance both from the perspective of financial stability and sustainability.[3]

To anticipate the impact of climate-related shocks on the financial system, the European Commission (EC) has mandated the ESAs to perform regular climate change stress tests or scenario analyses and to develop methods, parameters and scenarios for supervisors to use in their own climate stress testing (EC, 2021). In addition, as detailed in Textbox 1, the ESAs have a mandate to conduct a one-off climate change stress test across the financial sector in coordination with the ECB and ESRB, reporting results by 1Q25 (EC, 2023).

ECB and ESRB (2023) present recent work on macroprudential frameworks for managing climate risk, including simulations for the investment fund sector by ESMA based on the methodology set out in this article, and building on previous reports (ECB and ESRB 2021; 2022). Within the fund sector, Amzallag (2021) provides climate risk scenario analysis of a network of funds, indicating potential system losses of over EUR 400bn[4]. Crisóstomo (2022) estimates investment fund losses due to climate transition risk of EUR 17.5bn in Spain alone, equivalent to over EUR 800bn in losses if extrapolated to the whole European fund sector.

To support the development of ESMA's climate-related stress testing of the investment fund sector in line with these new mandates, this article outlines a possible dynamic approach to modelling the impact of asset price shocks.

First, the article explains how climate scenarios are specified and used to simulate shocks to asset prices, through modelling work carried out by other authorities and international bodies.

Next, the article describes ESMA's dynamic modelling of effects within the investment fund sector given a set of asset price shocks, including an example calibration.[5] The model covers static impacts – the immediate price impacts on funds' direct and indirect asset holdings – and dynamic impacts, such as inflows and outflows by investors, portfolio rebalancing by managers and associated second-round price impacts. These dynamic effects are especially relevant among funds, which typically offer frequent redemptions and have relatively liquid positions compared with other parts of the financial sector. Finally, the article presents and discusses the main findings.

Textbox 1

Fit-for-55 one off exercise

In March 2023, the EC issued a request for a one-off scenario analysis exercise to be conducted jointly by the ESAs, the ECB and the ESRB, as envisaged by the Commission's Strategy for Financing the Transition to a Sustainable Economy (EC, 2021; EC, 2023).

The one-off exercise will test the resilience of the EU financial system during the implementation of the Commission's 'Fit For 55' package to reduce net greenhouse gas emissions by at least 55% by 2030 from 1990 levels. The exercise aims to anticipate financial shocks that could threaten financial stability or hinder the financing of the green transition, with results due by 1Q25. The Commission's request specifies that the exercise should analyse two adverse scenarios:

i. A first scenario involves climate-change related risks that materialise in the near term, with asset price corrections triggered by a sudden reassessment of transition or physical risks.

ii. A second scenario combines these climate-related risks with other, non-climate-related stress factors.

The analysis in the present article is not based on either adverse scenario from the one-off exercise, and the illustrative results below are separate from that exercise. Nonetheless, ESMA may adapt the general modelling framework presented here to specific mandates and tasks, including the one-off exercise.

[2] Sources: Global figure from Investment Company Institute (2023) covers regulated open-ended funds as of 2Q23. Assumed exchange rate: EUR/USD = 1.05. EEA figure from European Fund and Asset Management Association (2023) covers total Assets under Management (AuM) in UCITS and AIFs, excluding those domiciled in UK, as of end-2022.

[3] As explained in the next section, these climate risks include transition risks and physical risks. The dynamic modelling framework presented can be applied to asset price shocks arising from either risk source (or both). The adverse scenario used to illustrate the model considers transition risk.

[4] In that analysis, "brown" funds' losses are 2-3 times those of "green" funds and have greater systemic impact.

[5] For illustration, the article considers an adverse scenario over a 5-year horizon, though longer-term modelling could follow the same approach.

Identifying scenarios

Repricing shocks may arise in different climate scenarios, which can be classified according to their level of physical risks and transition risks (NGFS, 2020; BIS, 2021). Physical risks are financial costs associated with changes in climate. These changes may be acute, such as more frequent or severe adverse weather events, or chronic, such as sea level rises. Transition risks involve changes to climate policy, changes in consumer behaviour or changes in the development of technologies that affect the shift to a lower-carbon economy (via net emissions or in relation to the mitigation of physical risks).

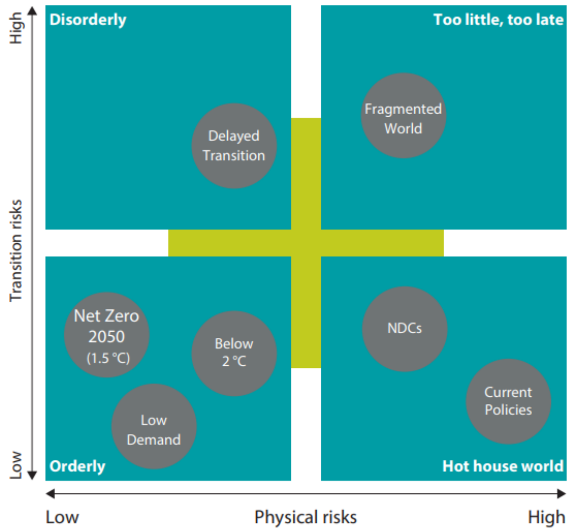
The Network for Greening the Financial System (NGFS) has produced a range of different scenarios to facilitate comparable analysis across jurisdictions (Chart 1).[6] For example, the *Current Policies* scenario, in which only currently implemented policies remain in place in the coming decades, entails higher physical risks than alternative scenarios in which additional policy action is taken to reduce emissions. In the alternative scenarios, new policies are implemented that reduce physical risks.

