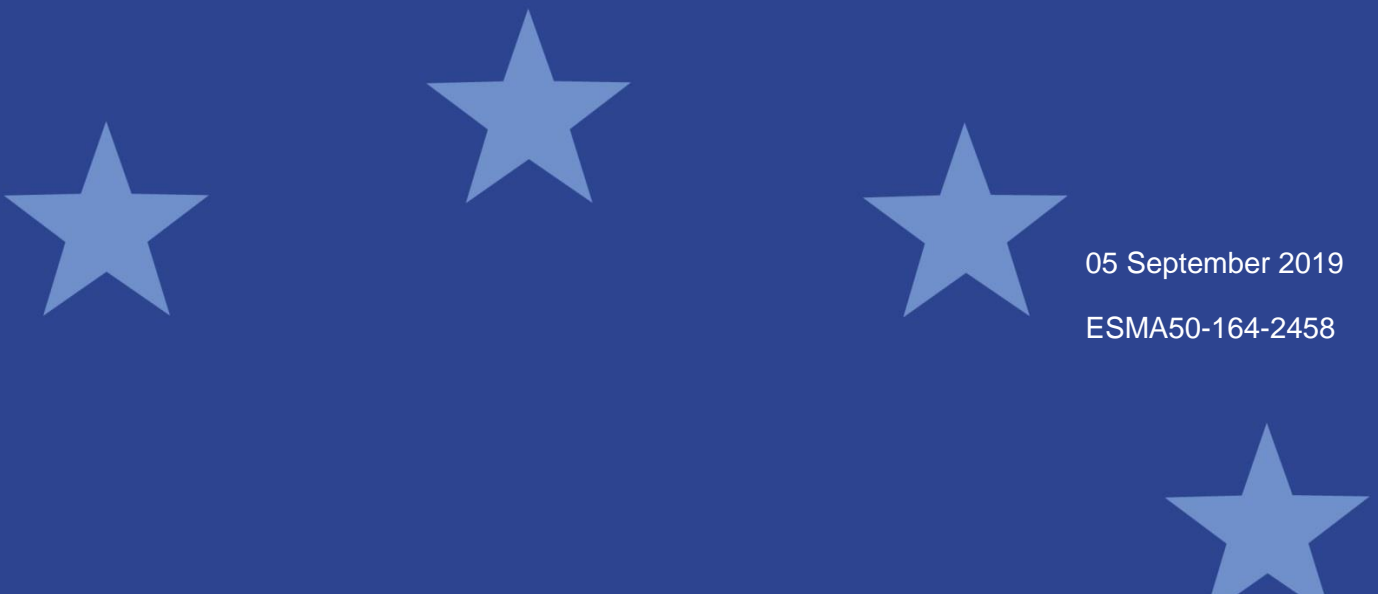




European Securities and  
Markets Authority

ESMA Economic Report  
**Stress simulation for investment  
funds**  
2019



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ESMA Economic Report on stress simulation for investment funds

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# Executive summary

Over the last decade, the asset management industry has experienced strong growth driven by rising asset valuation and steady investors' inflows. The net asset value of EU alternative investment funds (AIFs) amounted to EUR 4.9tn in 2017, and total net assets managed by EU-domiciled undertakings for collective investment in transferable securities (UCITS) amounted to EUR 9.3tn in 2018 against EUR 6.2tn in 2007. The development of the fund industry contributes to the diversification of the EU financial system and provides retail and institutional investors with a range of investment vehicles that can be used to gain exposures to specific asset classes (equities, bonds etc.) and investment policies.

Therefore, it is crucial to make sure that the fund industry is resilient and is able to absorb economic shocks. In that context, the Financial Stability Board has issued recommendations to address structural vulnerabilities from asset management activities, which include provisions related to stress tests.

This report provides an overview of the framework used by the European Securities and Markets Authority (ESMA) for stress simulations. The different building blocks of a stress simulation framework are outlined, along with a menu of options that can be selected by stress testers. In particular, we discuss the calibration of redemption shocks for investment funds, methods to assess the resilience of funds to shocks, ways to measure the impact of fund managers' liquidation strategies on financial markets, and possible second-round effects.

Beyond the methodological aspects of the framework, we provide a case study showcasing how the framework can be applied, based on a sample of more than 6,000 UCITS bond funds. We simulate a pure redemption shock, whereby funds experience large but plausible weekly redemptions ranging from 5% to 10% of their net asset value.

Our results show that overall, most funds are able to cope with these shocks, as they have enough liquid assets to meet investors' redemptions. However, pockets of vulnerabilities are identified, especially for high yield bond funds, given that under the severe but plausible assumptions of our simulations, up to 40% of them could experience a liquidity shortfall, i.e. a situation in which their holdings of liquid assets alone would not suffice to cover the redemptions assumed in the shock scenario and recourse to less liquid assets would need to be taken.

We also model the impact of funds' liquidation on financial markets, as funds need to sell assets to meet investors' redemptions, which mechanically exerts downward pressure on asset prices. Our results show that the overall price impact is limited for most asset classes, as sales by funds are only a fraction of aggregate trading volumes. However, for asset classes with more limited liquidity, such as high yield bonds and emerging markets bonds, fund sales could have a material impact, ranging from 150 to 300 basis points, and generate material second round effects. Second round effects are significantly larger when fund managers sell assets in proportion to their weights in the portfolio, as funds exposed to assets that are less liquid need to dispose of those securities. In contrast, when asset managers use their cash buffers first, the price impact is limited and second-round effects are low.

Looking forward, we intend to use this stress simulation framework as part of our regular risk monitoring to identify risk and assess possible adverse scenarios that might affect the EU fund industry.

## ESMA approach to stress testing

# Supervisory stress exercises

In a context of sustained growth of the asset management sector, concerns about the systemic impact of the asset management sector in times of market stress have been raised. Stress testing has been identified as one tool available to regulatory authorities to assess the resilience of the asset management sector to shocks. The concept of stress tests covers a range of exercises, as reflected by the three separate work streams developed within ESMA: supervisory convergence principles for fund-level stress tests by asset managers, “bottom-up” stress test scenarios and stress simulations. The ESMA stress simulation (STRESI) framework is a simulation-based approach combining micro and macro prudential objectives. On the micro side, its output is an assessment of the resilience of relevant parts of the investment fund sector with a view to informing regulators. On the macroprudential side, the STRESI framework will include an estimation of the impact of an adverse scenario on the fund sector and its potential spillovers to the financial system, thus capturing financial stability risks beyond the individual fund level.

## Introduction

At the outset of the financial crisis, supervisory stress testing was identified as one tool available to policy makers to assess the financial system's resilience to shocks. This developed primarily in the banking sector where national competent authorities (NCAs) wanted to test banks' ability to meet applicable prudential requirements under the stress scenario, potentially leading to supervisory or management action such as recapitalisation (Committee of European Banking Supervisors, 2009). While the resilience of the banking sector remains a core financial stability concern, investment fund stress tests are now increasingly being discussed in international fora, including the Financial Stability Board (FSB), the International Organization of Securities Commissions (IOSCO) and the European Systemic Risk Board (ESRB).

Indeed, the growth of the asset management sector makes it increasingly important for financial stability. Since 2007, investment funds assets under management (AuM) have risen from EUR 6.2tn to EUR 9.3tn for EU-domiciled UCITS, while the net asset value (NAV) of EU alternative investment funds (AIFs) amounted to EUR 4.9tn end-2017. As highlighted by the FSB (2017), investment funds have generally not caused financial stability concerns in recent periods of stress and heightened volatility, with the exception of some money market funds. However, given their sheer size, it is important to ensure that any risks stemming from investment funds are properly understood and addressed. One of the main concerns relates to the risk that

funds may be forced to sell assets in a stressed environment further depressing asset valuation and transmitting stress to other institutions with a risk of a knock-on effect (Office of Financial Research, 2013; IMF, 2015a).

Against this background, the FSB's recommendations to address structural vulnerabilities from asset management activities include provisions related to stress tests. At individual fund level the FSB recommends that authorities require and/or provide guidance on stress testing to support liquidity risk management to mitigate financial stability risk (Recommendation 6). The requirements and/or guidance should address the need for stress testing and how it could be done. IOSCO also published recommendations related to liquidity risk management (IOSCO, 2018a), and a review of best practices among regulators and asset managers (IOSCO, 2018b). Similarly, in the EU, the ESRB recommends that ESMA develop further guidance on how fund managers should carry out liquidity stress tests (ESRB, 2018).

At aggregated level, the FSB recommends that authorities give consideration to system-wide stress testing that could potentially capture effects that collective selling by funds and other institutional investors have on the resilience of financial markets and the financial system more generally (Recommendation 9).

## Different types of stress exercises for different purposes

Stress tests can serve different purposes depending on their level of aggregation, for example individual or system-wide, and on whether they are led by supervisors or managers.

ESMA's approach to investment fund stress testing regroups three separate work streams, corresponding to different levels of stress exercises (ER.1):

- supervisory convergence principles for fund-level stress tests by asset managers;
- sectoral fund-level stress test scenarios, the result of which has to be reported to the supervisor;
- simulation-based stress simulation on fund industry and wider system.

ER.1

Stress test exercises

### Different levels of stress exercises

Item	Fund-level stress test	Sectoral stress test	System-wide simulation
Lead/actor	Manager	Authorities	Authorities
Calculation	Manager	Manager	Authorities
Data	Granular	Granular	Public, commercial
Objective	Risk management	Supervisory risk assessment	Supervisory risk assessment
FSB Rec	REC 6	–	REC 9

Source: ESMA.

## Stress tests as a risk management tool

Fund stress tests are generally viewed as an important risk management tool for asset managers. Stress tests simulate severe but plausible shocks in order to assess the consequences on the fund performance and its ability to fulfil its obligations, including its capacity to meet redemption requests. By informing the fund manager about the risks of its investment strategy, they are part of the decision-making process and crisis management planning.

There are provisions on stress testing in both the UCITS Directive and the alternative investment fund managers directive (AIFMD). In summary, UCITS are required to carry out stress tests 'where appropriate' as part of their risk management<sup>1</sup>. ESMA guidelines recommend stress testing for UCITS that use the Value-at-

Risk (VaR) approach (Committee of European Securities Regulators, 2010) or receive at least 30% of their assets in collateral (ESMA, 2014). Under the AIFMD, stress testing is obligatory as part of the liquidity management requirements (Article 16(1) of the AIFMD). Alternative investment fund managers (AIFMs) must report the results of their stress tests to NCAs (who must then pass the information on to ESMA)<sup>2</sup>.

In line with FSB and ESRB recommendations, ESMA has developed guidelines for fund managers in order to promote convergence in the way NCAs supervise funds liquidity stress testing across the EU. More specifically, the guidelines will set out principle-based criteria for managers to follow when executing liquidity stress tests on their funds.

## Supervisory scenarios performed by supervised entities

Bottom-up stress tests are another type of fund-level stress tests centrally organised by regulatory authorities. Scenarios are designed by regulators, and managers model the reaction of the funds to the stress scenario. One of the advantages of this approach is that it is based on fund-level granular data available to the fund manager, so it considers funds' characteristics more precisely.

ESMA is to initiate union-wide stress tests in cooperation with the ESRB: ESMA coordinates the exercise and the ESRB designs the adverse scenario. The newly established money market fund (MMF) stress tests illustrate this approach. Article 28 of the MMF Regulation provides that ESMA shall develop stress test guidelines for MMFs, including common reference parameters:

- liquidity changes of the assets held in the portfolio of the MMF;
- credit risk, including credit events and rating events;
- changes in interest and exchange rates;
- redemptions;
- spread changes of indexes to which interest rates of portfolio securities are tied;
- macro-economic shocks.

For each risk factor, fund managers have to implement the scenarios designed by ESMA, in cooperation with the ESRB and the European

<sup>1</sup> Article 40(2) of Commission Directive 2010/43/EU.

<sup>2</sup> Commission Delegated Regulation 231/2013.

Central Bank (ECB), and report the results to ESMA and the NCAs. In addition to the use of common scenarios, the consistency of the results between MMFs will be ensured by the use of prescriptive guidelines (ESMA, 2019c).

Considering the destabilizing effects of the run on MMFs in 2008 (IOSCO, 2012), MMF stress tests will be useful from both a financial stability perspective and a supervisory perspective.

## Stress simulations led by supervisors

Stress simulations such as ESMA's STRESI framework are top-down exercises led by regulators, whose general objective is to assess the resilience of the investment fund sector and its capacity to transmit or amplify shocks to the rest of the financial system.

Typically, stress test scenarios imply redemption shocks or price shocks that affect the liabilities or assets of the vehicle respectively. In reaction, funds sell assets; the collective selling by funds and other institutional investors might generate second-round effects (price decline, redemption, asset sales) and contagion to other financial institutions.

In practice, fund managers can use a range of liquidity management tools (LMTs) to mitigate the impact of redemptions. LMTs include redemption fees, gates and swing pricing. Stress tests and stress simulations do not usually take mitigating measures into account, since the objective is to assess the resilience of investment funds, independently of possible correcting actions. Afterwards, the outcome of stress tests and stress simulations can inform asset managers and supervisors of the potential need for mitigating actions, including the use of LMTs.

In contrast with the bottom-up approach, a simulation-based approach necessitates having access to appropriate data and a sophisticated methodology. Regulators have to model a scenario and define numerous assumptions, including:

- definition of the sample subject to the stress simulation, such as definition of fund sub-sector(s) and coverage within sector(s);
- development of common redemption and/or price shocks calibrated on historical or hypothetical scenarios;
- model reaction of funds and fund investors to the shock;

- feedback loops between investor redemptions and fund performance;
- contagion to other entities.

