Commission de Surveillance du Secteur Financier

CSSF Working Paper

Liquidity Stress Test for Luxembourg Investment Funds: the Time to Liquidation Approach

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March 2023

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Abstract

We present in this working paper a liquidity stress testing framework for investment funds, characterised by: 1) a time to liquidation approach, whereby a dynamic dimension is integrated in the assessment of the fund portfolio liquidity, 2) a dual impact shock, by which shocks hit both the liability side (redemption shocks as derived from a macroeconomic model and from the historical distribution of redemptions) and the asset side (application of a haircut to the liquidity of assets) and 3) a macroprudential perspective with both a contagion (via the price impact of first-round sales) and an amplification (via second-round effects of redemptions) channel.

Based on this framework, a liquidity stress test is applied to a sample of Luxembourg investment funds with total net assets of EUR 1.1 trillion and diversified investment policies (equity funds, bond funds, high yield (HY) bond funds, emerging market (EM) bond funds, among others). As outcomes, we show the time required for funds to meet the redemption and asset liquidity shocks, but also the proportion of funds, in terms of fund investment strategy and size, that can meet the shocks for a given time horizon as well as the average time to liquidate per fund investment strategy and size.

Among the key findings, we note that 83% of the funds can meet the macro redemption shocks within two days and 96% within five days. While overall results are reassuring, the figures also show that some funds are more vulnerable in case of larger shocks than others. The HY bond funds category, for instance, would take more time for liquidation, as only 87% of these funds can meet the macro redemption shock within five days. As to the price impact, by which all funds are affected following the initial macro-based redemption shock (contagion channel), it would amount to a market-wide impact, that is, a loss of around EUR 12 billion (compared to a market size of around EUR 5 trillion). We finally note that second-round effects have a relatively moderate impact. The empirical exercise relies on a set of assumptions on the size of the redemption shocks, on liquidity haircuts, on "participation rates" and on asset-specific liquidation features and is complemented by sensitivity analyses.

This framework, based on the time to liquidation approach, is a helpful risk management tool at individual investment fund level, but also a powerful supervisory tool for regulators, critical for those funds with less liquid assets in their portfolio, such as EM or HY bond funds. This paper also aims at contributing to the FSB (2022) goal of promoting the "*use of fund-and system-level stress testing"* and the "*sharing of experiences among authorities on the design and use of such stress tests*".

JEL Classifications: G110, G12, G18, G23

Keywords: Investment funds, liquidity risk management, macroprudential stress test, price impact, redemptions, time to liquidation

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[1] The views expressed are those of the authors and do not necessarily reflect the views of the CSSF. Any errors or omissions are the responsibility of the authors. The authors would like to thank Alain Hoscheid, Georg Kiefer, Tom Ungeheuer for detailed feedback and the market participants that shared their views/approaches to liquidity stress testing, with a focus on time to liquidation.

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1. Introduction

The Luxembourg investment fund industry amounted to EUR 5.0 trillion at the end of December 2022, while posting a growth of around 8% annually over the last 10 years. The size and recent growth of the investment fund sector at a global level as well as its potential vulnerabilities and impact on financial stability have been at the centre of attention of various international authorities, regulators and central banks (e.g. FSB, IOSCO, ESRB, ESMA).

Based on the most recent market experiences around financial market liquidity (e.g. COVID-19, the Ukraine crisis), global regulators are particularly interested in assessing whether non-bank financial intermediaries (e.g. investment funds) have the potential to initiate, amplify, but also mitigate financial stability risks, with a special focus on investment funds' and financial market liquidity. Various market participants, but also regulators, are hence interested in the regular assessment of the fund sector's resilience, especially regarding their liquidity and impact on market liquidity (see IMF (2017b) and ESMA (2019a, 2019b) among others).

This working paper is designed to present the key features of a liquidity stress testing framework in place at the level of the CSSF for the investment fund sector, thereby contributing to the ongoing discussions among national and international supervisors/authorities on liquidity stress testing for investment funds and recent publications relating thereto (see for instance FSB (2022)).

The key characteristics of this liquidity stress testing framework are the following:

1) The assessment of the liquidity on the funds' asset side integrates a dynamic dimension, called the time to liquidation approach, which assumes that liquidation takes a time proportional to the asset's liquidity. This approach is specifically useful for funds investing in less liquid assets, such as emerging market (EM) or high yield (HY) bonds, for which the traditional tiered approach, which assigns liquidity weights per asset group, does not yield meaningful results (i.e. the High-Quality Liquid Assets (HQLA) approach typically sets the liquidity of high yield bonds to zero whatever the liquidation horizon).

2) The systemic stress is simultaneously imposed on the asset side (by stressing the market liquidity of all invested assets) and on the liability side (by applying a redemption shock resulting from a macroeconomic model/scenario and a uniform redemption shock).

3) It incorporates a macroprudential perspective by integrating a potential contagion (via the price impact of first-round sales) and an amplification (via second-round effects of redemptions) channel.

This liquidity stress testing framework for investment funds (hereafter "TTL-LSTIF", where TTL stands for time to liquidation) has been implemented at the CSSF on a representative sample of 448 Luxembourg funds representing EUR 1.1 trillion of total net assets (TNA), comprising the vast majority of EM and HY bond funds for which the TTL approach provides the most added value, but also other fixed income funds, equity funds, mixed funds and alternative investment funds. While performed on a yearly basis, the detailed portfolio information used in this paper comes from a specific data collection exercise performed by the CSSF with the Luxembourg fund industry in July 2021.

This analysis is organised as follows: Section 2 provides an overview of liquidity stress testing frameworks for investment funds and two specific applications for Luxembourg investment funds. Section 3 presents our approach, that is the TTL-LSTIF. We discuss the key outcomes in Section 4 and conclude in Section 5.

2. Stress Testing Frameworks

2.1 Solvency and liquidity stress tests

Stress tests are (supervisory and industry) tools designed to assess the resilience of economic entities to pre-determined adverse shocks. They were initially developed as solvency stress tests for the banking sector to assess individual banks' prudential capital adequacy and the potential need for supervisory actions or re-capitalisations (see Adrian, Morsink and Schumacher (2020) for a perspective on the chronological development of stress tests at the IMF).

However, the solvency stress test perspective/framework used for the banking sector cannot be adopted as such for investment funds. Investment funds typically inform investors explicitly in their fund documentation that they might lose parts or all of their initial investment, as underlying asset prices fluctuate and as there are in principle no capital guarantees. The investors in investment funds are absorbing potential losses in the underlying assets of the investment funds via fluctuating fund prices. Other methodologies and tools have therefore been developed for investment funds.

Although investments funds are generally not faced with solvency risk, they generally bear liquidity risk. Investment funds typically pool investors' capital to invest in target assets with a heterogeneous and often also time-varying degree of liquidity (e.g. equity, fixed-income instruments, other instruments), while at the same time often granting investors the right to redeem their investment for cash in a short time frame (except for closed-ended funds, which are out of the scope of this analysis). It is through this liquidity transformation and the resulting potential risk of liquidity mismatch that systemic risk considerations emerge. In a scenario of large and unexpected redemption requests (e.g. during a financial crisis), the fund manager would need to sell larger parts of the assets held by the investment fund in financial markets to meet the obligation to redeem investors, possibly at a discount, should the market not be able to absorb them smoothly. As stated by the IMF (2021), "*while stress facing a fund (or funds investing in certain asset classes) per se might not directly generate a systemic impact as funds are highly substitutable, it can trigger systemic market turbulence and distress of other financial institutions through their interconnectedness*" (for instance via similar asset holdings with banks, insurance companies, etc.).

Consequently, investment fund-specific stress tests are generally designed from a liquidity risk perspective (see Bouveret (2017), ESMA (2019b) and IMF (2021) for a review of some liquidity stress testing approaches designed for investment funds).

2.2 Tiered approach versus time to liquidation approach

The outcomes of liquidity stress tests depend on the way liquidity on the asset side of investment funds is assessed. There are broadly two approaches:

- The tiered approach consists of grouping the assets into specific liquidity buckets and assigning static liquidity weights to these buckets that reflect the proportion of assets that could be sold for meeting investors' redemptions.
- The TTL approach consists in determining the liquidation time of assets, the time being dependent on the degree of liquidity of the assets held.