However, while policy action may be carried out in an orderly fashion through timely, coordinated measures (bottom left quadrant of Chart 1), there is also a risk that it could be undertaken in a disorderly fashion, delayed or uncoordinated across countries and economic sectors (upper quadrants of Chart 1). For instance, the *Below 2°C* scenario assumes that climate policies become steadily more stringent. The *Delayed Transition* scenario results in similar levels of physical risk, but via later, more abrupt policy tightening that brings greater transition risk.

Macroeconomic conditions

Fully identifying a scenario for the purpose of assessing financial sector vulnerabilities includes specifying macroeconomic conditions. For example, a baseline scenario may assume relatively benign macroeconomic variables in conjunction with current climate policies. When identifying adverse scenarios, it is important to consider the possibility that climate risks may materialise at a time of existing macroeconomic stress.[7] Indeed, adverse macroeconomic conditions may complicate efforts to achieve a timely, orderly transition. Additionally, physical risks can affect macroeconomic variables and increase market volatility (e.g. through physical disruption of value chains, operational outages, lower agricultural yields, or higher morbidity).

Chart 1
NGFS climate scenarios
Range of climate scenarios



Note: Diagram reproduced from NGFS website, which gives full definitions of the scenarios, as updated in 2023 (Phase IV). The positioning of the scenarios (grey circles) is approximate. The top left quadrant represents disorderly scenarios with relatively high transition risks and low physical risks. In particular, the 'Delayed Transition' scenario assumes global annual emissions do not decrease until 2030. Strong policies are then needed to limit warming to below 2 °C, and negative emissions are limited. The top right quadrant represents scenarios where limited action is taken late, entailing relatively high transition and physical risks. In particular, 'Fragmented World' assumes a delayed and divergent climate policy response among countries globally. Those with net zero targets only achieve 80% of the targets, while other countries follow current policies. The bottom right quadrant involves high physical risks but lower transition risks. 'NDCs' = Nationally Determined Contributions, which includes all pledged policies even if not yet implemented, such that emissions decline but nonetheless lead to 2.6 °C of warming. 'Current Policies' assumes only currently implemented policies are preserved. The bottom left quadrant involves lower physical and transition risks. 'Below 2 °C' gradually increases the stringency of climate policies, giving a 67 % chance of limiting global warming to below 2 °C. 'Net Zero 2050' limits global warming to 1.5 °C through stringent climate policies and innovation, reaching net zero CO_2 emissions around 2050. 'Low Demand' assumes that significant behavioural changes, reducing energy demand, mitigate the pressure on the economic system to reach global net zero CO_2 emissions around 2050.
Sources: NGFS, ESMA.

Mapping scenarios to asset prices

For a given scenario, the transition or physical risks involved will directly affect the financial position of firms across the economy. This direct impact may be greater in some sectors than others. For example, the profitability of firms carrying out carbon-intensive activities such as transportation or resource extraction may be

[6] The NGFS is a group of central banks and supervisors committed to sharing best practices, contributing to the development of climate –and environment– related risk management in the financial sector and mobilising mainstream finance to support the transition toward a sustainable economy. As of 24 November 2023, the NGFS consisted of 129 members (including ESMA) and 21 observers. The scenarios discussed in this article are from Phase IV of the NGFS framework.

[7] The need to consider vulnerabilities arising from climate-related and non-climate-related risks materialising together is highlighted in the mandate for the one-off scenario testing exercise set out in EC (2022).

especially sensitive to an increase in carbon prices or availability of emission allowances, or other constraints imposed by new climate policies. An increase in transition risk under a given scenario versus a baseline will therefore lead to a relatively large fall in equity prices or increase in bond yields for these firms, other things equal.

Additionally, transition or physical risks will affect firms' financial positions through macroeconomic channels, e.g. by reducing economic growth compared to the path implied by the assumed underlying macroeconomic conditions.

Finally, quantifying the overall impact of transition and physical risks in different scenarios is complicated by interactions between direct and indirect effects and potential feedback mechanisms. For example, changes in asset prices may lead to a change in the discount rate, which in turn affects asset prices.

Taking these effects into account results in a specification of asset price trajectories over time versus a baseline. This specification is the starting point for detailed modelling of the impact on a part of the financial sector such as investment funds.

Illustrative assumed scenarios

Given a scenario and a baseline that specify asset prices for a given period and frequency, the impact on the investment fund sector can be modelled in different ways. To illustrate the different possibilities, we consider a scenario and baseline over 5 years (2023 to 2027) provided in ECB and ESRB (2023), as follows.[8]

Baseline scenario:

- Macroeconomic conditions per baseline in EBA (2023).
- Climate-related variables per NGFS Current Policies scenario.

Adverse scenario:

- Macroeconomic conditions per adverse scenario in EBA (2023), driving the majority of the drop in asset prices.
- Climate-related variables are shocked in 2023 due to a sudden, disorderly change in policy stance in the context of adverse macroeconomic conditions, as in ECB and ESRB (2023).