## STRESI as an analytical method

The ESMA STRESI framework is a simulation-based approach combining micro and macro prudential perspectives. Depending on the perspective considered, it can deliver two different outputs: an assessment of investment fund resilience, and an assessment of the extent to which funds transmit shocks to the financial system. The two approaches can be seen as complementary, although the macro and micro perspectives can occasionally lead to different analyses (ER.2).

ER.2

STRESI as an analytical method

### Complementarity between micro and macro prudential

The de Larosière Group defines the objective of macro-prudential supervision as to limit the distress of the financial system as a whole. While risks to the financial system can in principle arise from the failure of one financial institution alone, a much more important global systemic risk arises from a common exposure of many financial institutions to the same risk factors. Macro-prudential analysis therefore must pay particular attention to common or correlated shocks and to shocks to those parts of the financial system that trigger contagious knock-on or feedback effects.

In the fund sector, single entities are generally not large enough to be considered systemic. However, regulators would be concerned if there was a risk that a 'large number' of funds would need to be liquidated. Indeed, the regulation generally takes into account the macroprudential perspective. For example, the AIFMD requires ESMA to assess if "the leverage employed by an AIFM, or by a group of AIFMs, poses a substantial risk to the stability and integrity of the financial system" (Article 25 of the AIFMD).

The risk of a conflict of objectives between micro and macro prudential policies is rare. It can however be the case if the optimal regulatory response differs at the micro and macro levels:

- In order to protect investors, it is generally considered that managers should 'slice their portfolio' to meet redemption requests, i.e. to sell assets pro-rata of the fund portfolio, and not sell liquid assets first. Otherwise it would disadvantage remaining investors.
- However, macro simulations generally show that selling liquid assets first mitigates the price impact of asset sales, while slicing the portfolio has a bigger impact on market prices for less liquid assets and generate spillovers.

In this example, there is a contradiction between micro-prudential and macro-prudential objectives. The contradiction can be lifted if we consider that selling liquid assets first could create a first-mover advantage and thus exacerbate the shocks. But it also means that (i) the macro approach is necessary to complement the micro approach and (ii) it is necessary to remain cautious when using the result of a simulation for policy decisions.

## Assessing fund resilience

STRESI's first output is an assessment of the resilience of the investment fund sector. ESMA will compare, for each fund, the size of liquid assets available with a redemption shock. It will allow the identification of 'vulnerable' fund profiles (by investment policy, country...) or sub sectors. This assessment will become part of ESMA's regular monitoring of the sector.

Based on the results, micro-prudential supervisors could decide whether or not follow-up investigations are necessary. Indeed, even if stress simulations can identify areas of focus they cannot directly identify fund-level issues; an individual analysis would rather require a tailored assessment (e.g. outflows, liquidation methods) based on more granular data, including the range of LMTs available at fund-level.

## Macroprudential perspective

From a macroprudential perspective, one limitation of this approach is that it treats funds in isolation, not taking into account the results of their collective actions or potential mitigating effects, e.g. funds receiving inflows compensating for other funds outflows at the aggregated level. This is all the more true in the investment fund sector: there are very few examples of a single fund creating financial distress system-wide. Therefore, systemic risk is likely to come from their common reaction to the same shocks and takes into account spillovers and second-round effects.

To capture such effects, STRESI aims to estimate the impact of an adverse scenario on the fund sector and its potential spillovers to the financial system.

## Other stress exercises

The IMF Financial Sector Assessment Programme (FSAP) is one of the main drivers behind the development of stress simulations at global level. The 2015 US FSAP was a large-scale exercise measuring the impact of a redemption shock on 9,000 open-ended mutual funds (IMF, 2015b). Since then, FSAP exercises have been more granular, with a focus on riskier fund categories — e.g. MMFs, high yield (HY) bond fund, emerging markets (EM) bond funds — and in complexity by taking into account cross-sector exposures and cross-border interconnectedness. This is especially the case with Ireland and Luxembourg FSAPs. In the EU,

stress simulations have been increasingly used: in 2016, 8 authorities had carried out a stress exercise (not all published). Recently, the framework developed by the Central Bank of Ireland put the emphasis on the operationalisation of macroprudential stress, allowing financial stability analysts to rapidly prototype stress tests. (Fiedor and Katsoulis, 2019).

The next section provides details on the STRESI framework, along with a range of modelling options and guiding principles that can be used to perform stress simulations on investment funds.



## STRESI framework

# ESMA stress simulation framework

This section provides an overview of a framework that can be used for stress simulations on investment funds. The framework encompasses a range of building blocks including the calibration of the redemption shocks, methods to estimate the impact of the shock on the investment fund industry, financial markets and other institutions, and the inclusion of second-round effects. The most important building blocks are reviewed, and several modelling options are provided, along with guiding principles.

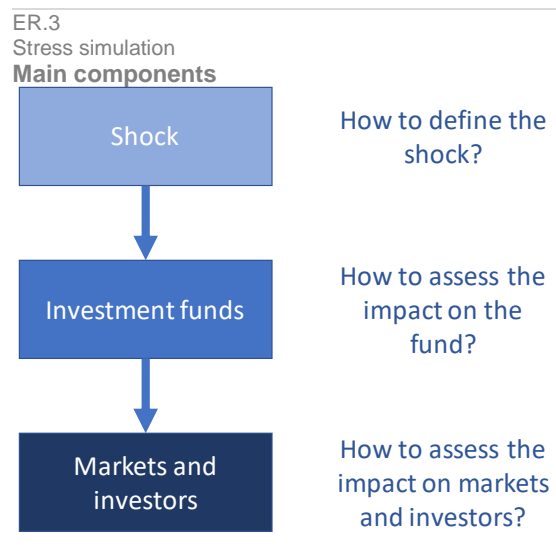
## Introduction

Stress tests and stress simulations have been used for some time in the banking sector (solvency and liquidity stress tests) and the insurance sector, and more recently by central counterparties (CCPs). However, there is little guidance on how to perform liquidity stress simulations for investment funds. The framework presented in this section can be used to perform stress simulations to assess liquidity risk for investment funds, such as UCITS and AIFs.

This section outlines the different components of the STRESI framework that can be used for stress simulations. For each component, data needs and modelling options are discussed. Applications of STRESI are shown in the next section (STRESI simulation).

The main objectives of the stress simulation are: (i) to assess the resilience of investment funds to severe but plausible shocks and (ii) to estimate the impact of investment funds' response to shocks on financial stability. Both objectives can also be considered separately. For example, some bond funds could be resilient to shocks, while at the same time the selling pressure from those funds could have a large impact on financial markets and financial stability.

Schematically, the stress simulation can be described by the combination of (i) a shock, (ii) its impact on funds, and (iii) the impact of funds' response to the shock on markets and investors (ER.3). Therefore, any stress simulation requires (i) a definition of the shock applied to funds, (ii) a method to assess the impact of the shock on the fund, and how the fund manager will respond to the shock, and (iii) a way to estimate the impact of the fund's behaviour on markets and investors. Each of these components is explored in more detail in the next sub-sections.



## Definition of shocks

Multiple types of shocks can be applied to funds depending on the risk factor: market risk, credit risk, counterparty risk or liquidity risk. From a financial stability standpoint, liquidity transformation performed by funds warrants specific attention, so more emphasis is given to liquidity shocks, but the methods could be applied to other types of shocks.

The liquidity shock could be a pure redemption shock or could be the result of other types of shocks derived from a range of scenarios. In the following, it is assumed that the simulation focuses on the short-term impact of shocks, typically at a one-month horizon.

## Pure redemption shock

In the case of a pure redemption shock, the calibration can be based on a variety of methods: (i) historical approach, (ii) event study or (iii) expert judgment.

### Historical approach

Under the **historical approach**, the shock is based on severe outflows observed in the past. The distribution of net flows is used to calibrate the shock, where net flows are equal to subscriptions minus redemptions.

Net flows in percentage of NAV are defined by:

$$flows_t = \frac{Flows_t}{NAV_{t-1}}$$

If data on net flows are not available, net flows can be estimated using data on NAV and returns. Since the change in NAV is related to net flows and performance, flows are proxied by the change in NAV adjusted for the return  $R_t$ :

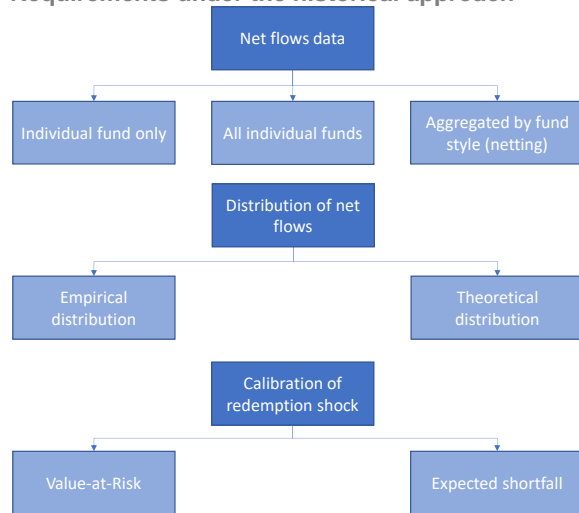
$$Flows_t = NAV_t - NAV_{t-1} \times (1 + R_t)$$

The historical approach requires three decisions (ER.4): (i) the granularity at which net flows are computed, (ii) the method to estimate the distribution of net flows and (iii) the approach to calibrate the redemption shock.

ER.4

Pure redemption shock

#### Requirements under the historical approach



**Net flows** can be computed at the fund-level by designing the redemption shock for each specific fund using only its own net flows' (heterogeneity assumption). This approach has some drawbacks, since by construction, the fund managed the outflows in the past without severe issues, and relatively new funds might not even have faced significant outflows in the past. The heterogeneity assumption makes it more difficult to aggregate the results, since one would need to assume that all funds experienced one of their worst outflows at the same time, which is unrealistic.

Alternatively, net flows can be computed for each individual fund based on all flows in the sample.

The redemption shock will then be similar for all funds in the sample (homogeneity assumption) which can give a clearer picture of likely outflows in the case of a shock, although for some funds the shock can be very large compared with historical experience (IMF, 2018).

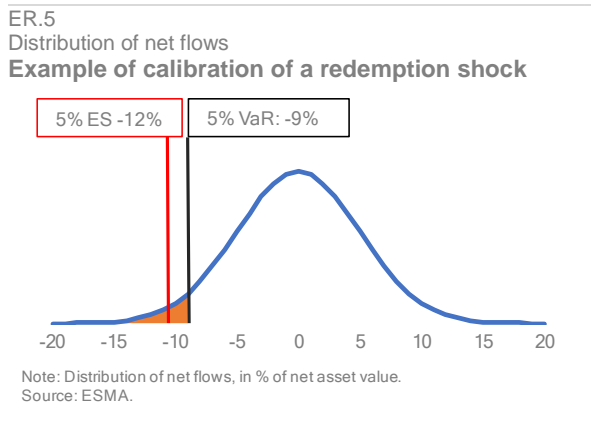
Data on flows can also be aggregated directly at the fund style level (or fund category), i.e. allowing netting within funds. Such an approach tends to lead to milder shocks, since, within one fund style, net flows might compensate for each other (inflows into some funds compensating for outflows from others).

In theory, fund flows could also be distinguished by investor types (institutional versus retail investors), as investors' behaviour might be different. In practice, data on flows usually do not make a distinction between the investors' types because of data gaps. An alternative is to rely on fund share classes, as some commercial providers can identify fund share classes as institutional or non-institutional.

Once the data on net flows are obtained, the **distribution of net flows** can be estimated. One approach is to rely only on the empirical distribution. Another option is to consider that data on net flows provide only a partial view of the underlying patterns of investors, as observed flows are specific draws from an underlying unknown distribution. In that context, distributions can be fitted to the data (normal, lognormal etc.) following a parametric approach (theoretical approach).

Once the distribution of net flows is obtained, the **calibration of the redemption shock** can be done using a VaR approach or an expected shortfall (ES) approach. The VaR approach is based on a certain percentile (worst or fifth worst net flows), whereas the expected shortfall approach is based on the average net flows below the VaR. For example, ER.5 shows a distribution of net flows, along with the 5% VaR and the 5% ES (computed as the average of the distribution in the shaded area).

Recent work done by the IMF in the context of FSAPs typically relies on the historical VaR approach, based on the first percentile of the empirical distribution of net flows (ER.6).



ER.6  
Calibration of redemption shocks  
**Examples from recent IMF FSAPs**

Country	Scope	Calibration method
United States	Agg. by fund style	Historical VaR 1%
Sweden	Agg. by fund style	Historical VaR 1%
Luxembourg	Agg. by fund style Individual fund	Historical VaR 1%
Brazil	Agg. by fund style Individual fund All Individual fund	Historical VaR 1%

Note: 'Agg. by fund style' estimates net flows by aggregating all net flows at the fund style level, thereby netting out inflows and outflows between funds. 'Individual fund' is based on specific fund flows (heterogeneity assumption) and 'all individual fund' uses the distribution of net flows for all the funds in the sample (homogeneity assumption).  
Sources: IMF (2015b, 2016a, 2017, 2018).

One potential issue with the VaR approach is that it discards any flows that are below the VaR: if large redemptions shocks occurred in the past, but were below the VaR, they are therefore completely ignored. The ES approach can address this issue, since it takes into account all the extreme events (net flows below the VaR) and weights them equally (ER.7).

Given that the calibration of the shock focuses on the tail, extreme value theory (EVT) can also be useful to model large shocks using the parametric approach. The intuition is that large shocks do not follow usual distributions (normal or lognormal distributions) and hence the distribution of net flows requires to be modelled by two distributions: one for the tail (EVT) and one for the body of the distribution (ER.8).