Under the tiered approach, the liquidity buckets can be inspired from the work of the Basel Committee on Banking Supervision under Basel III concerning the calculation of High-Quality Liquid Assets (HQLA) (see ESMA (2019b) and Bouveret (2017)). Under such an approach, for illustration, liquidity weights might be 100% for investment grade (IG) sovereign bonds, 50% for HY sovereign bonds and 0% for HY corporate bonds. The ability of investment funds to respond to redemptions will depend on the proportion of the portfolio invested in the different liquidity buckets and that can be liquidated based on these exposure-weighted HQLA percentages. As an alternative to the HQLA approach, the liquidity buckets can be simplified into a binary classification with liquid assets on the one side (cash and short-term debt securities) and illiquid assets on the other side (all other securities), the former having liquidity weights of 100% and the latter of 0%.

Under the TTL approach, the liquidity of an asset is no longer determined by a liquidity weight (bucketing approach), but by the proportion of a position that can be liquidated, for instance per day, without impacting the market prices. The liquidation of less liquid assets takes more time than that of liquid assets, with the speed of liquidation being dependent on the market depth as measured by indicators such as turnover ratio, trading volume, price volatility or bid-ask spread, which can be assessed either at an asset class level or, more granularly, at an individual security level.

The two approaches have costs and benefits. The main cost of the TTL approach is the need to have detailed and reliable information on the characteristics of the underlying securities held in the fund portfolios, including related liquidity, to gauge adequately their respective TTL. For the tiered approach, the cost/limitation is its relative inapplicability to funds with less liquid assets (e.g. funds fully invested in HY corporate bonds are considered as completely illiquid according to the above illustration).

Based on a specific industry data collection exercise led by the CSSF and providing for granular information on the underlying assets of fund portfolios, the CSSF implemented the TTL approach.

2.3 Microprudential and macroprudential stress tests

A macroprudential stress test is a "*methodology to assess financial vulnerabilities that can trigger systemic risk and be used to support the recommendation of mitigating measures for the system*" (IMF, 2021). While microprudential stress tests assess the resilience of individual financial entities (banks, insurance companies, funds) and mainly lead to a "pass or fail" binary outcome (with potential consideration of different time horizons, for instance, in the case of liquidity stress tests for investment funds), macroprudential stress tests extend the microprudential framework by incorporating potential contagion and amplification channels to other financial market actors and by extending the perimeter of analysis to the whole financial system.

The contagion channel highlights a consequence of the price impact resulting from the aggregate asset liquidations. This channel was originally illustrated by Cetorelli et alii (2016) for US bond funds: they "*calculate the losses caused by the decrease in market prices for all mutual funds holding any of the [liquidated] assets and then sum these losses across the system. [They] call these losses aggregate vulnerability*". This "aggregate vulnerability" somehow measures the cost of the overall asset sales for the larger financial system and leads to the discussion on the loss absorption capacity of the system. It was inspired from Greenwood et alii (2015) who developed it for stress tests on the banking sector. The aggregate vulnerability varies over time and depends on the degree of similarity of the fund portfolios, amongst others. This approach was extended and applied to equity funds by Fricke and Fricke (2021) and to Luxembourg funds by Lee (2020).

The amplification channel generally operates via the so-called "second-round effect". In the context of the initial redemption shock, the affected investment funds liquidate assets to meet the redemption requests of investors. As a result of these asset liquidations, it is assumed that the market prices of the target assets decrease in value, which further depresses the net asset value of the funds and in turn leads to a "second-round" of redemptions and asset liquidations. The response of further net redemptions to past negative performance is generally referred to as the "flow-performance relationship". This amplification channel is a common feature of a macroprudential perspective, where a universal stress test scenario is considered simultaneously on all investment funds and where prices become endogenous.[4] Second-round effects are now standard features of macroprudential stress tests (see for example ESMA 2019b), although the implementation details differ largely from one framework to the other (especially the assumptions underlying the price elasticities and the modelling of the flow-performance relationship).

Another feature of macroprudential stress tests relates to the perimeter of the liquidity stress testing framework and the interconnectedness of financial market actors. As emphasised in its definition, the macroprudential approach aims at assessing the systemic risk rather than the risk of an individual fund or of a sector. Some stress tests are applied to equity funds (Fricke and Fricke 2021), others to bond funds (Cetorelli et alii 2016), others cover equity, bond and mixed fund categories (Lee 2020, ESMA 2019b). Still other stress tests cover the linkages between investment funds and banks (IMF 2017a), or consider a perimeter including investment funds, hedge funds and security dealers (Baranova et alii 2017), while again others are fully transversal by integrating the bank, insurance and investment fund sector into a stress test devoted to commercial real estate assets (HCSF 2016). The broader the perimeter, the more macroprudential the stress test can be considered.

While our investment fund stress testing framework integrates both the contagion channel (via the losses associated with the price impact) and the amplification channel (via second-round effects of redemptions), it focuses on certain investment fund categories and related asset classes, while leaving other financial market actors out of scope. In terms of perimeter, this analysis covers a wide set of investment fund strategies, but does not consider further interlinkages with other financial market actors (e.g. banks or insurance companies).

2.4 Liquidity stress tests for LU investment funds

Beside the practical guides or reviews referred to so far (Bouveret 2017, Grillet-Aubert 2018, ESMA 2019b and IMF 2021), we now summarise two liquidity stress tests specifically developed for, and applied to, the Luxembourg investment fund sector, one related to the 2017 Luxembourg Financial Sector Assessment Program (FSAP) (IMF 2018) and a working paper published by the Luxembourg Central Bank (Lee 2020).

The IMF performed a macroprudential stress test on the Luxembourg investment fund sector as part of the IMF's 2017 Luxembourg FSAP mission (IMF 2017a, 2017b and 2018), by computing for each fund its redemption coverage ratio (defined as the ratio of liquid assets to net outflows), thereby assessing the "*capacity of individual funds to cope with severe but plausible redemption shocks. Shocks are calibrated based on the historical approach and on an adverse scenario combined with a macro-financial model*."

The redemption shock is then compared, via the redemption coverage ratio, to the fund liquidity as defined in two ways. The first (and most restrictive) measure includes only cash and short-term debt securities (with maturity of less than one year) and the second "*follows a high-quality liquidity asset (HQLA) approach by attributing liquidity weights to each asset class depending on the rating, instrument type and issuer*."

[4] In other words, when investment funds are considered on an aggregate basis, prices are no longer taken as given/exogenous, but partially reflect the sum of their actions.

The liquidity stress test does not incorporate amplification or contagion channels within the investment fund sector as in our approach. The macroprudential dimension of the stress test mainly results from the wide perimeter of the FSAP where stress tests are operated for banks, investment funds, insurance and household sectors and integrated through common assumptions (macro scenario) similarly applied to all sectors. "*Liquidity stress tests reveal that most fixed income funds would be resilient to severe redemption shocks, when liquidity buffers are measured by HQLA, with HY funds more vulnerable than others.*"

Lee (2020) assesses the "aggregate vulnerability", an indicator measuring the "*percentage of aggregate equity of all funds that would be wiped out by their assets liquidation (or fire sales) following initial [redemption] shocks*", in the Luxembourg investment fund sector by implementing a macroprudential stress testing model based on Greenwood et alii (2015), Cetorelli et alii (2016) and the working paper version of Fricke and Fricke (2021). The paper "*focuses on the calibration of key parameters such as the flow-performance sensitivity and price impacts that are included in the model to capture the so-called second-round effects of an initial adverse shock to funds' returns. According to the empirical results, limited degrees of vulnerability were found for the main fund categories such as equity, bond and mixed funds. This implies that the investment fund sector in Luxembourg does not raise any particular concern for financial stability as of November 2019.*"