The adverse scenario considered for expositional purposes in this article involves an initial shock. The shock is a combination of (i) adverse macroeconomic conditions that arise for non-climate-related reasons and (ii) a climate-related shock in the form of a disorderly transition, including a spike in the carbon price.[9] The adverse scenario aims to be severe but plausible. It generates very large asset price changes, with equities typically falling in price by 45-70% in the first year primarily due to a sudden deterioration in macroeconomic conditions, with the effect exacerbated as governments suddenly impose climate policy measures in a disorderly fashion. In subsequent years, asset prices are assumed to follow a gradual and partial recovery. The specification of the scenario is outside the scope of the ESMA modelling approach within the fund sector. ECB and ESRB (2023) provide an accompanying narrative.[10]

Modelling investment fund sector impacts

To model how the investment fund sector is affected by a given scenario, the starting point is a set of asset prices. For simplicity, this article restricts attention to shocks to equity prices, and considers the resulting change to the value of EEA-domiciled investment funds.[11]

[8] The scenarios in ECB and ESRB (2023) combine shocks from the 2023 EBA stress test and the 2022 version (Phase III) of the NGFS scenarios. Shocked variables vary across countries and sectors. The main adverse scenario implies that the carbon price increases more than 20 times as part of an initial shock, which is modelled as frontloaded version of the NGFS Delayed Transition scenario. ECB and ESRB (2023) also consider an additional adverse shock in the form of an increase in uncertainty and risk premia, which is excluded from the present analysis.

[9] Around 80% of the equity price shock is in fact attributable to the macroeconomic conditions. As noted above, climate risks may materialise at a time of existing macroeconomic stress, creating a vulnerability. The modelling framework would however apply equally to a scenario with price shocks arising solely from climate-related risks (whether physical risk, transition risk or both).

[10] A summary of the possible narrative is as follows. Following severe natural disasters, increasing societal and political pressure, and global tensions driving energy markets away from climate objectives requires a sudden change in policy stance, with governments implementing stringent regulations and a dramatic tightening of carbon pricing policy. This major crystallisation of transition risk comes alongside a sudden and severe macroeconomic deterioration.

[11] Both direct and indirect holdings of equities (through funds holding shares in other funds with direct exposure to equities) are subject to shocks in the illustrative modelling. Holdings of assets in other classes such as

Conceptual framework

The impact of a price shock to underlying assets can be broken down into components, as follows.

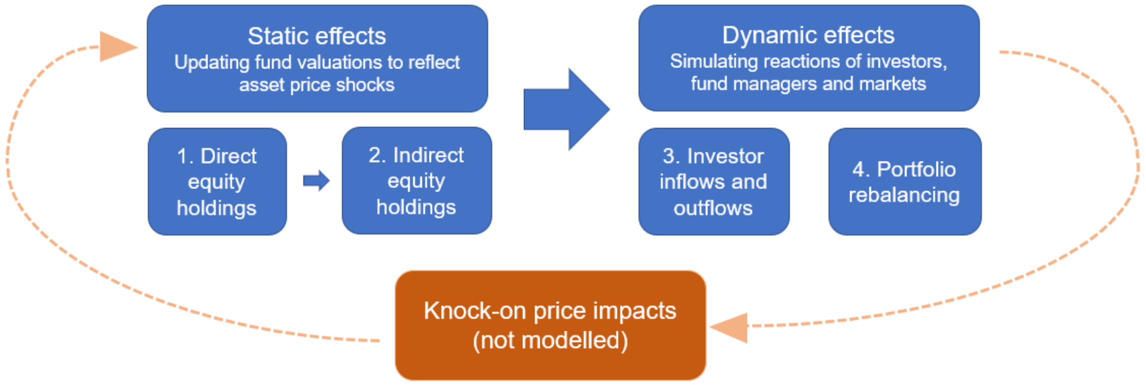
1. **Static effects**. A shock to equity prices leads to an immediate reduction in the value of funds directly holding equities. Additionally, there is an immediate reduction in the value of indirect equities holdings, e.g. where funds hold shares in other funds that hold equities.[12]

2. **Dynamic effects**. Once the value of funds is adjusted for the static effects, there may be additional effects due to the actions of economic agents. These include **(i) inflows and outflows** by investors in response to changes in their financial positions and expectations; **(ii) portfolio rebalancing**, whereby fund managers buy or sell assets in line with their mandate, in response to the changing financial conditions. Additionally, if these dynamic responses lead to large-scale buying or selling of certain assets, there may be **(iii) knock-on (second-round) price effects**. For example, if there is initially a large fall in equities prices for a certain sector, asset managers may decide to 'tilt' their portfolios away from the sector. If many managers make the same trade, even if only a small value of each portfolio is liquidated, the selling pressure could push down prices of the equities even further.

Modelling these effects requires them to be calculated in sequence. The static component is calculated first, as the price shock takes immediate effect. Investor flows and portfolio rebalancing, on the other hand, take place over a longer time horizon – whether days, weeks or months. Subsequent second-round price effects are sensitive to the assumed time horizon, as rapid net sales or purchases of assets result in crowded trades, leading to price spikes.

In principle, this modelling process can then be iterated within a given time period (Chart 2), as the second-round price changes can be used to update the value of portfolio assets, which results in further investor flows and rebalancing according to the assumed reaction functions. These actions, in turn, then generate third-round price changes, and so on.[13]

Chart 2
Overview of ESMA modelling framework
Sequencing and potential iteration of static and dynamic effects



Note: Schematic representation of sequencing of modelling stages (numbered boxes). Potential for iteration via knock-on price impacts represented via orange dashed lines; such price impacts are not modelled in the present analysis.
Source: ESMA.

A related modelling question is the extent to which any knock-on price impacts in one year would persist in subsequent years. There are arguments for either approach, as follows.

bonds, cash and derivatives (even those referencing equities) are excluded from the analysis.

[12] Indirect static effects are calculated via iteration, as follows. First, define S1 to be the set of funds that hold direct equities only, for which direct static effects are first calculated. Then define S2 to be the set of funds that hold shares in funds in S1 and otherwise only directly hold equities. Given the updated valuation of funds in S1, static effects in S2 can be calculated, and so on at higher levels. Assuming the population of funds is *regular* as in Gourdel and Sydow (2022) – i.e. there is no subset containing only funds that are fully owned by each other – then it can be partitioned in this way and static effects calculated for all funds.