ER.7  
Calibration of redemption shock  
**Difference between the VaR and the ES**

The VaR at the  $\alpha$  confidence level corresponds to the  $\alpha^{\text{th}}$  percentile of a distribution. Formally, the VaR is given by :

$$VaR(\alpha) = F^{-1}(\alpha)$$

where  $F^{-1}$  is the inverse of the distribution function. In the case of net flows, the 5% VaR is equal to the 5<sup>th</sup> lowest percentile of net flows experienced by a fund.

The VaR does not take into account tail events: events that have occurred below the threshold are ignored. This could be a problem if in some extreme cases outflows were very high. One way to address this issue is to use the ES approach.

The ES measures the average net flows below the VaR. Formally, the ES is given by:

$$ES(\alpha) = \frac{1}{\alpha} \int_0^\alpha VaR(l) dl$$

or equivalently:

$$ES(\alpha) = E(Z|Z < VaR(\alpha))$$

The 5% ES is therefore equal to the average net flows when net flows are below the fifth percentile.

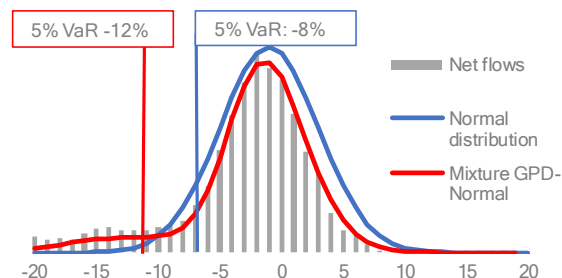
Another advantage of the ES is that it is less subject to model uncertainty, since it is based on an average rather than a single value as in the case of the VaR. For further details on VaR and ES, see Emmer et al. (2015).

ER.8  
Calibration of redemption shock  
**Extreme value theory to model large redemption shocks**

Financial variables, including returns and flows, can have fatter tails than predicted by commonly used distributions (normal or lognormal). In that context, EVT can offer some insights. For further details see Coles (2001).

In the example below (ER.9) one can see that actual data on net flows (grey bars) are not well approximated by a normal distribution (blue curve), given the existence of large outliers on the left side. Calibrating the redemption shock on the theoretical VaR would yield a shock too benign (-8%). Instead of using a normal distribution, a generalized Pareto distribution is fitted to the left tail of the historical distribution (red curve), and numerical methods (Monte Carlo simulations) are used to estimate the VaR. Overall, the redemption shock using this approach is more severe (-12%) than under the parametric approach (normal distribution).

ER.9  
Distribution of net flows  
**Calibration using EVT**



Note: Distribution of net flows, in % of net asset value.  
Source: ESMA.

When working on net flows from different funds or fund styles, copulas can be used, to describe the dependence between random variables. Copulas are multivariate probability distributions that model the joint distributions of the variables of interest (flows from funds or returns from different funds for example). Based on the statistical properties of the underlying data on net flows, different types of copulas can be used (Brechmann et al., 2013). One advantage of copulas is that they model the entire dependence structure between different marginal distributions (Jouanin et al., 2004). Therefore, copulas can be used to calibrate redemption shocks on one fund (or fund styles), conditional on other funds (or fund styles) facing a severe shock. For example, assuming that HY bond funds face a severe redemption shock, copulas could directly provide an estimate of the corresponding shock for sovereign bond funds, based on the dependence structure (ER.10).

ER.10

Calibration of redemption shock

**Modelling joint redemption shocks using copulas**

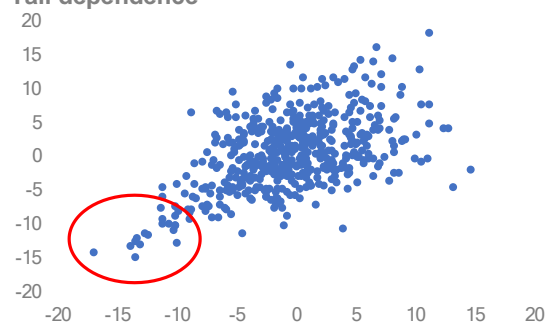
Net flows between funds and fund styles might be correlated with each other. For example, sharp outflows from one fund might result in outflows for similar funds within the same style, and possibly inflows into funds from different styles due to a flight-to-quality effect.

Copulas can be used to model the dependence structure of such fund flows to take into account non-linear effects. In the example below (ER.11), net flows from two funds are displayed: fund A (x-axis) and fund B (y-axis). There is an indication of a left tail dependence: when one fund experiences outflows, the other fund also faces large redemptions. However, when net flows are positive, the correlation is lower.

ER.11

Joint redemption shock

**Tail dependence**



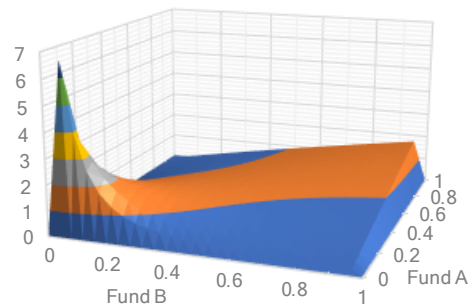
Note: Simulated net flows of two funds in % of NAV. Source: ESMA.

In that case, the joint distribution of net flows can be estimated by choosing a specific copula that will feature this left tail dependency (Clayton copula in this case with a parameter  $\alpha = 1$ ). ER.12 shows the joint distribution of net flows, with a clear dependence for lower values, represented by the spike in the density on the left.

ER.12

Joint redemption shock

**Tail dependence**



Note: Distribution of net flows for fund A and fund B and density function. Source: ESMA.

Once the copula is estimated, two analytical results can be used. First, one can compute the joint probability of funds A and B experiencing large outflows at the same time (outflows higher than 5% of NAV). Using the same example, this is given by:

$$P(F_B \leq -5\%, F_A \leq 5\%) = 8\%$$

The probability of both funds experiencing outflows equal to or larger than 5% of their NAV is 8%.

Second, expected net flows of one fund conditional on the other fund can be computed. The expected net flows for fund B conditional on fund A facing outflows of at least 5% is given by:

$$E[F_b | F_a < -5\%]$$

This conditional expectation can then be calculated using numerical integration or Monte Carlo simulations.

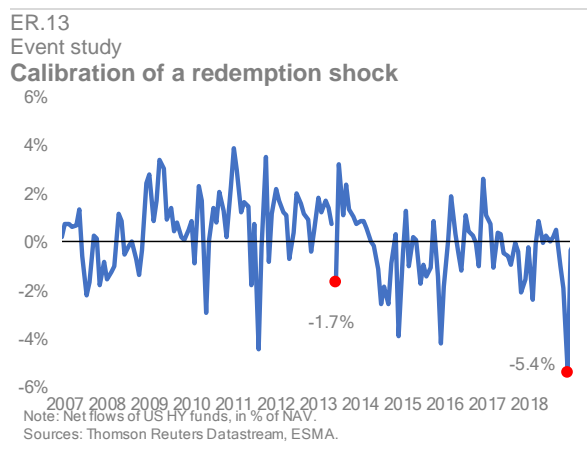
One option to calibrate the shock is therefore to (i) assume that fund A faces net flows equal to its 1% VaR (5% of NAV in this example) and (ii) calibrate the redemption shock for B equal to the expected net flows of B conditional on fund A's net flows.

*Event study*

A second approach to define the redemption shock is to focus on specific historical events. For example, the shock can be calibrated based on net flows observed during the Lehman failure in September 2008, the taper tantrum in May-June 2013 or the more recent market turbulence at the end of 2018.

ER.13 shows monthly net flows for US HY bond funds. If the shock were calibrated on the taper tantrum, it would be -1.7%, whereas using the recent period of market turbulence, the shock would amount to -5.4%.

The event study approach is very easy to use but has some drawbacks. First, this approach is subject to the same limits faced by the heterogeneity assumption: by construction the funds managed this shock in the past. Second, for some fund styles no large shocks might have been observed in the past. Finally, past events are already included in the historical approach, so the added value of the event study might be limited.



### Expert judgement

A third option is to use expert judgment to calibrate the shock. In that case, the shock is defined *ex ante* and applied uniformly to all funds in the sample. This approach lacks theoretical or empirical underpinnings but is very flexible and easy to use. The 2016 Ireland FSAP uses such an approach: funds face three redemption shocks of 5%, 10% and 20% (IMF, 2016b).

### A comparison of the different approaches

The choice of the calibration approach has an impact on the size of the shock. Using aggregated data will tend to result in milder shocks. Indeed, by allowing the netting of flows within funds styles, flows will be lower, resulting in milder redemption shocks.

As an example, a sample of 50 EU HY bond funds is chosen, covering the period January 2008 to December 2018. For each fund in the sample, net flows are estimated, along with flows aggregated across the 50 funds. Different redemption shocks are then calibrated.

Under the empirical approach, the shock is calibrated at the 5% ES based on (i) individual fund data (heterogeneity assumption), (ii) all funds data (homogeneity assumption) and (iii) aggregated flows.

Under the theoretical approach, a Student distribution is used to model net flows, based on goodness of fit tests. The distribution is chosen because the empirical data indicate fat tails (high kurtosis) and low asymmetry (skewness).

As shown in ER.14, the different methods yield different severities for the shock ranging from 5.1% to 8.5%. Overall, the shock is milder when aggregated flows are used, owing to netting effects, under both the empirical and the event study approaches. Using individual fund data leads to a slightly more severe shock at 6.2% of NAV, while using all funds net flows results in the

most severe shock at 8.5% of NAV. The theoretical approach results in a shock that is also relatively close to those two approaches.

ER.14  
Calibration of redemption shocks  
**Comparison of approaches**

Approach	Scope	Redemption shock (%)
Empirical	Individual funds (median)	6.2
	All funds	8.5
	Aggregated	5.1
Theoretical	All funds	5.5
Event study (Dec. 2018)	Aggregated	5.4

Note: The redemption shock is calibrated on the 3% ES, using weekly data on net flows for HY bond funds. The theoretical approach uses a Student distribution with 2.5 degrees of freedom.  
Sources: Morningstar, ESMA.

Overall, the choice of an approach depends on the objective of the stress simulation. If the goal is to assess each fund's resilience to redemptions, individual fund data (bottom-up approach) or all fund data could be used to calibrate the shock, with a preference for the latter, since it allows results to be comparable across funds.

## Redemption shock based on a scenario

Two limits of the pure redemption shock are that the cause of the shock is not explained, and it is a partial equilibrium approach (all other macrofinancial variables are fixed).

One way to address those issues is to design a scenario that is used to project redemptions. The **scenario approach** also allows results to be aggregated across fund styles since all funds are subject to the same macrofinancial shocks. Banking sector solvency stress tests typically feature a baseline and an adverse scenario, which are used to project the solvency of the institutions in the sample. In the context of funds, the scenario would provide a macrofinancial background — along with a narrative — that would result in net flows into or out of investment funds. In that context, the scenario approach is superior to a pure redemption shock approach, since the former provides a consistent macrofinancial background that enhances the credibility of the shocks used in the stress simulation.

The design of a structured adverse scenario is inherently complex. Following the Basel Committee for Banking Supervision (BCBS)

stress testing principles, adverse scenarios need to be ‘severe but plausible’, which means that they may deviate substantially from the baseline while remaining realistic (BCBS, 2018). For example, in the 2019 MMF stress exercise, the probability of the shocks to the triggering variables is below 1% over the horizon of one quarter. The scenario calibrated by the ECB is the outcome of several simulations reflecting the risk assessment from the ESRB and the risk factors identified by ESMA, thus involving different sources of expertise. Once the shocks have been calibrated, another source of complexity is the need to estimate the relationship between the macro financial variables and the risk factors.

In that context, it is not straightforward to model the spillover of macro financial shocks to funds as different transmission channels can be used. On the one hand, the flow-performance relationship can be used: shocks have an impact on fund returns which in turn lead to investors outflows. On the other hand, shocks can have a direct impact on flows without taking funds’ performance directly into account.

#### *Scenario based on flow-return relationship*

Under this approach, one needs to assess first the impact of the shock on the returns of the fund, and then, given the projected returns, the net flows from investors.

A choice needs to be made to examine the performance at the fund level or at the fund style level (where returns are aggregated across funds from the same fund style).

Although the relationship between flows and returns is a stylised fact in literature (Sirri and Tufano, 1998; Berk and Green, 2004; Barber et al., 2016), a variety of estimation strategies may be adopted in order to assess the fund flows’ sensitivity to performance. The magnitude of the estimated effect could then vary depending on the chosen econometric specification (ER.15). Most empirical analyses find a positive relationship between funds’ past performance and investor outflows.

ER.15

Flow-return relationship

#### **Empirical estimates**

Reference	Main explanatory variables	Parameter
Morris, et al. (2017)	Lagged returns, change in lagged VIX	0.4 -0.7
Fricke and Fricke (2017)	Lagged returns and flows	0.3
Baranova et al. (2017)	Current and lagged returns, VIX	0.5
ECB (2017)	Lagged returns and flows, size	0.5
Van der Veer et al. (2017)	Lagged returns and flows, leverage, size	0.04-0.13

Note: Parameter estimates of the regression of fund flows on the explanatory variable. For example, a value of 0.5 implies that a 1 percentage point decline in returns lead to outflows of 0.5% of the NAV.

Source: ESMA.

A common approach in the literature (Chevalier and Ellison, 1997; Cetorelli et al., 2016) is to first regress excess fund returns on aggregate market excess returns (stocks and bonds) to estimate each fund’s alpha, representing the fund idiosyncratic performance. Flows are then regressed on past values of alpha, and eventually on dummy variables, indicating if past returns were negative to capture asymmetries.

One potential issue arising with fund-specific estimates of the flow-return relationship might be the high degree of dispersion of parameters across funds, with possible negative values. Alternatively, the sensitivity to returns might be estimated at fund type level using panel-like techniques. In a baseline scenario, funds employing a similar strategy would be then pooled together to compute the flows’ sensitivity to performances over time. The Fama-MacBeth (1973) two-step methodology, which is standard in asset pricing, provides a natural benchmark estimation strategy as it aims to test how different factors describe portfolio returns. The goal is to find the premium from exposure to these factors.