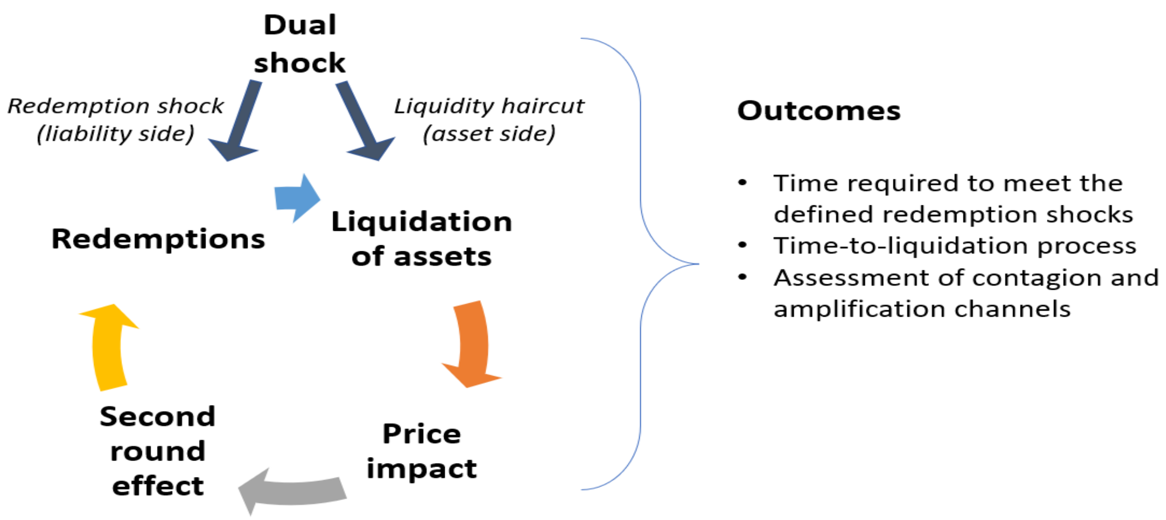
Our approach complements these two applications of liquidity stress testing to the Luxembourg fund sector, the application of the TTL to Luxembourg funds being in our view the key contribution of our analysis.

3. Investment Fund Liquidity Stress Testing Framework

3.1 Overview

Before going into the implementation details, we provide a sequential overview of the TTL-LSTIF, starting from the shock, going through the liquidation process, the price impact, second-round effects and finally presenting the key outcomes, as illustrated in Figure 1.

FIGURE 1 - Overview of the LU TTL-LSTIF



Dual shock: The TTL-LSTIF is designed to assess the resilience of Luxembourg investment funds to some predetermined systemic shock. We consider a dual shock: (1) a shock on the liability side via redemption shocks calibrated with two alternative approaches, either (i) based on a macroeconomic model or (ii) on historical distributions of redemptions, and (2) a shock on the asset side, which captures the systemic dimension of the stress, materialised by the application of a haircut on the liquidity of the assets held in the fund portfolio (assuming a reduction of market liquidity of assets). The shocks and their calibration will be detailed in Section 3.4.

Liquidation of assets: Our framework has at its core the TTL approach, whereby the portfolio liquidity is assessed dynamically by determining the number of days necessary to liquidate each specific portfolio position held by a fund.

This liquidation of assets is made on a pro rata basis on all portfolio assets and is determined by the size of the applied redemption shock. The amounts that can be liquidated per day are calculated at the most granular level of the portfolio (i.e. at individual security level) and depend on the following:

i. The daily liquidation amount, which refers to the amount of assets that can be liquidated every day for a given portfolio position held in the fund and which depends on the average historical daily trading volume of the assets as well as on several asset specific features (e.g., size, sector, rating) that will be detailed in Section 3.3.
ii. A participation rate, which refers to the proportion of the market liquidity (daily trading volume) that is assumed to be available for a given fund in normal times. We assume that 1) a given fund manager can only access a limited portion of the market liquidity of a given asset to avoid impacting market prices (the so-called participation rate) and that 2) the market liquidity (depth) of a given asset is represented by its average historical daily trading volume, while considering, based on the experience gathered from our supervisory work, that market depth appears generally to be higher than the historical trading volumes displayed by the available data.
iii. A haircut, which captures the systemic dimension of the stress by reducing the available daily liquidation amount under an adverse market shock.

While the liquidation amounts (before application of the haircut) are capped (through the application of the participation rate) by the condition that the liquidation of the assets of a fund has no impact on the asset prices in normal times, it is assumed that the aggregation of all asset liquidations for the funds in the sample, as a result of the systemic shock, has an impact on market prices, as referred to in the next paragraph.

Price impact: Given the systemic perspective of the liquidity stress test, we consider that the aggregation of asset liquidations across funds will impact market prices. We therefore rely on the estimates of ESMA (2019b) to assess the price impact at the asset class level and get a view on the market losses materialising as a result of the assumed market-wide effect.

Second-round effects: Besides inducing direct market losses, the price impact also has a separate effect on redemptions. The investment fund's past return is generally found to be a key driver of subsequent capital flows of investors: bad performance triggers further capital outflows of investors (i.e. redemptions). We therefore integrate this amplification channel into our framework, by measuring at fund strategy level second-round effects, where additional outflows depend on the performance of the fund determined by the price impact of initial redemptions. This second-round effect of redemptions amplifies the shocks and results in additional time needed to meet the overall redemption shock. Typically, a fund might take, for instance, three days to meet the initial redemption shock and one additional day to meet the second-round redemptions. We do not consider third-round effects. The price impact and the second-round effect will be detailed in Section 3.5.

Outcomes: Having performed the analysis, we will have a view on the time needed for the funds (per size and fund strategy) to meet the redemption shocks under a systemic shock also affecting the asset liquidity as well as the related distribution of the TTL for our sample of funds. We will then shift from the fund perspective to the asset category perspective by showing the TTL of the asset categories held across the funds' portfolios, to give a view on the way the fund portfolio composition affects the results of the stress test. Finally, we quantify the price impact induced by the asset sales resulting from the initial redemption shock and their impact for the funds (contagion channel) and estimate the second-round redemption shocks (amplification channel). These outcomes will be presented in Section 4 where an illustrative application of the TTL-LSTIF to Luxembourg investment funds is provided.

3.2 Data

An industry data collection exercise was initiated by the CSSF in July 2021 for monitoring the liquidity risks in Luxembourg funds, in continuation of the work performed in 2020 via the ESMA Common Supervisory Action on liquidity risk management for UCITS and the ESRB recommendation to ESMA to assess the preparedness of corporate debt and real estate funds to potential future adverse shocks, including any potential resumption of significant redemptions and/or an increase in valuation uncertainty (ESRB 2020).

The data collection exercise covered a sample of 448 investment funds, representing around EUR 1.1 trillion of total net assets (TNA) as at 30 June 2021 and focused on quantitative data related to portfolio composition and liquidity information. The scope of the exercise encompassed UCITS and alternative investment funds, mainly investing into fixed income, but also equity. Most funds have a daily redemption frequency, with only a limited number of AIFs having a weekly or monthly redemption frequency.

The data collection included detailed information on "line-by-line" portfolio holdings and, in particular, for each individual security position, information on the total issue size, the average historical daily trading volume and the proportion of the individual security position that could reasonably be expected to be liquidated within one day, one week, one month, one quarter, one semester, one year.

We use the exact same sample of investment funds for the calibration of the TTL-LSTIF (especially the calibration of the time to liquidation, but also the model-based estimation of the macro redemption shock and the estimation of the second-round effects) as for the illustrative application presented in Section 4.

As detailed in Table 1 below, in our paper we cover four fund strategies, namely Bond funds (BOND), Equity funds (EQTY), Mixed funds (MIXD) and Other funds (Other IFs), as based on the BCL (Banque centrale du Luxembourg) classification (i.e. Other IFs being the residual category). We further provide a more granular view on the BOND category by splitting it into EM bond funds (BOND-EM), HY bond funds (BOND-HY), Global bond funds (BOND-GB) and Other bond funds (BOND-OTHR).

We first note that Bond funds are the main fund category, being also the focus of our analysis given their specific exposure to the developments during the March 2020 COVID-19 turmoil (ESMA, 2020) and the specific vulnerabilities identified for EM and HY bond funds during this episode. We then note that the funds in the sample are relatively large, with a median NAV of EUR 1.5 bn (going up to EUR 2.5 bn for mixed funds).