[13] The precise conditions under which this process converges to a stable set of fund portfolios is left to further research. Informally, however, convergence happens if given price impacts lead to smaller investor and manager reactions that in turn yield smaller next round price impacts.

1. Changes in demand for assets may be temporary if flows and rebalancing are a one-off phenomenon. In particular, if price impacts are largely attributable to a burst of trading activity resulting in 'crowded trades', their effect will be largely transient. If so, knock-on price effects will only apply within-period, not in subsequent periods.
2. To the extent that the buying and selling of assets is due to lasting shifts in demand from fund investors and managers, the knock-on price impacts may be reflected in equilibrium market prices in the longer term.

In principle, it would be possible to model some combination of the two – whereby some but not all knock-on price impacts persist into future years. For simplicity, however, we exclude modelling of knock-on price impacts from the present analysis. As ESMA work continues in this area, future modelling may seek to capture such impacts. The section below on calibration discusses the possibility further.

Data used

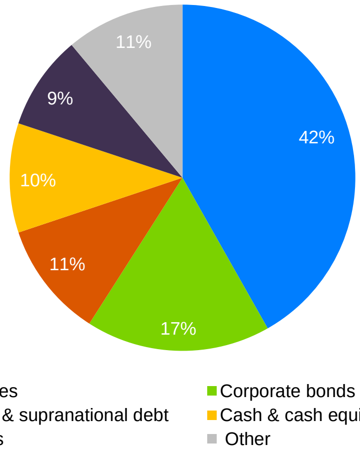
In addition to the simulated equity price shocks, we use an extensive dataset of fund portfolio holdings obtained from Morningstar and enriched with further information from Refinitiv Eikon. The dataset represents a portfolio snapshot as of June 2023 and covers around 19 000 investment funds from the EEA with EUR 10 trillion assets under management. Around 16 000 of the funds in the sample are UCITS, 700 disclose under Article 9 of the Sustainable Finance Disclosure Regulation (SDFR) and 1 400 disclose under SFDR Article 8.[14] Equities form the largest asset class (Chart 3). Around 34% of equities are issued by companies from the US, followed by France with 7%, the UK with 6%, and China, Germany, and Japan with around 5% each.

In the illustrative exercise, we consider all funds in the dataset, but only equity holdings are subject to a price shock. Results are presented for these equity holdings, taken together.

The raw portfolio data have been cleaned by removing duplicates and funds with reported position values older than 2022.[15] To account for outliers, e.g. currency conversion or fat-finger errors, the largest and smallest 0.5% of fund portfolio positions are removed.

The dataset used does not distinguish between active and passive funds. Especially for the modelling component on portfolio rebalancing, updating the dataset to enable such a distinction would be a useful extension of the work.[16] Nonetheless, as active funds generally represent around 85% of UCITS AuM, simply assuming that all funds follow the same dynamic process is a helpful way to illustrate how the model works.[17]

Chart 3
Distribution of fund portfolio holdings by asset class
Equities are the most-held asset class



Note: Morningstar portfolio holdings dataset, distribution of asset classes.
Sources: Morningstar, ESMA.

Assumptions

Certain assumptions can be made to simplify the modelling. Key assumptions made in the present analysis include the following.

– **Assumption 1.** Changes in fund valuations come solely from changes in the price of fund assets and from simulated asset

---

14 SFDR sets out how financial market participants have to disclose sustainability information. SFDR Article 8 funds promote environmental or social characteristics, while SDFR Article 9 funds have sustainable investment as their objective.

15 Short positions have also been removed. Short positions in equities represent less than 1% of the total net value of equity holdings in the dataset.

16 A distinction relevant to modelling investor flows is whether each AIF is closed-ended or open-ended (UCITS are open-ended. The dataset used in the present exercise does not contain this information.

17 According to Refinitiv Lipper data, as of 2Q23, 86% of AuM among non-ETF equity or bond UCITS was in active funds. If ETFs are included the overall population, around 68% of total AuM is in non-exchanged traded fund (ETF) active funds. Future development of the model presented in the current article could consider calibrating fund flow elasticities conditioning on active versus passive fund status. The rebalancing component could potentially include some rebalancing for passive funds if index composition is assumed to be updated intra-year.

sales/purchases. Neither fund dividend distribution policy nor investor reinvestment are modelled.

– **Assumption 2.** Investor inflows are proportional to positive fund performance (see calibration section below). Outflows are proportional to negative performance up to the point that a fund's net assets are zero, in which case its positions are thereafter set to zero. Implicitly, investors are financially unconstrained. Flows are frictionless and independent across funds.

– **Assumption 3.** Liquidity shocks are not modelled; there is always sufficient demand to meet asset sales at (post-shock) market prices.[18]. Prices are not adjusted based on the dynamic component of the model, as discussed in the previous section.

Calibration

Investor inflows and outflows

As investor inflows are proportional to positive fund performance while outflows are proportional to negative performance (Assumption 2), flows are a piecewise linear function of returns. The strength of the inflow/outflow responses is conditioned on whether a fund is categorised as ESG or non-ESG, using the coefficients found by Renneboog et al. (2011) and summarised in Table 1.[19]

Table 1
Calibration of flow-return elasticities
Negative performance leads to outflows

	Flow-return elasticities	
	Positive return	Negative return
ESG funds	1.014	0.121
Non-ESG funds	1.014	0.285

Note: Flow-return elasticity defined as flows as a % of the fund's value at the start of a time period given % performance during that time period. Positive coefficients therefore imply inflows in the case of positive performance and outflows in the case of negative performance (Renneboog et al. (2011).