When estimating the flow-return relationship, it is possible to assume that the relationship is not linear. For example, Goldstein et al. (2017) find a concave flow-performance for US corporate bond funds: the sensitivity of investors to poor performance is much higher than to good performance. Quantile regressions can also be used to allow the flow-return relationship to vary over the distribution of the variables, especially since stress simulation focuses on tail events (ER.16).

ER.16

Flow-return relationship

**Using quantile regressions to account for tail events**

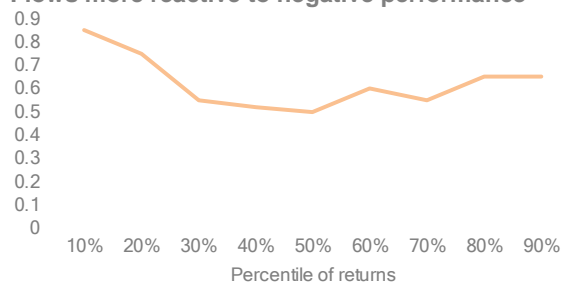
The flow-return relationship is likely to be different when funds experience large shocks, as investors might be more likely to redeem than during normal times. In that case, the parameter relating flow to returns could vary based on the distribution of returns and flows.

Usually, linear regressions estimate the mean of one variable (net flows) conditional on the level of independent variables (returns). Quantile regressions estimate the conditional quantile of an explained variable (net flows) as a linear combination of independent variables.

ER.17 shows the different parameters obtained using a hypothetical example: when returns are very low (10<sup>th</sup> percentile), outflows tend to be higher (parameter of 0.9) than when they are close to average (around 0.5). In other words, when returns are very low, a 1 percentage point decline in returns leads to 0.9% of outflows, whereas when returns are close to their average, a 1 percentage point decline in returns leads to 0.5% of outflows.

ER.17

Flow-return relationship

**Flows more reactive to negative performance**

Note: Parameter estimates of a regression of fund net flows on fund past returns, at different percentile levels.

Source: ESMA.

Another approach is to regress flows directly on returns and macrofinancial variables. Focusing on EU AIFs, Van der Veer et al. (2017) find that investors in leveraged and unleveraged AIFs have similar sensitivities to positive returns, but investor flows of leveraged funds are more sensitive to negative returns. The ECB (2017) and ESMA (2019a) regress flows on past returns directly, with fund-specific control variables but no macrofinancial variables. Baranova et al. (2017) run a panel regression for each fund type by regressing individual fund flows on current and lagged returns and the level of the VIX index.

The choice of approach has an impact on how the scenario will be integrated. If the approach relies only on the flow-return relationship without taking macrofinancial variables into account, one needs to assess how fund returns will be affected by the shock. For example, Cetorelli et al. (2016) assume a 100 basis point increase in interest rate, which translates into a shock to bond funds' returns depending on the duration of their portfolios. In their model, flows are entirely driven by funds' excess returns over the stock market. In that context, the interest rate shock directly

affects excess returns. However, this type of approach could not be used to model a joint shock to the interest rate and the stock market since in that case, excess returns might be unaltered. ESMA (2019a) calibrates a scenario on past episodes of market stress and calculates the impact on bond fund returns using the duration of benchmark bond indices as a proxy for the duration of bond funds. In this setting, only shocks to fixed-income asset classes are taken into account.

If the model used already features macrofinancial variables, the impact on returns and hence flows, can be directly projected.

*Scenario based on flows*

In that setting, the relationship between flows and macrofinancial variables is directly estimated. Net flows at the fund, or fund-style level, are assumed to be correlated with macro financial variables of interest, possibly augmented with control variables. Commonly used macrofinancial variables include a measure of expected volatility (VIX or VSTOXX), a proxy for credit risk for bond funds (spreads) and a measure of the term premium.

For example, Bouveret (2017) estimates the relationship between net flows for four different fund styles (HY, EM, bond and mixed funds) using the monthly change in VIX, 3-month Euribor, 10-year euro area sovereign yield, term spread and Eurostoxx50 augmented with the relevant spread measure (HY spread for HY funds etc.). The ECB (2017) regresses fund flows by category on the relevant benchmark for each bond fund category, distinguishing between positive and negative performance.

*Guiding principles for the design of redemption shocks*

Several approaches can be used to design a scenario for stress simulations. Choices can be made based on empirical or econometric considerations or on the specific characteristics of investment funds subject to the stress simulation.

Overall, some guiding principles can be outlined in the case of a pure redemption shock (ER.18).

First, as a general principle, it is better to use **individual fund data rather than aggregated data** by fund styles, as the latter would tend to overestimate the resilience of investment funds. One of the objectives of the stress simulation is to assess individual funds' resilience to severe but plausible redemption shocks; therefore it is more realistic to use individual fund net flows than

aggregated flows. Because of the netting effect, redemption shocks calibrated on aggregated flows will be too mild and will not represent what individual funds have experienced during stressed periods.

ER.18

Modelling choices

**Guiding principles for the pure redemption shock**

Module	Preference	Comment
Net flows	Individual fund data rather than aggregated data at fund style level	More realistic shocks and makes use of all available data
Distribution of net flows	Historical approach	More tractable than expert judgment or event study
Calibration of shock	ES	More robust than VaR
Flow-return relationship	Panel regression by fund styles	Allows differences between fund styles while preserving similarity within fund styles

Source: ESMA.

Second, for a pure redemption shock, **the historical approach** might be preferable to alternative approaches, as it makes use of all the available data to calibrate the redemption shock. If time series are too short, the parametric approach can be used to simulate more data points. The event study approach can be complementary and serve to perform sensitivity analysis and check the robustness of the results obtained under the historical approach. Regarding the calibration method, **the ES approach** is superior to the VaR approach, as it takes into account the most severe shocks and is robust to data quality issues since it is based on an average of values whereas the VaR is based on a single value.

Third, regarding **the flow-return relationship**, although there is a variety of approaches, using panel regressions by fund styles might be preferable. Panel regressions make it possible to take into account differences between fund styles (different parameters for the relationship), while restricting the effects so that they are similar within fund styles. This avoids having counterintuitive results when regressions are done at fund level (negative parameters for some funds) due to idiosyncratic effects not captured by fund fixed effects.

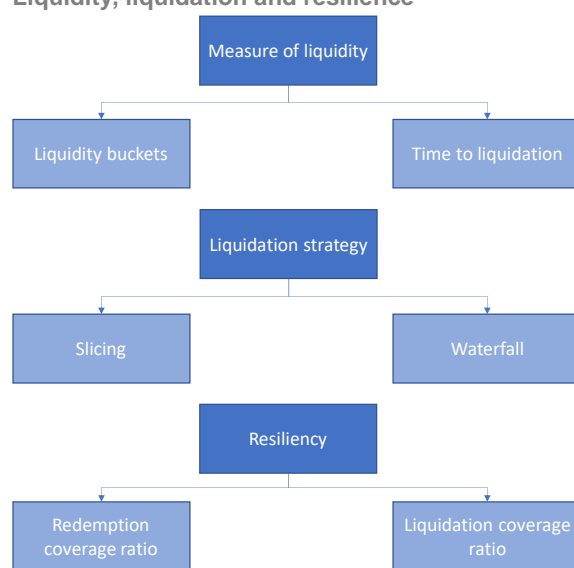
## Impact of the shock on investment funds

Once the shock is calibrated and net flows are estimated, the next step is to assess the impact on the fund. The measurement of the impact is closely linked to the resilience of the fund industry.

The first step is to measure the liquidity of investment funds, the second is to integrate the liquidation strategy of the fund manager, and the last step is to estimate the resilience of the fund (ER.19).

ER.19

Impact of shocks on funds

**Liquidity, liquidation and resilience**

## Liquidity of investment funds

One approach is based on **liquidity buckets**. Assets in the portfolio of funds are classified in different buckets representing different degrees of liquidity.

Several bucketing approaches can be used. For example, in the US, the Securities and Exchange Commission requires fund managers to classify their portfolio holdings into four groups from highly liquid to illiquid instruments (SEC, 2018). In the EU, the ESRB measures liquidity by the ratio of cash and short-term debt securities (residual maturity of less than one year) to NAV (ESRB, 2016).

ESMA (2015) applies the high-quality liquid assets (HQLA) approach, used for banks under Basel III liquidity regulatory requirements, to investment funds. The HQLA approach gives different weights to each asset type, which makes it possible to compute a liquidity index for each entity:



$$Liquidity = \sum_{k=1}^n \omega_k \times s_k$$

where  $\omega_k$  is the liquidity weight for security  $k$  and  $s_k$  is the share of security  $k$  as a percentage of the NAV.

ESMA (2015) uses liquidity weights from the Basel Committee, with liquidity based on the asset type (cash, corporate bond, equity etc.) and the credit rating, although other types of weights could be used. The HQLA measure can be applied at the security level (i.e. each security is given a liquidity weight) or by broad asset class. Using data for funds in Luxembourg, Bouveret (2017) finds that both approaches provide similar results.

The HQLA approach is very attractive from an operational point of view since it is easy to compute and interpret. However, this approach has two drawbacks.

First, the approach gives cash (and cash equivalents) a 100% liquidity weight. This assumption is debatable, since part of the cash might be used for purely operational purposes and hence should not be considered a liquidity buffer. In addition, funds using derivatives might have a large amount of cash to meet future margin calls, rather than to meet investors' redemptions. Indeed, based on AIFMD data, ESMA (2019b) reports that hedge funds with the highest exposures to derivatives also have the highest levels of cash. One option to address this issue would be to split the cash into two components — fully unencumbered cash and cash that is contingently unencumbered (i.e. would be used if margin calls were to occur) — and to adjust the contingent cash holdings based on margin calls that would occur given the scenario used in the simulation, or alternatively increase the redemption shock by including margin calls. The Bank of England has recently performed a similar analysis by assessing the liquidity impact of an interest rate shock on UK non-banks (ER.20).

Second, by construction, the HQLA approach penalizes funds investing in less liquid asset classes (HY and EM bond funds), and the HQLA measure might not adequately represent the level of liquidity risk faced by the fund. In those cases, a liquidity measure based on time to liquidation (TTL) would be preferable.

ER.20

Liquidity impact of shocks on derivatives

**Impact of an interest rate shock on funds' derivatives portfolio**

Funds can enter into derivatives contracts for hedging and investment purposes. To meet future variation margin calls, funds need to set aside liquid assets (cash and other HQLA).

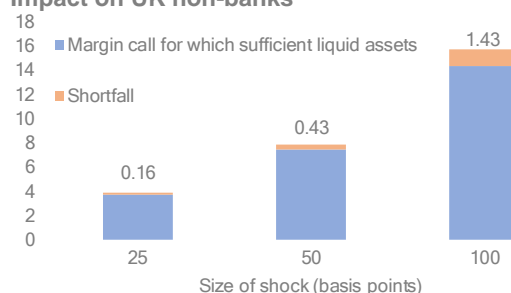
Recently, the Bank of England ran a simulation to assess the impact of interest rate shocks on non-banks liquidity (Bank of England, 2018). Its sample included around 100 non-banks that are the biggest derivatives users among pension funds, insurance companies, UCITS and AIFs. It simulates the impact of three interest rate shocks (25, 50 and 100 basis points) on over-the-counter interest rate derivatives portfolios. For each entity, it estimated the variation margins required, and compared them with liquid assets, adjusted for changes in the fair value of government bond holdings, variation margins on cleared derivatives and non-IR over-the-counter derivatives.

Overall, the results of the simulation indicate that most entities would have enough liquid assets to cover the margin calls (ER.21), and, for entities with a shortfall, the potential amount of forced sales would be small.

ER.21

Liquidity demands due to an IR shock

**Impact on UK non-banks**



Note: Total margin calls and subsequent shortfall faced by non-banks, in GBP billions.  
Source: Bank of England (2018).

In contrast to liquidity buckets, under the **time to liquidation** approach liquidity is measured by the time required to sell securities without causing a large price impact. The TTL can be implemented at an aggregate level, by comparing the selling pressure— amounts of securities needed to be sold given the redemption shock — with measures of aggregate liquidity by markets — (turnover, dealer inventories). The TTL can also be estimated using security-level data.

Although the TTL might seem more realistic than the HQLA approach, it has a series of limits. First, the TTL approach is difficult to implement at the security level since it requires a model of price impact for each security, which is either challenging to estimate given data needs, or very costly if outsourced to third-party providers. Using TTL at the aggregate level is more straightforward, yet the lack of granularity can introduce some biases as liquidity measures for corporate bonds do not usually distinguish between HY and investment grade (IG) bonds, thereby overstating the liquidity of HY bonds.

ER.22 provides an overview of approaches used in recent IMF FSAPs.

ER.22

Measurement of liquidity

**Examples from recent IMF FSAPs**

Country	Approach	Scope
United States	TTL	Aggregate
Sweden	TTL	Aggregate
Luxembourg	HQLA	Aggregate Security-level
Ireland	TTL	Security-level
Brazil	TTL	Aggregate

Sources: IMF (2015b, 2016a, b, 2017, 2018).

## Behaviour of fund managers: liquidation approaches

Once the results of the shock on investment funds are known, the reaction of fund managers needs to be integrated. In the context of stress simulations, mitigating measures such as the use of LMTs are not taken into account, since the objective is to assess the resilience of investment funds independently of corrective actions. However, the outcome of the stress simulations should be used to inform asset managers and supervisors of the need to contemplate mitigating measures. In the context of stress simulations, when faced with a redemption shock, the manager will have to liquidate part of the portfolio. There are two approaches to modelling the liquidation strategy.