We finally provide a first view on the fund asset allocation as averaged per fund category. To be noted that Mixed funds invest 16% of their portfolios in other funds (UCIs) and that the category Other IFs invests 21% in money market instruments (MMIs) and 9% in structured products.[5]

TABLE 1 – Description of the fund sample (figures in % of assets)

Fund category	#Funds	Median TNA (Euro)	Total TNA (Euro)	Cash or deposits	Equity	Bonds	MMIs	Structured products	Units of UCIs	Other
BOND-EM	63	1,350,037,358	112,174,386,101	8.87	0.40	87.09	0.70	0.46	2.42	0.05
BOND-HY	60	1,399,797,590	134,401,553,457	2.43	0.47	93.11	0.49	1.37	2.09	0.05
BOND-OTHI	106	1,546,898,381	231,813,273,282	8.61	0.24	83.43	0.34	5.39	1.96	0.03
BOND-GB	81	1,812,719,544	193,218,922,579	3.12	0.55	86.57	1.52	5.81	2.30	0.13
EQTY	61	1,426,224,027	119,257,700,303	2.42	88.02	5.64	0.22	0.00	1.85	1.85
MIXD	59	2,533,908,475	250,075,429,122	4.49	28.25	43.64	3.53	1.21	16.43	2.46
Other IFs	18	426,538,691	32,741,114,190	0.84	7.71	53.66	20.93	9.36	7.14	0.35
All funds	**448**	**1,569,923,878**	**1,073,682,379,035**	**5.08**	**16.45**	**66.94**	**2.03**	**3.01**	**5.66**	**0.83**

As the asset TTL is determined at the security position level, we provide in Table 2 a view on the average number of securities (with derivatives and cash excluded) held in the portfolios of the fund sample as well as the first, second and third quartiles of the distribution of the funds in the sample.

The funds have on average 457 positions with a median much smaller at 259, which suggests that some funds have a much larger number of securities. Bond and Mixed funds have typically more securities than Equity and Other IF funds, while the Mixed fund distribution looks quite asymmetric. These features give an indication of the level of diversification of the assessed funds. As smaller positions can be liquidated in a shorter time frame, diversified funds with many smaller positions (all else being equal) will have shorter TTL.

[5] Derivative instruments are not considered in the analysis.

TABLE 2 – Number of securities held in portfolio across all funds

Fund Category	Average	Q25%	Median	Q75%
BOND-EM	280	159	255	360
BOND-HY	479	225	298	511
BOND-GB	754	254	485	829
BOND-OTHR	473	177	320	502
EQTY	103	52	77	107
MIXD	635	76	213	802
Other IFs	145	38	111	190
All funds	**457**	**128**	**259**	**500**

3.3 Time to liquidation

3.3.1 Principles

Liquidity risk: Risk that a position in the UCITS portfolio cannot be sold, liquidated or closed at limited cost in an adequately short time frame and that the ability of the UCITS to comply at any time with its redemption obligations and/or other payment obligations (e.g. margin calls) is thereby compromised.

This (in)ability to sell asset positions ahead of a predetermined systemic shock (detailed in the next sub-section) will be translated into a TTL measure, that is a measure of the time needed by the fund to liquidate assets in proportion of the size of the liquidity shock. The liquidity of asset positions is assessed on a dynamic basis by gauging the amount that the market is able to absorb on a daily basis. The asset liquidation, as considered in the TTL-LSTIF, relies on a set of assumptions as set out hereafter.

Liquidation takes time: The TTL depends directly on the market depth available for given asset positions and, in particular, on the amount the market can absorb of a specific security which is approximated by the estimated average historical daily trading volume available for different groups/ classes of securities.

A specific downward adjustment (called a participation rate) is applied to the average historical daily trading volume to take into account that other financial actors transact in the market and to ensure that the amount to be traded (the order size) is well below the historical market depth available and will thus match the liquidity available in the market, without impacting the market price in normal times.

Other adjustments are made to make the measures more robust (by averaging per sub-fund category) and more consistent (to ensure that the market absorption capacity is positively correlated with liquidity features) in accordance with the methodology detailed in **Appendix 1**.

Time to liquidation depends on security characteristics: The TTL depends directly on the following parameters:

(i) the size of the asset position to be sold in the market;

(ii) the nature of the assets (equity, fixed income, UCIs, structured products (notably securitisations/ABS), MMIs, cash);

(iii) the rating of the instruments, if and when available (AAA, AA, A, etc.);

(iv) the issuer sector (financial, public sector, corporate); and

(v) the size of the issue of the instrument (when available/relevant and currently only used for fixed-income instruments).

However, the TTL is not considered to depend on the size and the characteristics of the fund. In other words, we consider that the time required to liquidate a given euro amount invested in a specific security will be the same for a small or a large fund. This is based on the view that the capacity of the market to absorb a given sale will not depend on the identity of the liquidating fund, but rather on the characteristics of the assets and its market (quality, size of the sale, market depth).

Liquidation does not depend on other funds: In the TTL-LSTIF, the TTL is not considered to depend directly on the sales of other funds (except on a general basis, via the participation rate which assumes that only a portion of the daily liquidity is available). In other words, the behaviour of other funds (or other financial market actors, e.g. banks), the potential synchronicity of sales, is not directly factored in the asset specific TTL.

However, the synchronicity remains a risk that needs to be considered. We address it in the framework by two separate blocks:

Firstly, the stress testing is exerted via a dual shock, one being on the asset side. The haircut (discount) imposed on the liquidity of the assets materialises the loss of liquidity derived from the systemic shock imposed by the synchronous/simultaneous redemptions (see Section 3.4 for more details on the shocks).

Secondly, the synchronicity of the sales induced by our macroprudential perspective will generate a price impact commensurate to the aggregate value of the sales to be made by the funds in the sample, which will give rise to direct losses for the funds through the contagion channel on the one side and to second-round redemption effects on the other side (see Section 3.5 for more details).

Liquidation is made on a pro rata basis: The asset positions held by the funds are sold in exact proportions of their corresponding weight in the fund's initial portfolio. For a redemption shock amounting to x%, the funds will liquidate exactly x% of each individual asset position held (e.g. x% of their cash, x% of each individual equity position, x% of each individual bond position, etc.).

At the end of the liquidation process, the portfolio will remain proportionally identical to its initial structure. However, it is worth reminding that the speed of liquidation is not the same for all asset positions. More particularly, while cash can be liquidated within one day, bond positions' liquidation process might take for instance a week. We thus may have a transitory change in the portfolio structure and related weights of individual positions, as more liquid assets could be liquidated quicker. In any case, however, the portfolio composition/allocation is kept identical at the end of the liquidation process.

Fund risk profile remains unchanged: The liquidation is assumed to have no effect on the risk profile of the fund, as captured by its financial leverage (as well as, for instance, its duration, but not its synthetic leverage as we have excluded financial derivatives from this analysis).

In other words, the ratio of the assets under management (AUM) to the NAV must remain constant. It implies that a redemption request of 10% (in terms of NAV) will give rise to a liquidation of 10% of AUM. For illustration purposes (and considering that most funds in the sample are UCITS having a temporary borrowing limitation of 10% of the NAV), a leveraged fund with an AUM/NAV ratio of 200% will then liquidate twice the amount of the redemption shock. The implicit rationale is that the liquidation proceeds will be used to meet both the redemption requests and the commensurate debt alleviation in view to keep the risk profile (or leverage) constant.

Without this assumption, leveraged funds would be more leveraged at the end of the liquidation process, which is not a conservative approach.

3.3.2 Liquidation rates/amounts

The TTL-LSTIF is based on the estimation, for different types of securities (fixed-income securities, structured products, equity, target funds/UCIs and cash), of the maximum amount that can be traded/liquidated for each security under normal and stressed market conditions. The stressed market conditions are reflected by the application of a haircut to the estimated daily liquidation amounts.

The estimation of these daily liquidation amounts is based on the rating, the size of the issue (amount issued) and its sector (sovereign, corporate and financial) for fixed-income securities. For structured products, it is based on its rating; for equities, we have estimated the average historical daily trading volume based on the market capitalisation (by differentiating small cap, mid cap and large cap); for target funds we have estimated a fixed conservative amount (in the absence of the application of a look-through on the underlying assets) that can be liquidated on a daily basis; while we assume that cash positions (which include cash equivalents such as units of MMFs and MMIs) have a daily liquidity.