In the present scenario analysis, the returns are obtained by comparing the pre-shock fund value to its post shock value. If for instance a fund's value falls by EUR 10mn, there are *outflows* of EUR 1.21mn (if it is an ESG fund), or EUR 2.85mn (if it is non-ESG). If the fund gains in value by EUR 10mn, in contrast, there are *inflows* of EUR 10.14mn.

One limitation of the fund flows calibration is that it assumes linearity in the flow-return relationship. In the extreme market conditions of the adverse scenario, however, it is possible that the linearity could break down, e.g. if investors regard the market as undergoing a paradigm shift.[20]

Portfolio rebalancing

Following the shock to asset prices and resulting net investor flows via the elasticities in Table 1, a fund's manager then acts in two steps, as follows.

– **Divestment and new asset purchases**. The manager divests entirely from the 20% of worst-performing assets (i.e. equities, in the simple case we are considering) in the portfolio. The proceeds are used to purchase new assets, which are the 20% best-performing equities among those held by a 'peer group' of funds.[21]

– **Intra-portfolio rebalancing**: The manager then reallocates capital within the resulting set of assets within the portfolio (i.e. including newly purchased assets and excluding assets from which the fund has divested). For fund i, the total proportion P_i of its value V_i to be reallocated equals the sum of (i) 1% of the fall in the value of the fund based on the static effects, and (ii) 25% of the absolute value of the net investor flows. For the large shocks to asset prices in the illustrative scenario, which are typically falls of over 50%, P_i is a little under 1%, and slightly larger for non-ESG funds than ESG funds. The amount P_iV_i is then redistributed among assets in proportion to their relative performance.[22] Textbox 2 gives an example.

The two steps modelled in the portfolio rebalancing stage are motivated by different

[18] This is a major simplification and limitation, as in reality certain assets may risk being stranded.

[19] The coefficients are for all types of fund. If estimating coefficients directly as part of a future calibration of the model, it would be useful to condition also on the asset type of the fund (e.g. equity funds vs bond funds).

[20] Another consideration when modelling investor flows in response to a shock is that funds could in fact use their cash buffer (around 10% of fund holdings by value in the dataset, as shown in Chart 3) rather than liquidate other assets. However, it seems likely that while cash buffers would be used to meet redemptions up front, in a one-year period that serves as the basis of the present analysis, funds might be expected to replenish their cash buffers back to their pre-shock levels.

[21] This 'peer group' is all funds within the same Morningstar Global Category (e.g. Energy Sector Equity, or US Equity Mid-Cap) and with the same Morningstar ESG rating.

[22] Formally, suppose fund i has N assets, following divestment and new purchases, with values $w_k > 0$ such that $\sum_k^N w_k = V_i$. Denoting the simple average

considerations. Step (1) – selling 20% of fund assets and spending the proceeds on new assets – involves an extensive and sudden change in fund's portfolio composition. The 20% figure used in this part of the calibration is intended to reflect the nature of the adverse scenario, where financial market participants have made a major and sudden reassessment of asset valuations, leading to an extreme and abrupt fall in equity valuations. Setting the percentage of divested assets to 20% within each fund is intended to be keeping with this narrative, though can readily be varied in future applications of the model.

However, the lack of a clear precedent that could be used to estimate the parameter empirically is an important limitation in the modelling approach.

Textbox 2

Example of intra-portfolio rebalancing

To give an example of the second step: if the static effects yield a 50% reduction in the value of an ESG fund i, this will generate outflows of $0.121 \times 50\% = 6.05\%$ of the fund's pre-shock value V_i. The total amount of capital to be reallocated will then equal $P_i V_i$, where:

$$P_i = (1\% \times 50\%) + (25\% \times 6.05\%)$$
$$= 0.61\%$$

For a non-ESG fund j also suffering a 50% drop in value from static effects, outflows specified by Table 1 would be higher, leading to $P_j = 0.86\%$.

Step (2) of the portfolio rebalancing – adjustments within the portfolio that results from step (1) – is somewhat similar to momentum-following strategies popular among fund managers during more normal market conditions. Grinblatt, Titman and Werners (1995) find that over three-quarters of fund managers carry out some form of momentum-based investing, disproportionately buying stocks that recently outperformed and selling those that underperformed. Over a year around 0.5% of total fund value was reallocated, broadly in line with our calibration.[23]

Knock-on price effects

As discussed above, the current model does not calculate price effects arising from investor flows or portfolio rebalancing. However, sizeable price effects could be expected in reality given large-scale market orders from an EU fund sector with ex-ante assets in excess of EUR 10tn.[24]

Price effect calculations could be calibrated at a general level by, for instance, using the Amihud illiquidity ratio measure for equities specified in EBA (2013). Alternatively, estimated Amihud illiquidity measures on an asset-by-asset basis may be available from different sources. Regardless of the data source used for calibration, there remains the fundamental question discussed above as to what extent the price effects are permanent.

Illustrative results

The model is applied to the dataset from 2023 to 2027, with annual frequency. The total value of equity holdings declines up to 70% under the adverse scenario versus the baseline (Chart 4).[25]

In the model, investor flows amplify the shock in the adverse scenario, while portfolio balancing has no immediate effect.[26] This is because the scenario has a single, initial shock, whereas rebalancing only affects subsequent fund performance, after the shock has hit, which is a general feature of the modelling approach.

performance due to the price shock as $\overline{r}$, the change in the value invested in asset k, Δw_k, is:

$$\Delta w_k = \frac{P_i}{N} \times \frac{(r_k - \overline{r})}{st.dev(r)}$$

Note that $\sum_k^N \Delta w_k$ is proportional to $(\sum_k^N r_k) - \overline{nr} = 0$, i.e. the changes in weights across assets sum to zero, consistent with the notion of within-portfolio rebalancing.