Under the **slicing approach**, managers try to keep the structure of the portfolio constant by selling all securities in the portfolio in the same proportion (Cetorelli et al., 2016). Such a strategy allows managers to ensure that the portfolio composition follows the investment policy very closely. In practice, if the shock is equal to 10% of the NAV, the managers will sell 10% of each asset class in the portfolio.

Under the **waterfall approach**, fund managers are assumed to liquidate their most liquid assets (IG sovereign bonds, cash) first before using less liquid securities. Assets are liquidated in descending order based on their liquidity weights: funds use cash first to meet redemptions, then IG sovereign bonds and IG corporate bonds, then HY sovereign bonds followed by equities and finally HY corporate bonds (IMF (2015b)).

In practice, fund managers can be constrained by the prospectus of the fund, which can define the usual composition of the portfolio of the fund. For UCITS, ESMA guidelines on liquidity stress testing provide that the liquidation strategy should reflect how manager would liquidate assets during normal and stressed conditions, in

accordance with applicable rules (legal requirements from the UCITS Directive or self-limitations from prospectuses of fund rules). For example, a HY fund would need to keep a significant proportion of its portfolio invested in HY bonds to avoid any breach of the investment policy.

The choice of the liquidation approach will have an impact on the result of the simulations.

Under the slicing approach, investor protection is emphasized, as the fund must keep the structure of the portfolio identical, and remaining investors are therefore treated equally to redeeming investors. It also implies that funds investing in less liquid asset classes will have to sell a large amount of assets, which could then have financial stability implications due to the price impact. Relatedly, the performance of the fund will suffer more since the price impact could be high.

Under the waterfall approach, financial stability risks are somewhat reduced, as funds sell their most liquid assets first, thereby limiting any price impact of their sales. However, it comes at the cost of a potential distortion of the portfolio structure, and a heightened risk of first-mover advantage since remaining investors end up with a less liquid fund than initially (Baranova et al., 2017).

In practice, both approaches can be used to assess the impact of liquidation strategies on markets. ER.23 provides an illustration of the impact of the liquidation strategies.

An additional mixed strategy can also be used whereby managers use cash first and then liquidate their assets under the slicing approach to cover the remaining redemptions.

ER.23

Liquidation strategies

**Slicing and waterfall approaches**

To show the differences between the two approaches, we look at a hypothetical fund with a NAV of EUR 100, with the portfolio composition shown in ER.24. Given the portfolio composition, the HQLA measure is equal to 22.75% of NAV.

ER.24

Illustrative example

**Portfolio composition**

Asset class	Portfolio share (%)	Liquidity weight (%)
Cash	2	100
IG sovereign	4	100
IG corporate	5	85
HY sovereign	25	50
HY corporate	64	0
<b>Total</b>	<b>100</b>	<b>22.75</b>

Source: ESMA.

We assume that the fund faces a large redemption shock of 30% of its NAV. Under the slicing approach the fund sells 30% of each of its assets. Under the waterfall approach, the fund uses first its cash, then its IG sovereign, IG corporate etc. ER.25 shows that under the slicing approach, the fund has to sell a large quantity of its less liquid assets (HY corporate), since most of its portfolio is composed of HY corporate bonds. In contrast, under the waterfall approach, the fund uses its more liquid assets first, resulting in lower liquidation of less liquid assets (HY sovereign bonds and HY corporate bonds) as shown in ER.25.

ER.25

Illustrative example

**Sales of assets**

Asset class	Slicing (in EUR)	Waterfall (in EUR)
Cash	0.6	2
IG sovereign	1.2	4
IG corporate	1.5	5
HY sovereign	7.5	19
HY corporate	19.2	0
<b>Total</b>	<b>30</b>	<b>30</b>

Source: ESMA

## Resilience of investment funds

The resilience of investment funds relates to the ability of investment funds to face large redemption shocks.

When liquidity is measured through the bucketing approach, the redemption coverage ratio (RCR) can be used to assess resilience:

$$RCR = \frac{\text{Liquid assets}}{\text{Net outflows}}$$

If  $RCR > 1$ , the fund is resilient since it has enough liquid assets to cover the redemption shock. If  $RCR < 1$ , the fund needs to sell some of its less liquid assets to meet redemption demands from investors.

For an  $RCR < 1$ , a liquidity shortfall can be defined (in percentage of NAV) as:

$$\text{Liquidity shortfall} = \text{Net outflows} - \text{Liquid Assets}$$

The RCR cannot be directly used when liquidity is estimated using the TTL approach. Instead, the resilience is measured by comparing the number of days required to liquidate a portfolio with a benchmark. This benchmark can be the redemption frequency (at least twice a month for UCITS, but usually daily) or a less conservative benchmark such as the settlement limits that are defined in national regulations for UCITS (for example five days in France, ten business days in Ireland). Similarly to the RCR, a fund liquidation coverage ratio (FLCR) can be defined:

$$FLCR = \frac{\text{Time to liquidation}}{\text{Benchmark limit}}$$

From a micro supervisory perspective, the emphasis will be on the resilience of investment funds. From a financial stability standpoint, the emphasis is on the impact that funds behaviour following the shock has on financial markets and other institutions (Grillet-Aubert, 2018). Usually both perspectives go hand in hand, but in some cases they might yield different results. For example, funds can be resilient to shocks because they have enough liquid assets to meet redemptions. However, the forced liquidation of some of their assets could amplify the impact of the shock and therefore affects other financial institutions, potentially raising systemic risk. The next section looks at those issues in more detail.

## Impact on markets and investors

The redemption shock and the ensuing liquidation of assets by fund managers to meet redemptions could have an impact on markets and investors through two main channels: (i) the price impact, and (ii) the funding liquidity impact.

### The price impact channel

Following the shocks, funds have to liquidate part of their portfolio to provide redeeming investors with cash. This selling pressure can have a price impact, especially when funds need to sell large amounts of illiquid assets. The extent of the negative price impact depends on the amounts to be liquidated and the liquidity of the underlying market. There is a trade-off between having price impact measures for a range of asset classes, and having precise price impact measures, which can be estimated only at security-level. Usually, price impact measures are not readily available, and are very complex to estimate, for reasons explained previously. For a detailed discussion

on challenges related to the assessment of liquidity see Grillet-Aubert (2018).

In most cases, a linear price impact curve is used. Cettorelli et al. (2016) use such a linear price impact curve with different parameters for each asset class. They assume that for corporate bonds, a sale of USD 10bn has a price impact of 10 basis points (bps) and calibrate the other asset classes relative to the liquidity weights in the Basel III framework (ER.26).

ER.26

Price impact

#### Asset-specific price impact

Asset class	Price impact (bps)
Corporate bonds	10
Sovereign	5.7
Municipal bonds and mortgage-backed securities	28.5
Covered bonds	18.5
Equities	15.7

Note: Price impact for a sale of USD 10bn of securities. Corporate bonds are taken as a benchmark and the price impact for the other asset classes is based on liquidity coverage ratio and net stable funding ratio liquidity weights.

Sources: Cettorelli et al. (2016), ESMA.

The IMF (2018) uses the Amihud illiquidity measure (a ratio of absolute returns to turnover) to assess the impact of funds' forced sales on the Brazilian sovereign bond market

Price impact measures estimated at individual bond level are more realistic and typically result in higher trading costs (ER.27). However, one important drawback is that they require granular data for each bond, or similar traded bonds, which are difficult to get.

ER.27

Price impact

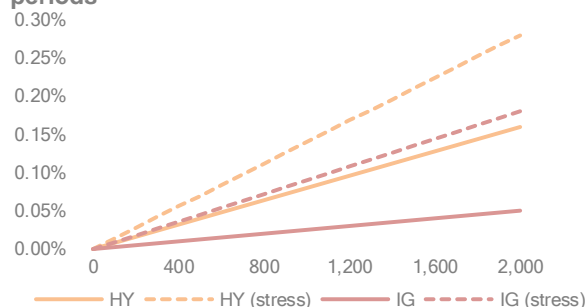
#### Empirical measures of price impact of trades

ER.28 shows the linear price impact of corporate bond sales in two different periods: a normal period (January 2016) and a stressed period (November 2008), based on Konstantinovsky and Phelps (2016). A sale of USD 1bn of IG corporate bonds has a price impact of 2.5bps (0.025%) and 9bps in stressed periods. For less liquid bonds, such as HY bonds, the price impact is 8 basis points in normal times and 14bps in stressed periods. Both estimates are more conservative than those of Cettorelli, et al. (2016), who use a price impact of 1bp for a sale of USD 1bn.

ER.28

Impact of funds' sales on bond markets

#### Corporate bond sales in normal and stressed periods



Note: Price impact (in %) of trades (in USD mn x-axis).  
Sources: Konstantinovsky and Phelps (2016), ESMA.

One issue with a linear price impact curve is that it is assumed that any quantity of securities can be traded: potential buyers will step in provided that the price is low enough. During stress periods, it is likely that some securities, especially if illiquid, cannot be traded at all.

Baranova et al. (2017) develop a calibrated model in which dealers and hedge funds provide liquidity, subject to funding and regulatory constraints. In that setting, there is a tipping point above which additional sales cannot be absorbed by the market. An interesting feature of this framework is that, when this tipping point is reached, funds can no longer liquidate their assets and are therefore unable to meet investors' redemptions. The overall impact on financial stability is unclear. On the one hand, the inability to trade could propagate the shock to other asset classes, thereby increasing systemic risk. On the other hand, since funds could not liquidate their assets any further, there would be no additional price impact.

Recently, Coen et al. (2019) have provided estimates of market impact measures based on the following relationship for market depth, derived from Cont and Schaanning (2017):

$$MD(\tau) = c \frac{ADV}{\sigma} \sqrt{\tau}$$

The market depth (MD) over time horizon  $\tau$  is a function of a scaling factor  $c$ , multiplied by the ratio between the average daily trading volumes (ADV) and the asset volatility ( $\sigma$ ), multiplied by the square root of the time horizon. The price impact is therefore lower, when the time horizon is longer. Once the market depth has been estimated, it is possible to infer directly the price impact of trades.

This approach is empirically tractable, and the estimation can be updated easily by relying on external sources. It also provides a framework

that can be used for a range of different asset classes, making it operationally attractive.

We follow this approach to estimate the price impact measures over a daily horizon for sovereign bonds, corporate bonds and EM bonds, using data for 2018 (see Coen et al. (2019) for details). The daily volatility is computed using Merrill Lynch bond indices for sovereigns and corporates. Daily trading volumes come from industry statistics: the Securities Industry and Financial Market Association (SIFMA) for the US, the Association for Financial Markets in Europe (AFME) for the EU and the Emerging Markets Traders Association (EMTA) for emerging markets. Additional details are provided in the appendix.

Overall the sale of EUR 1bn of sovereign bonds reduces the price by 2bps (ER.29), while the price impact is larger for corporate bonds (around 13bps for HY bonds) and EM debt (33 bps). The estimates are in line with previous studies (Cont and Schaanning, 2017; Coen et al., 2019).

ER.29

Price impact measure

#### Impact by asset class

Asset class	ADV (EUR)	Market depth (EUR)	Price impact of sale of EUR 1bn (bps)
Sovereign	30	4,615	2.1
Corp. IG	15	2,000	5.0
Corp. HY	7	800	12.5
EM debt	2.5	303	33.0

Sources: SIFMA, AFME, EMTA, Thomson Reuters Datastream, ESMA

Once a price impact function has been estimated, one can assess the impact of funds' liquidation on the market. The consequences of funds' sale of assets directly affect holders of the securities (common exposures), including investment funds and other financial institutions such as insurance companies and pension funds. Given the difficulty of precisely estimating the price impact of sales, caution is warranted in interpreting the results, and sensitivity tests should be performed to provide a range of estimates.

## The funding liquidity channel

Besides the market liquidity effect, the reaction of fund managers to the redemption shock can also entail funding liquidity effects for their counterparties. In particular, when cash is used to meet redemption, it mechanically implies that deposits are withdrawn from banks or MMF shares are redeemed. When deposits are withdrawn, counterparty banks suffer an outflow. If fund deposits are a significant part of bank funding, and those deposits are concentrated in

a few banks, then the liquidity impact can be sizeable. This channel might be particularly relevant to countries with a large asset management industry, where funds' deposits account for a large share of banks' deposits. For example, in Luxembourg, funds' deposits account for 14% of banks' deposits (Banque Centrale du Luxembourg, 2018). In the case of Luxembourg, Bouveret (2017) shows that redemption shocks could lead to the withdrawal of around 20% of fund deposits. If fund deposits are concentrated in a few banks — such as depositary banks in Luxembourg, where funds account for 40% of deposits (IMF, 2016a) — the deposit outflows could be sizeable.

Funds can also have part of their liquidity buffers in cash-like instruments such as reverse repo and securities borrowing transactions (securities financing transactions) and money market fund shares. To meet redemptions, the funds would have to end their securities financing transactions, which could have a funding impact on their counterparties. The impact is mitigated by the collateralized nature of the transactions, provided that funds' counterparties find other institutions willing to engage in similar transactions.

## Second-round effects

Once the price and liquidity impacts of the redemption shocks are known, second-round effects can be estimated. The transmission channels are depicted in ER.30. Following a shock, investors redeem their shares, causing asset sales by the fund. The price impact of the sales generates negative returns for the funds holding (and selling) the assets, leading to further outflows from investors, and further liquidation by the fund.

At the fund-level, the second-round effect is related to the price impact: the sale of assets reduces their price, which decreases further the net asset value of the fund. Given the relationship between investors' flows and returns, the negative performance will trigger additional outflows and require additional sales by fund managers.

The negative price impact and the reduction in funding liquidity could also have cross-sectoral consequences for holders of the securities (common exposures) and for funding counterparties.