To be conservative with the estimation of the daily liquidation amounts, we apply a participation rate (i.e. 10%, 20% or 30%, depending on the parameter choice, or in other words, a discount of 90%, 80% or 70%, respectively) to ensure that the liquidation does not affect the market prices in normal times. The participation rate applies to all categories (exception made of cash/MMIs).[6]

For illustration, let’s assume that a given Fund A holds EUR 50 mof debt securities issued by a corporate X, the total issue size being EUR 0.9 bn with a AAA rating. Based on these characteristics and the application of the participation rate (e.g. 10%), one could assume that 4% of EUR 0.9 bn could be liquidated per day, that is EUR 36 m per day. It will take 2 days for fund A to liquidate its corporate X position.

3.4 Shocks

The level of stress is determined by the magnitude and nature of the shocks operated on the funds. As mentioned before, our stress test affects the funds by simultaneously exposing them to two shocks, one on the asset side through the decrease of the asset liquidity (via a haircut) and another one on the liability side (via a shock on redemptions)[7].

3.4.1 Haircut

The macroprudential stress test assumes that the market liquidity deteriorates due to the synchronicity/systemic impact of the asset sales.

Such a deterioration of liquidity could be translated into the following:

1) higher bid-ask spreads or a negative price impact (price channel); or

2) in lower amounts that can be liquidated in the market without impact on the market price (quantity channel); or

[6] More details in Appendix 1.

[7] As an alternative to shocks to net redemptions, some liquidity stress tests initiate the shocks from market returns (see Fricke and Fricke (2021) and Lee (2020) where shocks are arbitrarily set at 5%).

3) both channels at the same time.

We combine the two views by applying a haircut on the amounts that can be liquidated per day and by considering a price impact of the sales (cf. Section 3.5). For illustration, the haircuts considered in this paper are 30%, 40% and 50%.

3.4.2 Redemption shocks

On the liability side, the calibration of the assumed net redemption shock will be based on two different approaches.

We first implement the stress test by using the shocks derived from a model based on an adverse macroeconomic scenario. The key benefit of a macroeconomic scenario is the consideration of a coherent stress testing framework across different fund categories/strategies. It allows building a common adverse scenario that will translate into different redemptions for each fund category. We will detail the macro model in Section 3.4.3.

As a complement, we also consider a more severe shock calibrated on the basis of the historical distribution of net redemptions, with a shock amounting to 20%. It corresponds to the maximum redemption shock considered in the stress simulation of the ESMA STRESI Report, 19.8%, which corresponds to the 1% expected shortfall statistics computed on historical weekly fund net flows (see table ER.36 in ESMA, 2017). Such a shock is particularly severe and leads to substantially higher net redemptions than the ones resulting from the macroeconomic model.

3.4.3 Model-based macro redemption shock

For the model we consider three input factors: 1) a satellite model that translates macro-financial scenarios into net capital flows; 2) the data to feed the model; and 3) an adverse macro-financial scenario.

The model translates the adverse scenario into net capital flows (hereafter "net flows", defined as subscriptions minus the redemptions, with negative figures referring to redemptions). We rely on a time series econometric modelling, similar to the one used for the liquidity stress test operated during the Luxembourg 2017 FSAP, estimated at the level of the fund strategy. We regress the net flows against a set of macro-financial explanatory variables, namely equity prices, equity volatility, industrial production in the eurozone and interest rates, as measured at the euro area level (Equation (1)).

$$Netflows_{j,t} = c_i + \beta_{1,j} * VIX_t + \beta_{2,j} * STX600_t + \beta_{3,j} * IndProd_t + \beta_{4,j} * STX600_{t-1} + \beta_{5,j} * IndProd_{t-1} + \beta_{6,j} * EONIA_t + \varepsilon_{j,t} \qquad \text{j = Equity, Mixed ...} \tag{1}$$

We estimate the model based on the sample of funds detailed in Section 3.2. Additional details are provided in **Appendix 2**.

We finally build an adverse scenario, set out in Table 3, applicable to each variable of the macroeconomic model. We mainly rely on the adverse scenario designed by the ESRB for the European banking stress test (ESRB (2021)) every year in January. This document includes adverse scenarios for a wide range of macro-financial variables, including for interest rates, GDP, equity prices. We use the adverse scenario for 2022 and obtain the following adverse scenario[8]:

TABLE 3 – Adverse scenario

	VIX	Eurostoxx600	IndProd	EONIA
Adverse Scenario	+100%	-45%	-3.8%	-0.54%

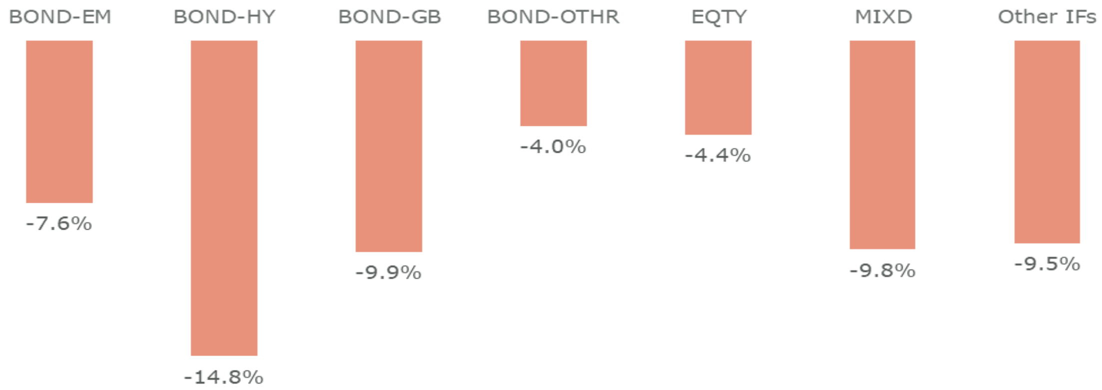
While the ESRB scenario is built on annual horizons, we assume the immediacy of the shocks in the sense that they will be integrated into the model using monthly information. The result is that we expose the funds to a redemption shock forcing them to proceed directly to asset liquidations.

According to this scenario, funds would be hit by a doubling of the market volatility associated to a quasi-halving of the stock market capitalisation, a drop of 3.8% in the industrial production and a shift of -0.54% in interest rates.

Based on the estimation of our model, we estimate for each fund category the shocks, as reported in Figure 2. We first note that the redemption shocks are within a range of 4% to 15%. The shocks are the most severe at around 15% for HY bond funds, 10% for global bond funds, mixed funds and other funds, and at around 4% for equity and other bond funds.

These redemption levels, which are to be applied to the fund strategies, provide for an extra layer of stress when compared to the redemption levels observed at fund level during the March 2020 episode, where the overall monthly net redemptions amounted to -2.7% for regulated UCIs in Luxembourg. Equity funds registered outflows ranging from -1.7% for global market equities to -6.5% for Japanese equities. For bond funds, the highest levels of redemptions over this period were recorded for HY bond funds (-8.5%) and EM bond funds (-7.7%), whereas Global market bonds registered redemptions of -4.2% (CSSF 2021).

FIGURE 2 – Redemption shocks calibrated by the macroeconomic model



[8] Eurostoxx set at -45% based on the ESRB 45% decline of EU stock prices; Industrial production set at -3.8% based on the ESRB 1.9% decline of the euro area GDP in 2022 and on a scaling factor of 2 (the standard deviation of Industrial production being twice the one of GDP growth); EONIA rate set at -0.54% as based on the ESRB 0.54% decline of the Swap EONIA 3M. We set the VIX adverse scenario at +100%, calibrated on historical data from the 2008 global financial crisis.

3.5 Macroprudential features

The TTL-LSTIF embeds two macroprudential features, namely a contagion effect due to the price impact of the sales (contagion channel) in the context of an adverse systemic shock and additional second-round redemptions (amplification channel) that result from the price impact.

3.5.1 Price impact

Liquidations taken on an aggregate basis might have an impact on market prices. The estimation of this market price impact constitutes an empirical challenge.