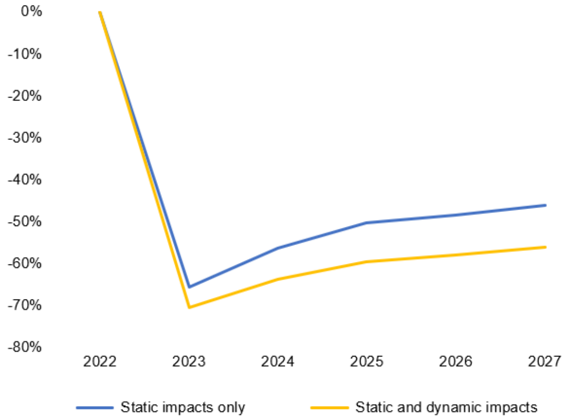
23 On average, the money reallocated to each stock multiplied by its excess returns was 0.74% of fund value per quarter, or around 3% annualised. Stocks bought had average returns around 6% above those sold, implying around 0.5% of fund value was reallocated.

24 Sydow et al (2021) show that interactions between the fund and banking sectors may be expected to amplify such price effects. By way of comparison, Mirza et al (2020) simulate a 'fire sale' of assets held by banks and funds. Based on a dataset covering equity holdings of around EUR 5 tn, the authors estimate knock-on price effects of the order of 1%. In contrast, the present scenario analysis does not consider a fire sale, as funds do not face liquidity constraints under Assumption 3. As rebalancing is assumed to take place in an orderly fashion over several months (i.e. within the yearly modelling frequency), the price impact may be more moderate. On the other hand, the far larger total value of equities held by the fund sector and the scale of the rebalancing are likely to push price effects higher.

25 The magnitude of this decline differs significantly from the estimate of a fall in AuM of -6% in Crisóstomo (2022), mainly due to the inclusion of macroeconomic stress, the focus on equity holdings and the dynamic fund adjustment mechanism.

26 The result that investor outflows exacerbate the shock (i.e. the direction of the effect) follows from the shock specification and the flows calibration. More generally, if the calibration has non-zero coefficients with the same signs as in Table 1, and if in a given period a scenario leads on average to negative returns among non-ESG funds as well as among ESG funds, there will be negative net outflows in that period.

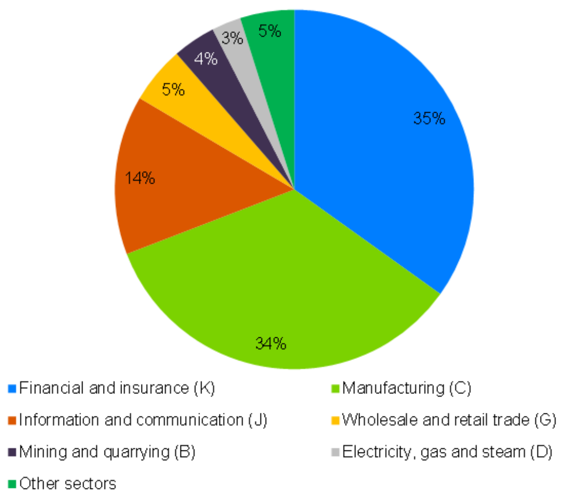
Chart 4
Main results from scenario modelling
Dynamic impacts exacerbate declines in value of funds' equity holdings



Note: Simulated proportional change in total value of equity holdings among a sample of EEA-domiciled investment funds, based on main adverse scenario in ECB and ESRB (2023). Static-only calculations plotted alongside cumulative effects of static and dynamic components. In the scenario taken as an input, around four-fifths of the static impact on equity prices in the first year is from adverse macroeconomic conditions, with the remainder attributable to materialised transition risk.
Sources: ESRB, NGFS, Morningstar, Refiniv Eikon, ESMA.

The results can be broken down by economic sector (Chart 5). Equities from only three sectors (financial & insurance; manufacturing; and information & communication) account for over 80% of the decline in value. However, the result reflects those sectors' dominance in equity markets and thus fund holdings.

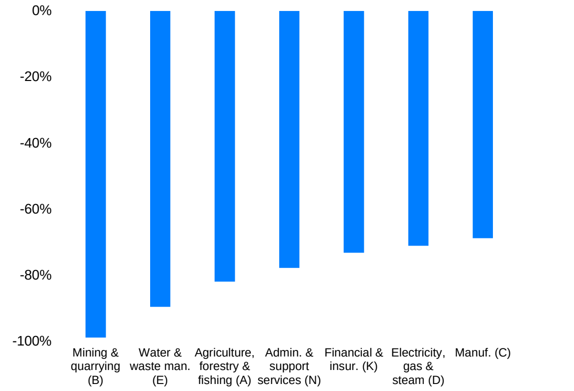
Chart 5
Sectoral breakdown of total decline in AuM
Aggregate fall in value driven by financial and manufacturing sectors



Note: Share of total fall in total assets under management for sample of EEA-domiciled investment funds by the general industrial classification of economic activities within the European Union (NACE) level 1 sector under the adverse scenario. The letters in brackets after sector names are classification codes.
Sources: ESRB, NGFS, Morningstar, Refiniv Eikon, ESMA.

When analysing losses among the most adversely impacted sectors (Chart 6), other economic activities such as mining and quarrying fare significantly worse under the adverse scenario.