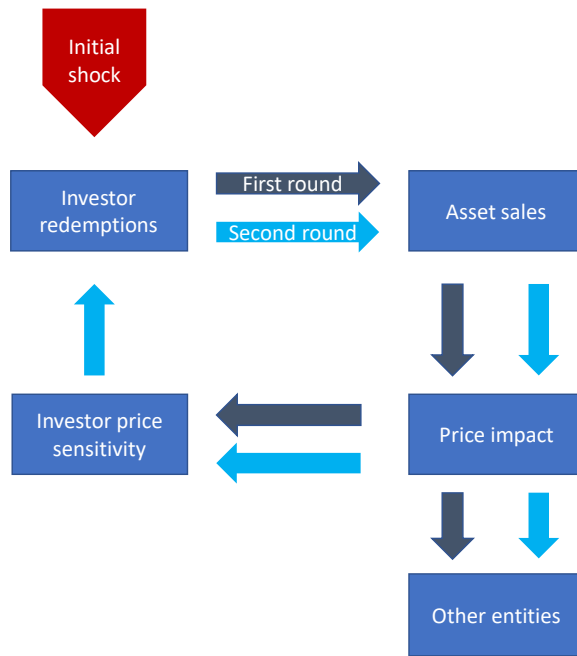
The simulation can then be run again to include possible third-round effects. However, since the emphasis of the simulation is on liquidity shocks

the estimation does not need to include further effects. In addition, the predictive power of third-round effects declines dramatically and therefore does not add robust and reliable outputs.

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 ER.30

Second-round effects

**Overview**


## Conclusion

The framework presented in this section is intended to cover the most important aspects of a stress simulation in the fund industry. Several modelling options are possible, depending on the objective of the simulation and data constraints. Some guiding principles on modelling options are provided to ensure that the simulation remains realistic and appropriate to assess the resilience of the fund industry and its potential impact on financial stability. Given the range of methods and modelling options available, sensitivity tests provide a valuable tool to assess the robustness of the approaches chosen.

The next section provides an application of the STRESI framework to assess the resilience of UCITS bond funds to large redemption shocks, and to estimate how funds could transmit shocks to the financial system.

## STRESI simulation

# Severe redemption shocks

This case study focuses on the impact of a severe but plausible redemption shock on the EU fund industry using a sample of around 6,600 funds with a NAV of close to EUR 2,500bn. The redemption shock is calibrated at the fund style level, whereby funds in the sample are split into five categories, with weekly redemptions ranging from 5% to 10% of NAV. Overall, most funds are resilient as they have enough highly liquid assets to meet investors' demand. HY bond funds are an exception, as around 40% of them do not have enough highly liquid assets to cover redemptions. Our results show that the overall price impact is limited for most asset classes, as sales by funds are only a fraction of aggregate trading volumes. However, for asset classes with more limited liquidity, such as HY bonds and EM bonds, fund sales could have a material impact, ranging from 150 to 300 bps, and generate material second round effects. Second round effects are significantly larger when fund managers liquidate their assets using the slicing approach, since some funds have to sell less liquid assets. In contrast, when asset managers use their cash buffers first, the price impact is limited and second-round effects are very low.

## Motivation and modelling choices

Stress simulations aimed at assessing liquidity risk in the EU fund industry can be done on AIFs and UCITS. Some AIF types, such as real estate funds tend to be exposed to significant liquidity mismatch as they offer daily to weekly redemptions to investors while investing in assets that might take up to three months to sell (ESMA, 2019d).

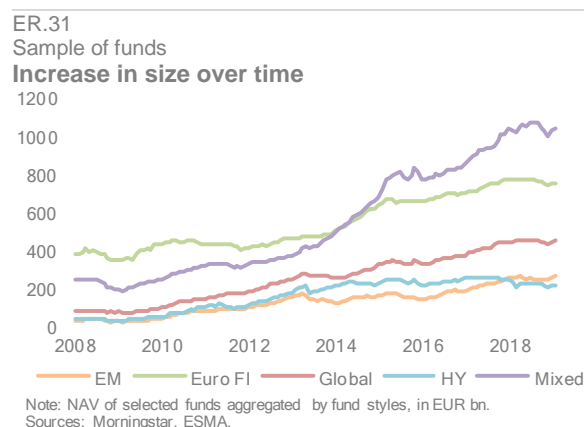
AIFs are usually targeted at professional investors, whereas UCITS are targeted at retail investors — although professional investors invest in UCITS as well. In that context, the emphasis of this stress simulation is on liquidity risk for UCITS. At a later stage, other simulations could be done, in particular looking at liquidity risk for AIFs.

Investment funds and UCITS in particular can invest in a broad range of assets with varying degrees of liquidity. In particular, UCITS offering daily redemptions to investors while investing in less liquid assets such as HY or EM bonds might be subject to a liquidity mismatch. Therefore, the objective of this analysis is to assess the resilience of UCITS to redemption shocks. Among UCITS, the emphasis is on funds investing primarily in fixed-income (FI) instruments since they are more likely to face a liquidity mismatch than equity funds.

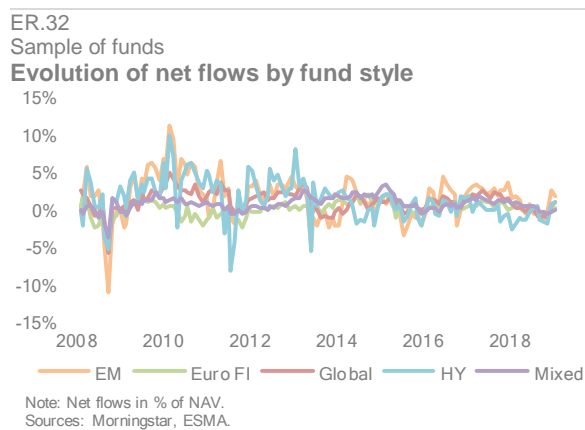
Given the diversity of fixed income UCITS, funds were classified into five different categories: HY bond funds, EM bond funds, euro fixed-income

funds, global fixed-income funds and mixed funds (see appendix for details).

ER.31 shows the evolution of the NAV for each fund style over time. Overall, the size of the fixed income fund industry increased from around EUR 775bn in 2008 to EUR 2,625bn at the end of 2018. Since 2008, the composition of the fund industry has changed with an increase in the proportion of HY and EM bonds funds (from 5% to 8%, and from 4% to 9% respectively) along with mixed funds and global FI funds (from 32% to 38% and 10% to 17% respectively), while the share of euro FI funds declined (from 49% to 28%).



Regarding net flows, ER.32 indicates that at the fund style level, HY and EM fund flows tend to be more volatile than other fund styles. In particular, EM and HY bond funds experienced large outflows (i.e. in the first percentile) during the global financial crisis, as well as during the taper tantrum in mid-2013. In the last few years, however, fund flows at the aggregate level have been more steady.



## Sample of funds

ER.33 provides an overview of the sample used. Monthly data on individual funds are retrieved from Morningstar, covering the period January 2008 to December 2018. Overall, the sample accounts for around 90% of the EU bond industry and close to 95% of EU mixed funds covered by Morningstar. The final sample includes close to 6,600 UCITS with an aggregate NAV of EUR 2,490bn at the end of 2018. Some funds were excluded because of data gaps regarding flows, NAV or portfolio composition (additional details are provided in the appendix).

ER.33  
Sample of funds  
**Main features**

Fund type	Database coverage		Sample		
	NAV (EUR bn)	Number of funds	NAV (EUR bn)	%NAV	Number of funds
HY	196	424	174	89	297
EM	243	500	229	94	439
Euro FI	800	2,363	734	92	2,030
Global FI	529	1,124	420	79	592
Mixed	993	3,855	933	94	3,240
<b>Total</b>	<b>2,761</b>	<b>8,266</b>	<b>2,490</b>	<b>90</b>	<b>6,598</b>
<b>Memo items</b>			<b>NAV</b>		
<i>UCITS bond funds</i>			2,536		
<i>UCITS mixed funds</i>			1,728		

Sources: Morningstar, EFAMA, ESMA.

## Summary of assumptions used

The modelling choices are summarized in ER.34. Overall, we follow the guiding principles outlined in the section presenting the STRESI framework. We use individual fund flows data to derive the distribution of net flows at fund style level. This allows us to use the entire dataset, including episodes when funds experienced very large outflows. The shock is calibrated using the ES approach as it encompasses all large outflows events and is robust to outliers, since the ES is computed as the average net flows below a given

percentile.

The resilience of funds is estimated using the HQLA approach. This approach provides an intuitive interpretation and is easy to compute, unlike TTL approaches which are not feasible given the large sample size (which would require having detailed liquidity information on several hundred thousand securities).

Regarding liquidation strategies, both methods are used since there is no consensus in the literature and using both approaches allows us to do some sensitivity analysis.

The price impact of trades resulting from the selling pressure from funds is estimated using high-level liquidity data by asset classes and assuming a linear price impact curve. Given the complexities and the uncertainties related to the estimation of price impact measures by instrument, using a high-level estimation provides more flexibility and is easier to implement. At the same time, this approach has limitations, since it assumes that all securities within an asset class have the same liquidity, and relies only on aggregate data to measure the price impact of trades.

Finally, the flow-return relationship is based on panel regressions allowing different parameters by fund styles, while restricting the impact to being similar within each fund style. This approach makes the interpretation easier and prevents counterintuitive effects from occurring (whereby negative returns lead to inflows).

ER.34  
Pure redemption shock  
**Summary of modelling choices**

Component	Constituent	Approach
Flows	Net flows	All funds by style
	Distribution of flows	Empirical
Calibration of shock	Scenario	Pure redemption shock
	Calibration method	ES
	Threshold	1%/3%/5%
Liquidity	Liquidity measure	HQLA
	Liquidation strategies	Slicing and waterfall
	Resilience	RCR
Second-round effects	Price impact	Linear price impact curve
	Flow-returns relationship	Homogeneous by fund style

Source: ESMA.

In this simulation, we model the impact of a pure redemption shock to the EU UCITS industry to assess the resilience of investment funds to severe but plausible shocks.



## Calibration of the redemption shock

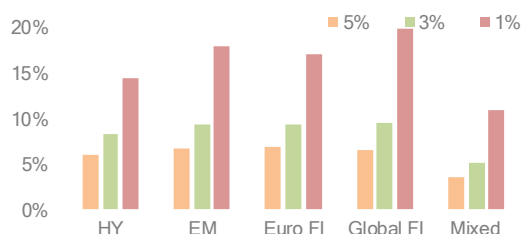
The shock is calibrated on historical data on weekly fund net flows from Morningstar. For each fund-style, all funds' net flows are used, in accordance with the homogeneity assumption. This approach makes use of all the data on net flows available and provides similar redemption shock within fund-styles, but different shocks between fund styles. Therefore, the heterogeneity between investment strategies is taken into account. One drawback is that results cannot be aggregated across fund styles, since different fund styles would not face the same type of redemption shocks at the same time. The shock is defined using the ES, since this method ensures that extreme events are taken into account. The ES is calibrated at three different levels — 1%, 3% and 5% — to check if redemption shocks are sensitive to the threshold level.

ER.35 and ER.36 show the estimated shocks by fund styles, with values ranging from around 4% for mixed funds to up to 20% for global FI, when using the 1% ES.

To put the redemption shocks in perspective, for the ESMA MMF stress tests, asset managers are subject to a weekly redemption shock of 20% for retail investors and 25% for institutional investors (ESMA, 2019c).

In the context of bonds funds, in the 2015 Ireland FSAP, HY and EM bond funds were subject to weekly redemption shocks ranging from 5% to 20% (IMF, 2016b), and in the 2016 Luxembourg FSAP bond funds were subject to redemption shocks ranging from 10% to 25%, although at a monthly frequency (IMF, 2017).

ER.35  
Redemption shock under the homogeneity assumption  
**Weekly shock by fund style**  
25%



Note: Weekly redemption shock calibrated using the expected shortfall at different levels (5%, 3%, 1%), based on the homogeneity assumption (all fund flows by fund styles).  
Sources: Morningstar, ESMA.

ER.36  
Calibration of shocks  
**Redemption shocks by fund styles (% of NAV)**

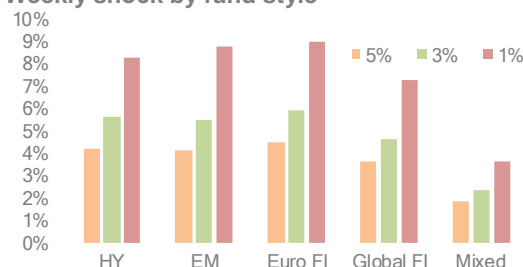
Fund style	ES 5%	ES 3%	ES 1%
HY	6.0	8.2	14.4
EM	6.7	9.4	17.9
Euro FI	6.8	9.3	17.1
Global FI	6.6	9.6	19.8
Mixed	3.6	5.2	10.9

Note: Redemption shock defined using the ES approach, based on all individual funds flows for each fund style (homogeneity assumption).  
Sources: Morningstar, ESMA.

As a robustness check, we also calibrate the redemption shock according to the heterogeneity assumption, whereby each fund has a different shock based on its historical flows.

ER.37 shows the estimated shocks for each fund style, with median values ranging from 2% for mixed funds to 9% for euro FI funds, when using the 1% ES. The magnitude of the shock is lower under the heterogeneity assumption (measured by the median) than the homogeneity assumption. This indicates that very large outflows tend to be concentrated in some funds.

ER.37  
Redemption shock under the heterogeneity assumption  
**Weekly shock by fund style**



Note: Median weekly redemption shock calibrated using the expected shortfall at different levels (5%, 3%, 1%), based on the heterogeneity assumption (shock specific to each fund).  
Sources: Morningstar, ESMA.