The price (semi-)elasticity to asset sales for corporate bonds varies between a 2.5% impact for a EUR 1 m sale (Lee 2020) and a 0.1% impact for a EUR 10 bn sale (Cetorelli et al. 2016). The apparent inconsistency between the different measures found in the literature comes from the empirical complexity of measuring price (semi-)elasticities, but also from the relative uncertainty on the correct perimeter to be used for assessing the sales, in the sense that the price impact is sometimes estimated at security level and sometimes at asset class level, which gives very large differences in terms of price impact.

We partially rely on the price (semi-)elasticities provided in Table ER.54 of ESMA (2019b), where the estimates are based on market depth measures at the asset class level calculated in accordance with the Coen et al. (2019) methodology.

Our price (semi-)elasticities are reported in Table 4. Similarly to ESMA, we assume that a daily sale of EUR 1 bn sovereign bonds leads to a 2.1 basis points (bps) impact on the sovereign bond market prices, a daily sale of EUR 1 bn Investment Grade (IG) corporate bonds to a 5 bps impact on the IG corporate bond market prices and a daily sale of EUR 1 bn HY corporate bonds to a 12.5 bps impact on the HY corporate bond market prices. We further assume that a daily sale of EUR 1 bn stocks leads to a 1 bp price impact and finally align all other asset categories (including target funds and structured products) on the HY corporate bond price impact. We assume that the liquidation of cash and MMI has no price impact.

TABLE 4 – Price impact assumptions of an aggregate sale of EUR 1 bn at the level of the asset class – based on ESMA STRESI

Asset class	Price Impact (in bps)
EQTY	1
Sovereign	2.1
Corp IG	5
Corp HY	12.5
Structured products	12.5
UCIs	12.5
Others	12.5

Given these price (semi-)elasticities assumptions and the sales induced by the redemption shocks, we calculate the total sales per asset class and determine the price impact per asset category and the resulting losses per fund strategy. Finally, we infer the impact applicable to the Luxembourg fund sector globally. For that purpose, as our sample is a fraction of the Luxembourg fund industry, we scale up these values to account for the full size of the Luxembourg fund industry and get the resulting price impact per asset class (as a result of the market revaluation of all funds) for both the macro redemption shocks and the 20% redemption shock.

Furthermore, due to the flow-performance relationship, the price impact, through its impact on the fund performance, will also trigger additional redemptions, the so-called second-round effect.

3.5.2 Second-round effects

Investor flows in and out of investment funds have been extensively studied, with a preponderant focus on the relationship between net capital flows and past performance. Empirical analyses show that past negative performance is positively related to net redemptions. We estimate panel regressions for each fund strategy with monthly observations and fixed effects at fund level, as inspired from standard approaches (see ESMA 2019b).

Monthly fund net flows (i.e. subscriptions minus redemptions) are explained by past fund performance and by risk variations (monthly VIX variations in percent) over 2008-2021. The model is the following:

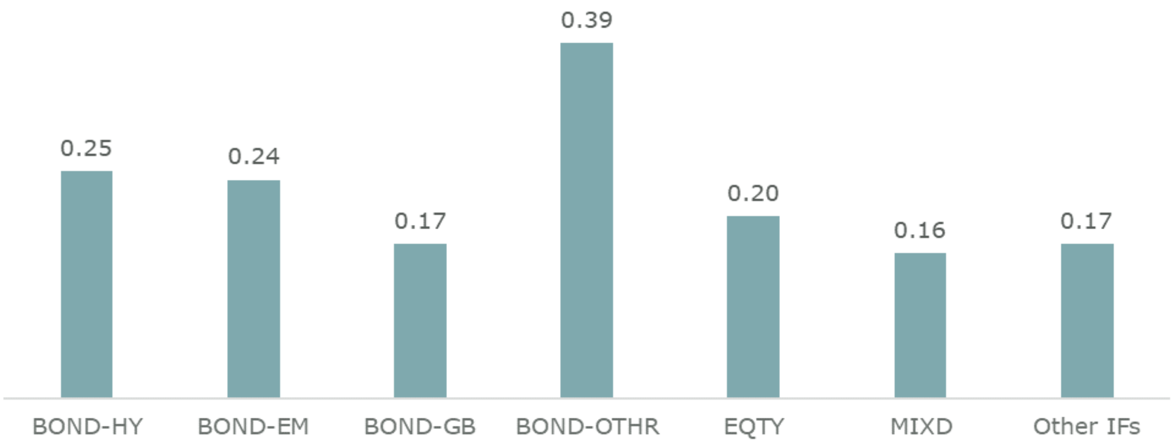
$$Net\ flows_{i,j,t} = c_i + \beta_{1,j} * VIX_t + \beta_{2,j} * Return_{i,t-1} + \varepsilon_{i,t} \qquad \text{j = Equity, Mixed ...} \quad \text{i = Fund i} \qquad (2)$$

Where i stands for fund i, j for the fund strategies (Equity, Mixed, etc.) and where $\beta_{2,j}$ is the coefficient of interest, namely the response of net flows to past fund performance.

The results are reported in Figure 3 for each fund strategy (with more details on the estimation results being provided in **Appendix 3**).

We find that the coefficients vary from 0.16 for Mixed funds to 0.39 for Other bond funds, which are in line with coefficients found in the literature (see ESMA 2019b). As an illustration, a 1 percentage point decrease in the performance of HY bond funds will give rise, in the next month, to net redemptions amounting to 0.25% of the NAV.

FIGURE 3 – Flow-performance relationship – coefficient estimates



4. Application to Luxembourg investment funds

To assess the liquidity profile of the Luxembourg investment funds and illustrate our empirical approach, we now apply the TTL-LSTIF framework to the sample of Luxembourg funds described in Section 3.2.

For this illustrative exercise, we set the liquidity haircut at 40% with a sensitivity analysis being provided for haircuts at 30% and 50%. The redemption shocks are the ones derived from the macro model and the uniform redemption shock is 20%. The asset liquidation process follows a TTL approach with pro rata slicing, using a participation rate of 20%, with a sensitivity analysis being provided for participation rates at 10% and 30%.

Based on these assumptions, we first assess the funds by looking at:

1. the time required for the funds in the sample to meet the defined redemption shocks;

2. the proportion of funds meeting the redemption shocks at the five days horizon, by looking per fund profile in terms of investment strategy and in terms of size;

3. the TTL distribution (median and 75th percentile) for funds, in terms of fund size and fund investment strategy, for meeting the redemption shocks.

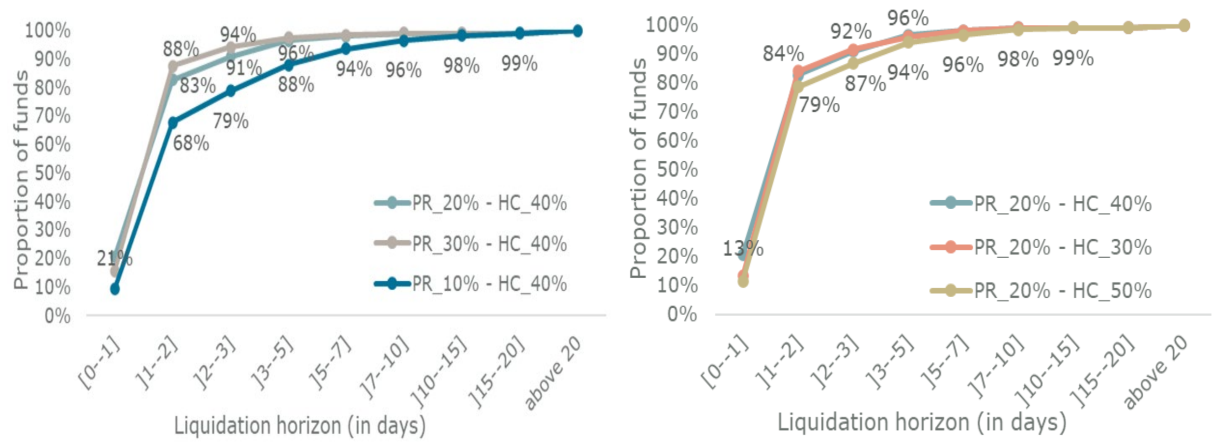
We then deepen the analysis by looking into the fund portfolios held by the Luxembourg funds to assess the TTL per asset category, which is a key driver of the results obtained at the fund level. We finally incorporate the macroprudential features into the analysis by showing the specific effects of the contagion (price impact) and the amplification (second-round effects) channels.