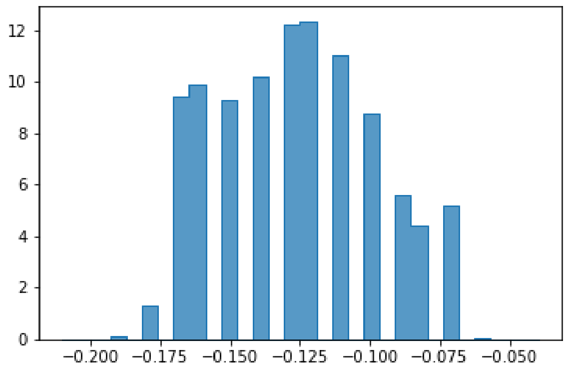
Chart 6
Largest relative falls in equity holdings values by sector
Very large falls for high-emitting sectors



Note: Average percentage changes in value of equity holdings losses by the general industrial classification of economic activities within the European Union (NACE) level 1 sector under the adverse scenario. "Waste man." = Waste management. "Admin." = Administrative. "Insur." = Insurance. "Manuf." = Manufacturing. The letters in brackets after sector names are classification codes.
Sources: ESRB, NGFS, Morningstar, Refinitiv Eikon, ESMA.

The contributions of the dynamic components of the model to the results can be compared (Charts 7, 8).

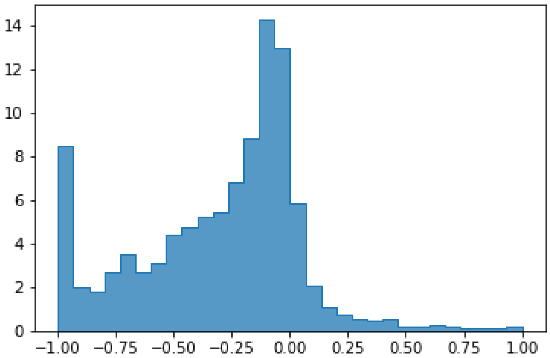
Chart 7
Impact of investor flows on fund assets
Most investor outflows from 7-18%



Note: Distribution of asset market value in % (y-axis) by proportional change in initial holding due to investor flows in the model (x-axis; bracket width 5 basis points.
Sources: ESRB, NGFS, Morningstar, Refinitiv Eikon, ESMA.

The model calibration yields larger changes in funds' asset positions due to rebalancing (Chart 8) than fund flows (Chart 7). Outflows due to investor redemptions mostly range up to around 18%, whereas most positions are rebalanced to a greater extent.

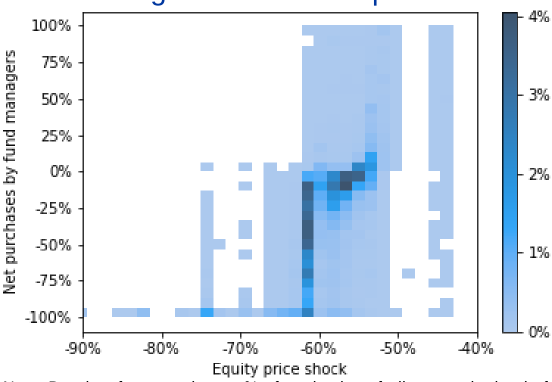
Chart 8
Net rebalancing by asset price shock
Extensive rebalancing in the model



Note: Distribution of asset market value in % (y-axis) by proportional change in initial holding due to investor flows in the model (x-axis; bracket width 5 basis points).
Sources: ESRB, NGFS, Morningstar, Refinitiv Eikon, ESMA.

To gain insight into how fund managers collectively respond to asset price shocks, Chart 9 plots the density of assets by total net buying/selling by managers (y-axis) and by price shock in the adverse scenario (x-axis).

Chart 9
Net rebalancing by asset price shock
Rebalancing correlates with price shocks



Note: Density of asset value as % of total value of all assets, by level of net purchases in rebalancing phase as a proportion of initial value held (y-axis; truncated at -0.99 and +0.99) and initial price shock in adverse scenario (x-axis). Darker colours indicate higher density.
Sources: ESRB, NGFS, Morningstar, Refinitiv Eikon, ESMA.

As expected, there appears to be some positive relationship between these two variables, with total net purchases by managers only among those assets with a higher performance ranking.

From a modelling perspective, a limitation of the fund-level approach taken is that prices are fixed throughout the rebalancing process. [27] In reality, however, widespread divestment of an asset would generate an additional discount in its market price, creating arbitrage opportunities. An informal check of the model's robustness in this regard is whether assets with similar price shocks are rebalanced by a similar amount. The results are encouraging, as much of the mass of the distribution follows a narrow range (darker cells in Chart 9). Nonetheless, for a given price shock, rebalancing outcomes often vary significantly.

Conclusion

Identifying vulnerabilities in the investment fund sector under climate stress scenarios is vitally important given its systemic place in the financial system and its crucial role in financing the green transition. In line with ESMA's recent mandates in this regard, this article outlines a first approach to modelling the impact of asset price shocks. As set out in the first section, various climate scenarios can be used to generate shocks to asset prices, based on modelling work carried out by other authorities and international groups.

ESMA's first approach to dynamic modelling of investor sector impacts takes a set of asset price shocks as the core input. For illustration, the model is applied to a severe but plausible scenario involving a large equity price shock driven primarily by adverse macroeconomic conditions but also from the materialisation of climate transition risk.

The dynamic component of the model gives insight into the expected directional effects of reactions by investors and managers, though involves some strong simplifying assumptions, including abstracting away from liquidity effects. Further ESMA work on this topic may involve refining the calibration of the model and incorporating second-round price impacts.