In the following sections, we focus on a redemption shock calibrated at the 3% level under the homogeneity and heterogeneity assumptions. This specific threshold is chosen for expositional purposes and also because the redemption shocks are in line with similar exercises. Additional information is included in the appendix.

## Highly liquid assets

For each fund in the sample, a measure of liquidity is estimated using the HQLA approach. This choice allows a comparison of liquidity levels between and within fund styles, which gives an indication of which types of funds are more likely to be exposed to liquidity risk. The liquidity

weights are derived from the Basel III framework and presented in ER.38.

ER.38 HQLA measures Liquidity weights by asset type (in %)				
Asset class	CQS1	CQS2	CQS3	<CQS3
Government bonds	100	85	50	0
Corporate	85	50	50	0
Securitised	65-93	0	0	0
Equities	50	50	50	50
Cash	100	100	100	100

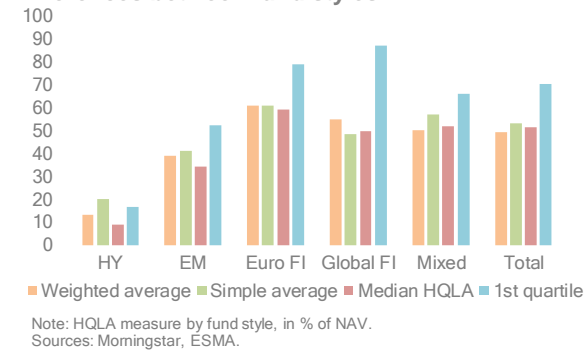
Note: CQS: credit quality step. CQS1 refers to AAA to AA ratings, CQS2 to A ratings, CQS3 to BBB ratings and <CQS3 any rating below BBB-. Liquidity weights are in %.  
Sources: EBA, ESMA.

For each fund, we get the portfolio composition by asset type (cash, equity, sovereign bonds, corporate bonds etc.) and by credit rating for bond holdings from Morningstar. However, data on credit quality apply to the overall bond portfolio without distinction by bond type, i.e. we have the proportion not of AAA sovereign bonds but only of AAA bonds. We apply the credit quality data to the entire bond portfolio; i.e., if 20% of bonds are rated BBB, we assume that 20% of sovereign and corporate bonds are BBB. Another approach could have been to assume that highly rated bonds are sovereign bonds first, with the remaining being corporate bonds. Our approach is more conservative, since liquidity weights for bonds with the same rating are higher for sovereign bonds than for corporate bonds. See Bouveret (2017) for a comparison of the two approaches.

Liquidity levels, measured by the HQLA approach, are quite heterogeneous between funds, reflecting the diversity of investment strategies (ER.39). HY funds have the lowest levels of HQLA (around 13% on average), followed by EM bond funds (close to 40%), while for other strategies, the HQLA measure is above 50%. The median and the simple average are quite close for most fund styles, indicating that the distribution of HQLA within fund styles is relatively homogeneous, which is also confirmed by the . HQLA measure using the first quartile.

These differences in liquidity levels are in line with other studies such as those by the IMF (2016b, 2017) which finds that EM funds tend to have higher levels of liquidity than HY funds, both in the US and in the EU.

ER.39  
HQLA measure  
Differences between fund styles

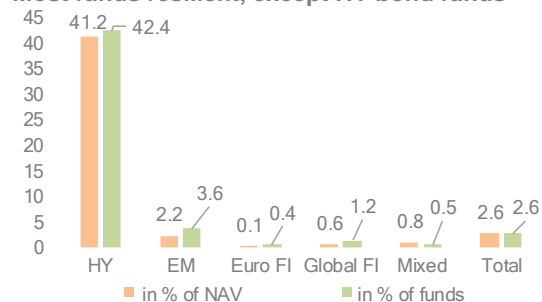


## Results

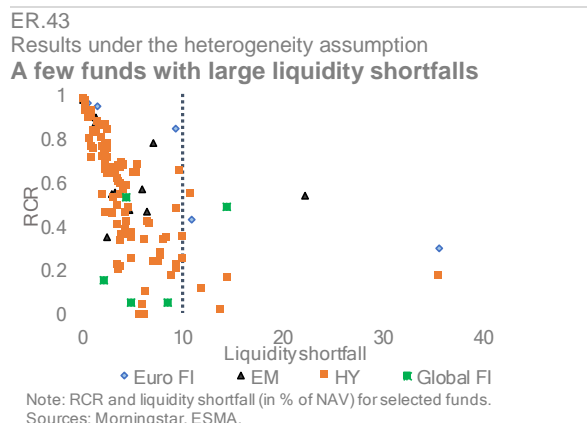
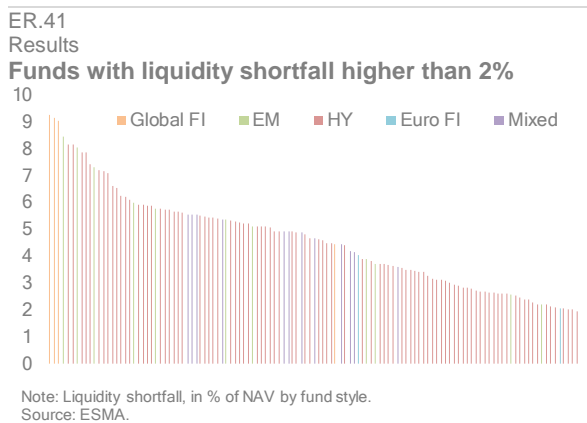
### Resilience of investment funds

Given the redemption shock and the measure of liquidity, the RCR can be directly computed for each fund and fund styles. Overall, most funds would be resilient to the redemption shock, as they have enough liquid assets to meet redemption demands. This is shown in ER.40, which indicates that for most fund categories, the proportion of funds with an RCR below one is lower than 1%. However, funds exposed to less liquid assets tend to be more vulnerable: funds with an RCR below one would amount to 2% of the NAV of EM bond funds and 40% of the NAV of HY bond funds.

ER.40  
Fund style shocks  
Most funds resilient, except HY bond funds



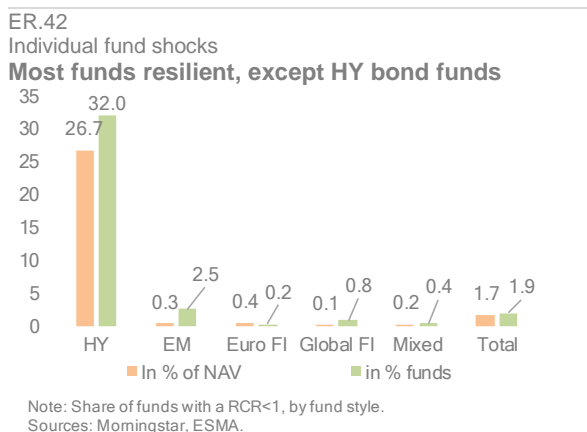
HY funds account for 75% of the funds with a liquidity shortfall higher than 2% of NAV, followed by mixed funds and EM funds with 10% each (ER.41).



Under the heterogeneity assumption, most funds would also be resilient (ER.42), except for HY funds, with around one third of funds having an RCR below one.

## Impact on markets

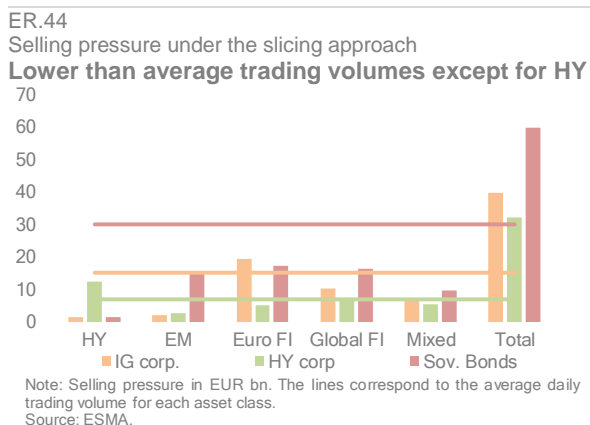
The consequences of the redemption shock on financial markets depend on the liquidation strategy pursued by fund managers. The liquidation strategy used by asset managers should comply with applicable rules (legal requirements from the UCITS Directives or self-limitations from prospectuses or fund rules). In that context, the slicing approach might be better at keeping the overall fund profile intact, thereby safeguarding investors. However, in certain cases, including during stressed periods, the waterfall approach might be better for investors, as it reduces the price impact of sales, preserving the fund performance. Therefore, the slicing and the waterfall approaches are used.



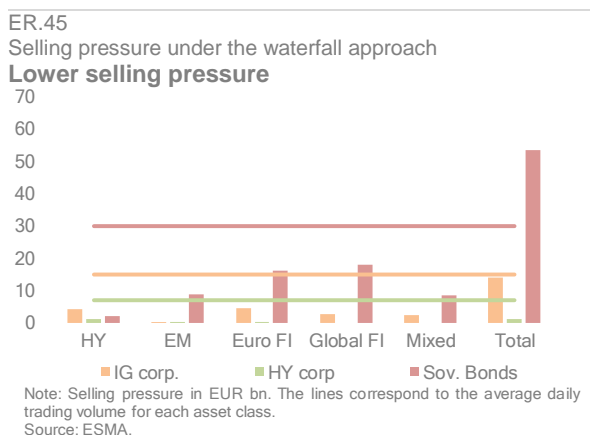
Most funds with RCR below one are HY funds, with a few funds from other categories and overall the liquidity shortfall is within 10% of NAV, implying that temporary borrowing allowed for UCITS could cover the shortfall. However, some funds would have a liquidity shortfall above 10% of NAV. This implies that, under this scenario, temporary borrowing would not be enough to cover investors' redemptions and funds might need to use liquidity management tools to cope with investors' outflows. Overall, under the heterogeneity assumption, the average redemption shock would be lower, but a few funds would face very large shocks (ER.43).

Under the waterfall approach, we assume that the liquidation strategy follows the liquidity weights defined by the HQLA. We also use a mixed liquidation strategy in which fund managers use cash first and then vertical slicing.

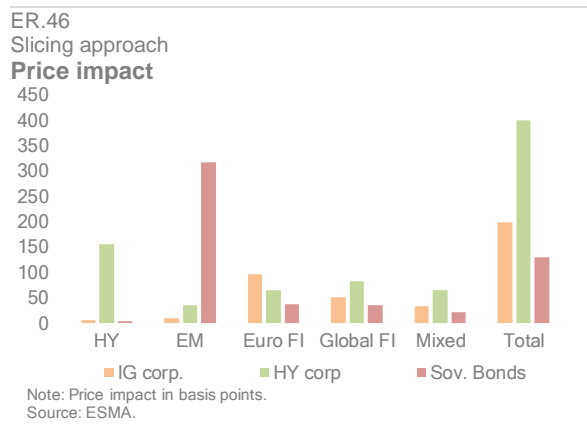
ER.44 and ER.45 compare the selling pressure with average daily trading volume under the slicing and waterfall approaches respectively. Under the slicing approach, sales from funds would be lower than average trading volumes, except for HY bonds, as HY funds would need to sell around EUR 12bn of assets against average daily trading volumes of EUR 7bn.



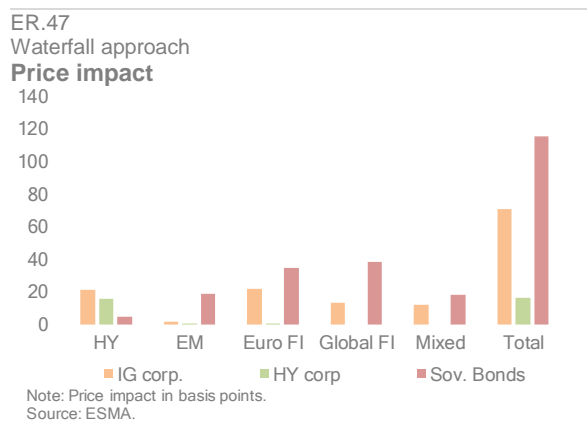
Under the waterfall approach, sales of bonds would be lower across all asset classes, since fund managers would first use their cash to meet investors' redemptions.



Using the price impact measures defined in the previous section (STRESI framework), we estimate the impact of fund sales on bond markets, assuming that fund managers need to liquidate their assets in one day, which is in line with the redemption frequency of most UCITS. Overall, the impact ranges from 40bps on average for sovereign and IG bonds, to 80bps for HY bonds (including up to 155bps when looking at HY funds) and up to 320bps for EM debt (ER.46).

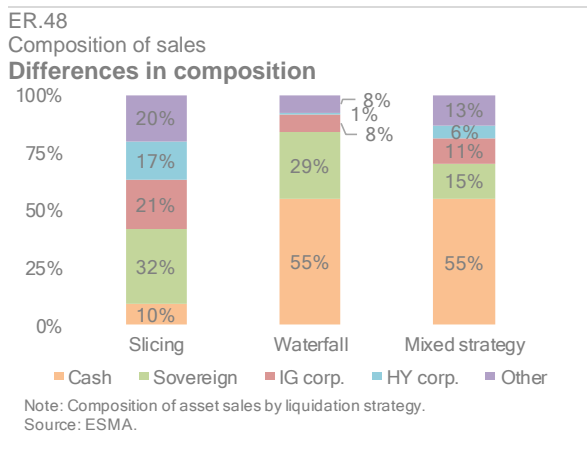


Under the waterfall approach, the impact on markets would be lower, since cash would be used first. Under the waterfall approach, managers would need to sell around EUR 70bn of bonds whereas under the slicing approach, bond sales would amount to EUR 130bn. The price impact on bond markets would be below 40bps in all cases (ER.47).



The large differences in the price impact stem directly from the liquidation strategies used: while the overall amount of assets to be liquidated remains the same, the composition of sales is very different.