4.1 Analysis of TTL

As first outcome, we note in Figure 4 (left panel) that 83% of the funds are able to meet the macro redemption shocks and the 40% haircut (with a participation rate of 20%) within two days, 91% within three days and 96% within five days.

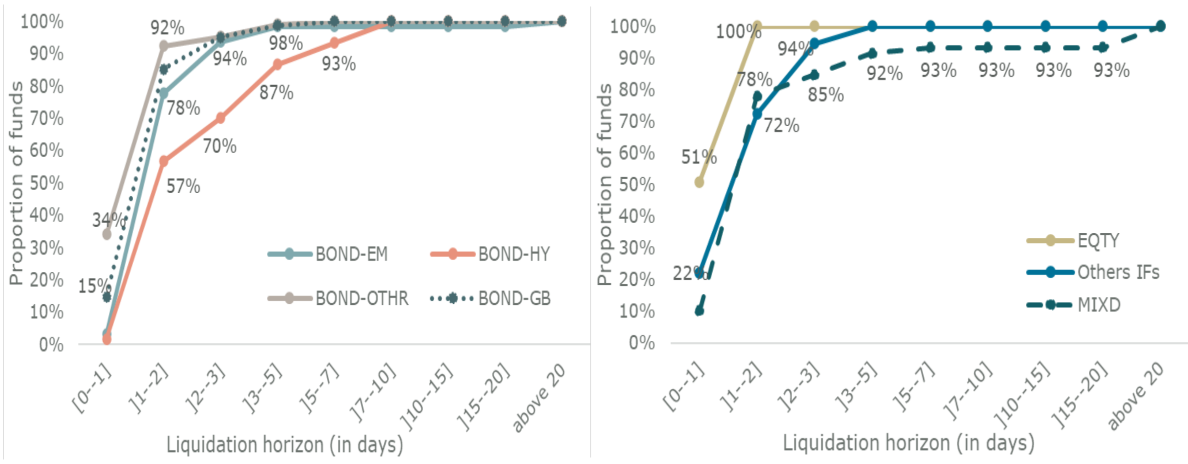
Using alternative haircuts (30% or 50%) has quite limited effects on the results (right panel), while the choice of the participation rate has more impact (left panel), with the effect being stronger for a participation rate of 10% and much lower for a participation rate of 30%.

FIGURE 4 – Macro redemption shocks: time required for funds to meet the shocks, with a sensitivity analysis based on the participation rate (PR, left panel) and the haircut (HC; right panel)



As reported in Figure 5, the TTL is lowest for Equity funds, with 100% of them being able to meet the macro redemption shock and the 40% haircut (with a participation rate of 20%) within two days (right panel); HY bond funds show longer TTL as only 70% of them can meet the shock within three days and 87% in five days (left panel). A significant proportion of Mixed funds (around 7%) takes more than 20 days to meet the shocks (right panel).

FIGURE 5 – Macro redemption shocks: time required for funds (by strategy) to meet the shocks (assuming a haircut of 40% and a participation rate of 20%)

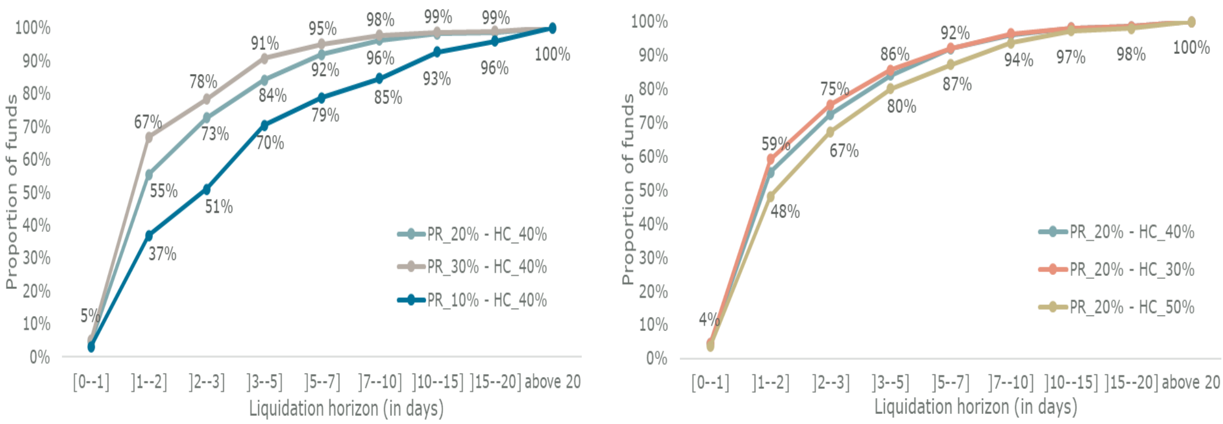


We now reiterate the analysis based on the alternative scenario of a uniform 20% redemption shock.

Not surprisingly, the more severe the redemption shock, the higher the TTL (Figure 6): 55% of the funds are able to meet the 20% redemption shock (assuming the 40% haircut and a 20% participation rate) within two days (compared to 83% under the macro redemption shocks), 73% of the funds within three days (compared to 91% under the macro redemption shocks) and 84% within five days (compared to 96% under the macro redemption shocks).

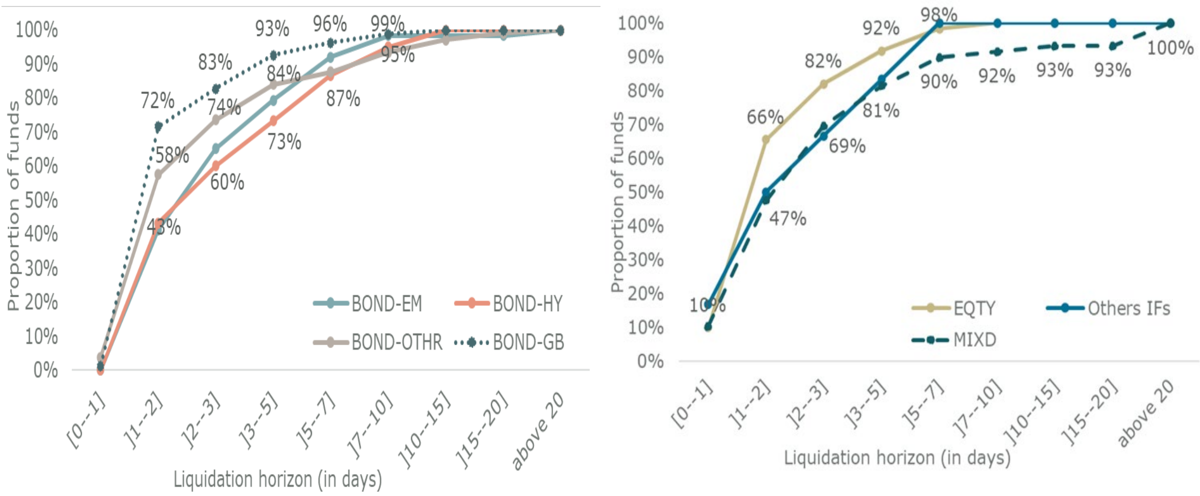
Again, the results are most sensitive to the participation rate. With a participation rate set at 10% (instead of 20%), only 51% (70%) of the funds can meet the redemption shock within three days (five days, respectively) (all left panel).

FIGURE 6 – 20% redemption shock: time required for funds to meet the shock, with a sensitivity analysis on the participation rate (PR, left panel) and the haircut (HC; right panel)



Equity and Global Bond funds have the lowest TTL; HY Bond funds showing higher TTL as only 73% of them can meet the 20% redemption shock within five days and 87% in 7 days. 7% of Mixed funds take more than 20 days to meet the 20% redemption shock (Figure 7).