The analysis focuses on understanding how dynamic effects can amplify or mitigate climate-related vulnerabilities in the fund sector. It suggests that the investment fund sector may be less resilient to climate-related shocks than a simple static analysis would suggest, due to outflows by investors. Portfolio rebalancing, on the other hand, is unlikely to make a large difference to acute, near-term vulnerabilities. Overall, therefore, dynamic effects may exacerbate short-term falls in asset values due to climate-related risks (such as a disorderly transition), which may in turn impede the sector's capacity to finance the green transition.

[27] In some cases, all fund positions in one asset are liquidated while managers collectively make large net purchases in other assets with similar performance. To avoid this unrealistic outcome, the model could in principle be extended by making prices endogenous to the rebalancing process and making managers base their trading decisions on these prices. This extension would be an ambitious undertaking, however.

Related reading

Amzallag, A. (2021), ‘Fund portfolio networks: a climate risk perspective’, *ESMA Report on Trends, Risks and Vulnerabilities*, No 1, https://www.esma.europa.eu/sites/default/files/trv_2021_1-fund_portfolio_networks_a_climate_risk_perspective.pdf.

Bank of International Settlements (BIS) (2021), *Climate-related Risk Drivers and Their Transmission Channels,* https://www.bis.org/bcbs/publ/d517.pdf.

Crisóstomo, 2022, “Measuring Transition Risk in Investment Funds”, Comisión Nacional del Mercado de Valores (CNMV) working paper no. 81.

European Banking Authority (EBA) (2013), ‘Report on appropriate uniform definitions of extremely high quality liquid assets (extremely HQLA) and high quality liquid assets (HQLA) and on operational requirements for liquid assets under Article 509(3) and (5) CRR’, https://www.eba.europa.eu/sites/default/documents/files/documents/10180/16145/cebf6837-2d13-43a7-8528-55647f1b20bb/EBA%20BS%202013%20413%20Report%20on%20definition%20of%20HQLA.pdf.

European Banking Authority (EBA) (2023), ‘EU-wide stress test: results’, https://www.eba.europa.eu/sites/default/documents/files/document_library/Risk%20Analysis%20and%20Data/EU-wide%20Stress%20Testing/2023/Results/1061374/2023-EU-wide-stress-test-Results.pdfECB and ESRB, 2021, “Climate-related risk and financial stability”.

European Central Bank (ECB) and European Systemic Risk Board (ESRB) (2021), ‘Climate-related risk and financial stability’, https://www.ecb.europa.eu/pub/pdf/other/ecb.climateriskfinancialstability202107~87822fae81.en.pdf.

European Central Bank (ECB) and European Systemic Risk Board (ESRB) (2022), ‘The macroprudential challenge of climate change’, https://www.esrb.europa.eu/pub/pdf/reports/esrb.ecb.climate_report202207~622b791878.en.pdf

European Central Bank (ECB) and European Systemic Risk Board (ESRB) (2023), ‘Toward macroprudential frameworks for managing climate risk’. https://www.esrb.europa.eu/pub/pdf/reports/esrb.report202312~d7881028b8.en.pdf?bc89d982ac0f87466507bbe82686f64a

European Commission (2021), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Strategy for financing the transition to a sustainable economy, COM(2021) 390, 6 July, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0390.

European Commission (2023), ‘Request for a one-off scenario analysis exercise to be conducted jointly by the European supervisory authorities, the ECB and the ESRB in accordance with the Communication from the Commission of 6 July 2021 “Strategy for Financing the Transition to a Sustainable Economy”’, Ares(2023)1699255, 8 March, https://www.esma.europa.eu/sites/default/files/library/Mandate_for_the_FF55_one-off_exercise.pdf.

European Fund and Asset Management Association (2023), *Fact Book 2023: Trends in European investment funds*, 21st edition, https://efama.vcpgraphics.online/efama-fact-book-2023.

European Securities and Markets Authority (ESMA) (2023), ‘Costs and performance of EU retail investment products 2023’, ESMA50-165-2357, https://www.esma.europa.eu/sites/default/files/2023-01/esma50-165-2357-esma_statistical_report_on_costs_and_performance_of_eu_retail_investment_products.pdf.

Gourdel, R., and Sydow, M. (2022), ‘Non-banks contagion and the uneven mitigation of climate risk’, *ECB Working Paper Series*, No 2757, European Central Bank, https://data.europa.eu/doi/10.2866/258109.

Investment Company Institute (2023), 'Worldwide regulated open-end fund assets and flows, second quarter 2023', Investment Company Institute website, 19 September 2023, https://www.ici.org/statistical-report/ww_q2_23.

Mirza, H., Moccero, D., Palligkinis, S. et al. (2020), 'Fire sales by euro area banks and funds: what is their asset price impact?' *ECB Working Paper Series*, No 2491, European Central Bank, https://data.europa.eu/doi/10.2866/55691.

Network for Greening the Financial System (NGFS) (2020), *Guide to climate scenario analysis for central banks and supervisors*, https://www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_scenario_analysis_final.pdf.

Renneboog, L., ter Horst, J. and Zhang, C. (2011), 'Is ethical money financially smart? Nonfinancial attributes and money flows of socially responsible investment funds', *Journal of Financial Intermediation*, Vol. 20, No 4, pp. 562–588, http://dx.doi.org/10.1016/j.jfi.2010.12.003.

Sydow, M., Schilte, A., Covi, G. et al. (2021), 'Shock amplification in an interconnected financial system of banks and investment funds', *ECB Working Paper Series*, No 2581, European Central Bank, https://data.europa.eu/doi/10.2866/68326.