This effect is shown in ER.48 by comparing the composition of sales by all funds under the slicing approach, the waterfall approach and a mixed approach in which cash is used first and then managers use vertical slicing. The sales of corporate bonds is always higher under the slicing approach than under the other two strategies. For less liquid asset classes, it implies that using vertical slicing in times of stress could lead to a sharp decline in prices, and therefore contagion effects.



## Second-round effects

To estimate the second-run effect on funds, we assume that the flow-return relationship is positive and derive our parameter from Fama-Macbeth regressions. First, cross sectional regressions are used in each time period to estimate the parameters that, in the second step are used in time series regressions to obtain the final estimates for parameters and standard errors. In contrast with standard ordinary least squares with time fixed effects, this amounts to equally weighting the period-by-period cross-sectional coefficient estimates. For each month, we run cross-sectional regressions of fund flows in  $t$  on the 12 lags of past monthly returns and flows and control for the fund size. Overall, we find that the flow sensitivity to past returns is always positively significant across fund types (ER.49).

ER.49  
Fama-MacBeth methodology  
**Sensitivity across fund types**

Bond funds	Return (t-1)
Emerging	0.554*** (0.194)
Euro FI	1.669** (0.816)
Global	0.621** (0.248)
High yield	1.896* (0.958)
Mixed	0.126*** (0.038)

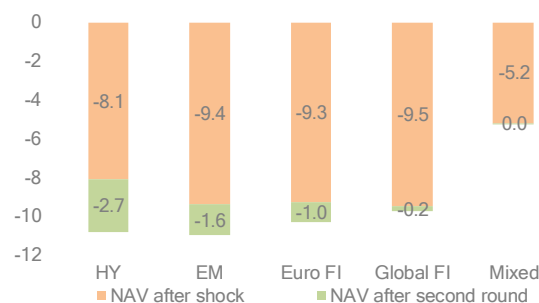
Note: Flow sensitivity to returns in  $t-1$  estimated by Fama-MacBeth regression. The coefficient displayed represents the time series average of cross-sectional regression coefficients. Newey-West standard errors in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5% and 10% levels respectively.  
Source: ESMA.

Compared with analogous analyses, our estimates point to a higher sensitivity of fund flows to returns for some bond fund categories. In the case of high yield bond funds, a one percent

decrease in returns leads to outflows equal to 1.9% of the NAV.

Using the price impact measures under the slicing approach, we can compute the second-round effect due to mark-to-market losses related to the liquidation of holdings by funds. The additional reduction in NAV ranges from close to 0% for mixed funds to 2.7% for HY bond funds. Most of the decline in NAV stems from the initial redemption shock rather than second round effects, yet for HY and EM bond funds, second round effects are sizeable. The overall redemption shocks for bond funds would range from 5.2% for mixed funds up to 11% for HY and EM bond funds (ER.50).

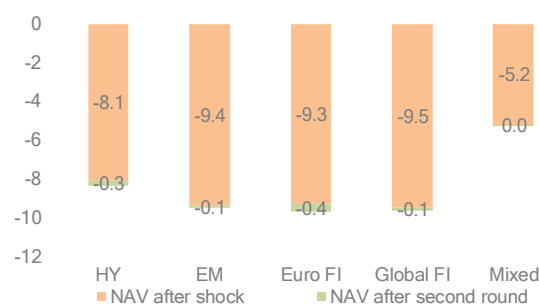
ER.50  
Decline in NAV under the slicing approach  
**Second round effects larger for HY**



Note: Change in NAV by fund style resulting from the redemption shock and second round effects.  
Sources: Morningstar, ESMA.

Under the waterfall and mixed approaches, second-round effects are very mild, since the price impact is low as the most liquid assets are sold first (ER.51).

ER.51  
Decline in NAV under the waterfall approach  
**Second round effects mild**



Note: Change in NAV by fund style resulting from the redemption shock and second round effects.  
Sources: Morningstar, ESMA.

## Conclusion

This case study shows how a pure redemption shock would affect European bond funds. Overall, most funds would be resilient to a weekly redemption shock of 5% to 10%, as they have enough liquid assets to meet investors' redemptions. Among fund styles, HY bond funds

would face more challenges given their low liquidity buffers measured under the HQLA approach. The forced liquidation due to investors' redemption would have a sizeable price impact on the market, especially under the slicing approach, yet under normal trading conditions, the market would be able to absorb the sales without disruptions for most bonds. The results presented here are illustrative of how the fund industry would react to a redemption shock, and modelling choices have a material impact on the results obtained.

Looking forward, ESMA plans to utilize the STRESI framework as part of its risk monitoring to monitor risks in the fund industry and safeguard financial stability.

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# Appendix

# Technical details

## Sample of funds and data cleaning

We used Morningstar to retrieve data on 8,266 EU UCITS. The time period covers January 2008 to February 2019. The funds were chosen based on the main strategies identified by Morningstar. Since the emphasis of the exercise is on liquidity risk, we focused on fixed-income funds and mixed funds that invest in fixed-income instruments and equities.

Five broad strategies are used: HY, EM, euro fixed-income, global fixed-income and mixed funds. HY funds invest mainly in lower-quality bonds. Morningstar changed its classification in October 2018 by redistributing former HY funds into different bond fund categories. Therefore, our sample of HY bond funds only include UCITS that were classified as HY by Morningstar up to October 2018. Emerging markets funds invest mainly in fixed income securities of issuers in emerging market countries, euro fixed income funds invest in euro-denominated bonds and global fixed-income funds invest in fixed income securities issued in developed countries throughout the world. The mixed funds category combines three different strategies in the Morningstar 'allocation' classification: aggressive (5% to 30% of the portfolio invested in fixed income securities and cash), cautious (50% to 80% in fixed income securities and cash) and moderate (30% to 50% in fixed income securities and cash).

For each fund, data on size, flows, portfolio composition and credit quality were retrieved from Morningstar. Funds for which those data were not available were excluded. Funds with less than 12 months of data were also excluded.

Data on daily flows were retrieved to estimate weekly flows. When daily data was not available, we used monthly flows converted into weekly flows by dividing the monthly flows by the number of weeks in each month. Data was cleaned by discarding flow data before the inception date of the fund, as well as flows larger (in absolute value) than 100% of the NAV of the fund in the previous period. Outflows higher than 90% of the NAV in the previous period were also excluded along with inflows higher than 3000% of the NAV.

Data on portfolio composition were retrieved at monthly frequency. Some funds only report quarterly data on portfolio composition. In such cases, it is assumed that portfolio structure remains the same between quarters. Data on credit quality were also retrieved at monthly frequency. When credit quality data was not available in Morningstar, we used Refinitiv Lipper to get the credit quality data, by matching funds using ISINs at the share-class level.

HQLA measures are computed based on the credit quality and the portfolio composition of each fund. Credit quality is available only for the whole portfolio (i.e. without distinction between sovereign and corporate bonds). Therefore, we distribute the credit quality indicators proportionally to the portfolio composition. For example, if 40% of the portfolio is HY and 60% IG, and 70% of the portfolio is comprised of sovereign bonds and 30% of corporate bonds, the implied credit composition is 42% IG sovereign ( $60\% \times 70\%$ ), 28% HY sovereign, 18% IG corporate and 12% HY corporate. In some cases, funds report a negative portion for cash, which we consider 0%, or cash higher than 100%, which we cap at 100%. Sometimes, the portfolio data do not cover 100% of the NAV, or the portfolio data includes derivatives that are not considered for HQLA purposes. The residual portion of the portfolio is always included in our analysis. For example, if we cover only 80% of the NAV of a fund and the fund experiences a shock of 20% of its NAV, the manager is assumed to liquidate only assets that are part of the 'known' portfolio (80% in that case).

## Computation of high quality liquid assets

For each fund in the sample, the level of HQLA is estimated using aggregated data to compare liquidity between and within fund styles. Using Morningstar data, securities available in a fund portfolio are grouped into six different asset classes, namely government bonds, corporate bonds, securitised products, equities, cash and derivatives. The liquidity weights assigned to each asset class are derived from the Basel III framework as indicated in ER.38. The different credit quality steps (CQSs) reflect the rating classification. As an example, CQS1 is the liquidity weight assigned to securities that are rated AAA and AA. Notably, cash are assigned a liquidity weight of 100% while derivatives are not considered. Securitised products in the CQS1 bucket are assigned a liquidity weight ranging from 65% to 93% as follows: 93% to covered bonds; 75% to agency mortgage-backed and non-agency residential mortgage-backed securities; 65% to commercial mortgage-backed and asset backed securities. Aggregated information on the credit quality is usually available only at portfolio level and not for each asset class. Given that the information on the portfolio and credit quality composition are available at different levels of granularity, averages are used to assess the final liquidity score of each asset class. The credit quality composition of analysed funds is retrieved from Morningstar and Refinitiv Lipper.

## Fund resiliency to redemption shock

ER.52 shows the share of funds with an RCR lower than 1 when the ES is computed under the homogeneity assumption and different levels of shock severity are applied.

ER.52

Fund style shock

### Fund resiliency under different levels of shock (ES)

Fund type	ES 1%		ES 3%		ES 5%		ES 10%	
	Nav (%)	Number of Funds	Nav (%)	Number of Funds	Nav (%)	Number of Funds	Nav (%)	Number of Funds
HY	66.9	218	41.2	126	28.5	87	15.8	48
EM	11.2	45	2.2	14	0.3	9	0.2	6
Europe FI	0.9	23	0.1	8	0.0	1	0	0
Global FI	2.7	25	0.6	7	0.1	4	0.1	3
Mixed Funds	1.1	26	0.8	16	0.7	13	0.6	12
<b>Total</b>	<b>3.8</b>	<b>340</b>	<b>2.6</b>	<b>171</b>	<b>1.8</b>	<b>114</b>	<b>1.0</b>	<b>69</b>

Note: Share of funds with a RCR < 1 under different levels of shock and the homogeneity assumption by fund style, in %.

Sources: Morningstar, ESMA.

ER.53 shows the share of funds with an RCR lower than 1 when the ES is computed under the heterogeneity assumption and different levels of shock severity are applied.

ER.53

Individual Fund shocks

**Fund resiliency under different levels of shock (Expected Shortfall)**

Fund type	ES 1%		ES 3%		ES 5%		ES 10%	
	NAV (%)	Number of Funds	NAV (%)	Number of Funds	NAV (%)	Number of Funds	NAV (%)	Number of Funds
HY	43.0	150	26.7	95	18.5	70	13.2	42
EM	3.0	37	0.3	11	0.2	7	0.1	2
Europe FI	0.6	15	0.4	5	0.3	3	0.3	2
Global FI	0.6	13	0.1	5	0.1	5	0.1	4
Mixed Funds	0.4	31	0.2	12	0.2	11	0.2	11
Total	2.3	246	1.7	128	1.1	96	0.8	61

Note: Share of funds with a RCR < 1 under different levels of shock and the heterogeneity assumption by fund style, in %.

Sources: Morningstar, ESMA.

## Estimation of price impact measures

We follow the approach of Coen et al. (2019) for measuring market depth:

$$MD(\tau) = c \frac{ADV}{\sigma} \sqrt{\tau}$$

We estimate market depth for the following asset classes: advanced economies sovereign, EM debt, IG and HY corporate bonds. Daily volatility is estimated using Bank of America Merrill Lynch bond indices for each asset class. Average daily trading volumes for sovereign bonds are taken from SIFMA and AFME data and weighted by euro area bond funds exposures to euro area countries, the US and the UK. For corporate bonds, trading volumes are assumed to be equal to the trading volumes of sovereign bonds multiplied by the relative size of corporate bond markets compared with sovereign bond markets. We use EMTA data for EM debt trading volumes and use the average of trading volumes for the two most traded instruments by country (Mexico and Brazil). All trading volumes are converted to euros using end of year exchange rates. Finally we set  $c$  equal to 0.4, in line with Cont and Schaanning (2017).

ER.54 below displays the estimated market depth and the price impact for a sale of EUR 1bn of assets. For example, for sovereign bonds, the market depth is given by:

$$MD(1) = 0.4 \frac{30}{0.26\%} \sqrt{1} = 4,615$$

The price impact is derived as the ratio of sales to market depth:

$$PI(\tau) = \frac{Sale}{MD(\tau)}$$

For a sale of EUR 1bn of sovereign bonds the price impact is therefore equal to 2.1 bps:

$$PI(1) = \frac{1}{MD(1)} = 0.021\%$$

ER.54

Price impact measure

**Impact by asset class**

Asset class	ADV	Volatility (%)	Market depth (EUR bn)	Price impact of sale of EUR 1bn (bps)
Sovereign	30	0.26	4,615	2.1
Corp. IG	15	0.30	2,000	5.0
Corp. HY	7	0.35	800	12.5
EM debt	2.5	0.33	303	33.0

Note: ADV is average daily trading volume, all values in EUR unless otherwise specified.

Sources: SIFMA, AFME, EMTA, Thomson Reuters Datastream, ESMA

When calculating the price impact for EM bond funds, we assume that such funds hold 50% of EM sovereign bonds and 50% of EM corporate bond. The price impact for EM corporate bond is estimated to be 33bps per EUR billion of sale. For EM sovereign bonds the price impact is calculated by adjusting the EM debt price impact of 33bps by the ratio of the price impact of sovereign debt to corporate debt, yielding a price impact of around 9bps.

## Estimation of second round effects

The second round effects are calculated by first adjusting the NAV by the size of the redemption shock and then estimating the additional outflows related to the price impact of sales. The price impact measures estimated previously are used to calculate the effect on funds' returns. We make the simplifying assumption that HY bond fund returns are entirely determined by HY bonds, EM bond fund returns by EM bonds, and those of other categories by the average of sovereign and IG corporate bonds. Once the negative performance has been obtained for each fund type, we apply the parameters of the flow-return relationship to estimate the additional outflows and calculate the final NAV.



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