FIGURE 7 – 20% redemption shock: time required for funds (by strategy) to meet the shock (assuming a haircut of 40% and a participation rate of 20%)

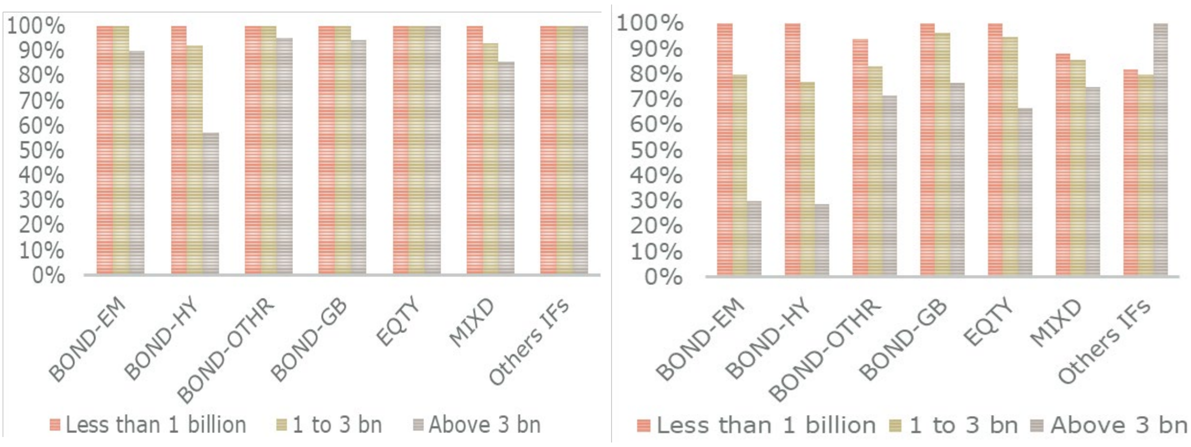


To complement our analysis, we now focus on the proportion of funds meeting the redemption shocks at the five days horizon and detail the results per fund profile in terms of investment strategy and in terms of size. The fund size is assessed in terms of NAV, by considering three size buckets, i.e. less than EUR 1 bn, between EUR 1 bn and EUR 3 bn and larger than EUR 3 bn.

Based on the macro redemption shocks (Figure 8, left panel), we find that a significant proportion of large HY bond funds (above EUR 3 bn) display TTL higher than 5 days, as only 57% of them meet the redemption requests within five days. For the same horizon, we also note that 86% of the large Mixed funds and 90% of the large EM bond funds can meet the redemption shocks.

For the 20% uniform redemption shock (Figure 8, right panel), the results deteriorate as only 29% of the large HY bond funds and 30% of the large EM bond funds can meet the redemption shock within five days. The effects also worsen, when compared to the macro redemption shocks, for the medium-sized funds (between EUR 1 bn and EUR 3 bn). The size clearly contributes to the extension of the time needed to meet the redemption shock.

FIGURE 8 – Proportion of funds meeting the macro redemption shocks (left panel) and the 20% redemption shock (right panel) at the five days horizon, with a 40% haircut (and a participation rate of 20%)

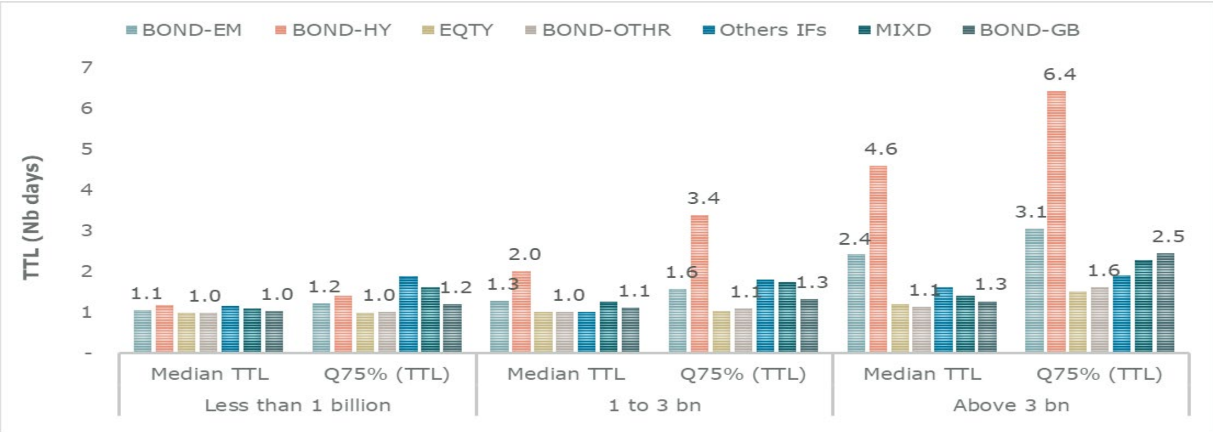


We finally present the results from another perspective, by focusing on the TTL (expressed in number of days) a fund takes to meet a redemption shock. We report, by fund size and by fund investment strategy, the median and 75th percentile of the funds' TTL distribution for the macro redemption shocks (Figure 9).

We first find, for the macro redemption shocks, that the median (75th percentile) TTL is not larger than two days (four days) for all fund investment strategies and sizes, except for the large EM bond funds for which the median (75th percentile) TTL reaches 2.4 days (3.1 days) and for the large HY bond funds for which the median (75th percentile) TTL reaches 4.6 days (6.4 days).

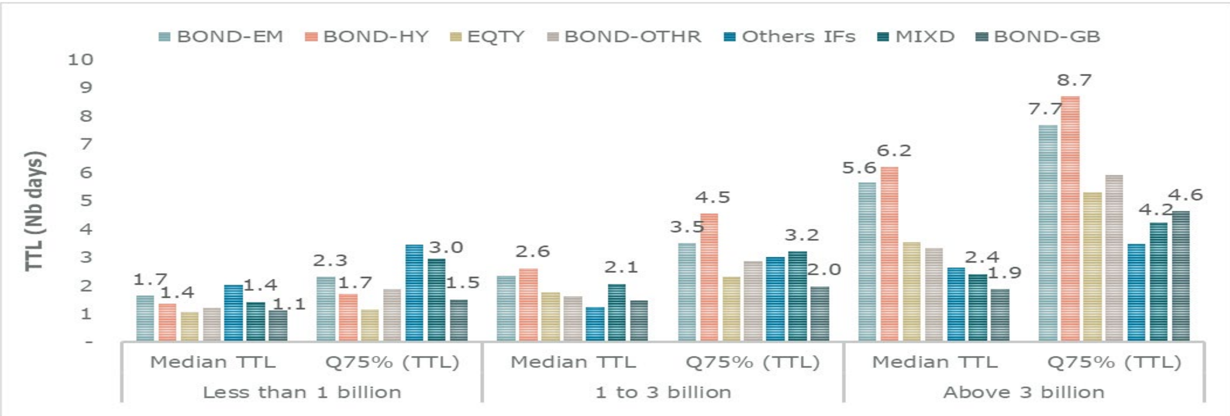
The TTL increases with the size of the funds (thereby reflecting that larger holdings take more time to liquidate). We also see that funds with less than EUR 1 bn and funds between EUR 1 bn and EUR 3 bn need between one and two days to respond to the redemption shock, exception made of the HY bond funds between EUR 1 bn and EUR 3 bn for which the 75th percentile TTL is 3.4 days.

FIGURE 9 – Macro redemption shocks: median and 75th percentile TTL by size and strategy



For the 20% redemption shock (Figure 10), we note that more severe redemption shocks (compared to the macro redemption shocks) mainly affect the larger funds and only marginally the smaller funds. For example, for the large EM bond fund category the 75th percentile TTL rises from 3.1 days under the macro shock to 7.7 days under the 20% shock and for the large HY bond fund category the 75th percentile TTL rises from 6.4 days under the macro shock to 8.7 days under the 20% shock.

FIGURE 10 – 20% redemption shock – median and 75th percentile TTL by size and strategy



4.2 Asset liquidation dynamics

To better understand the liquidation dynamics, we now turn to the portfolios of all funds subject to the liquidity stress test and assess the TTL behaviour per asset category (equity, bond, UCIs and structured products).

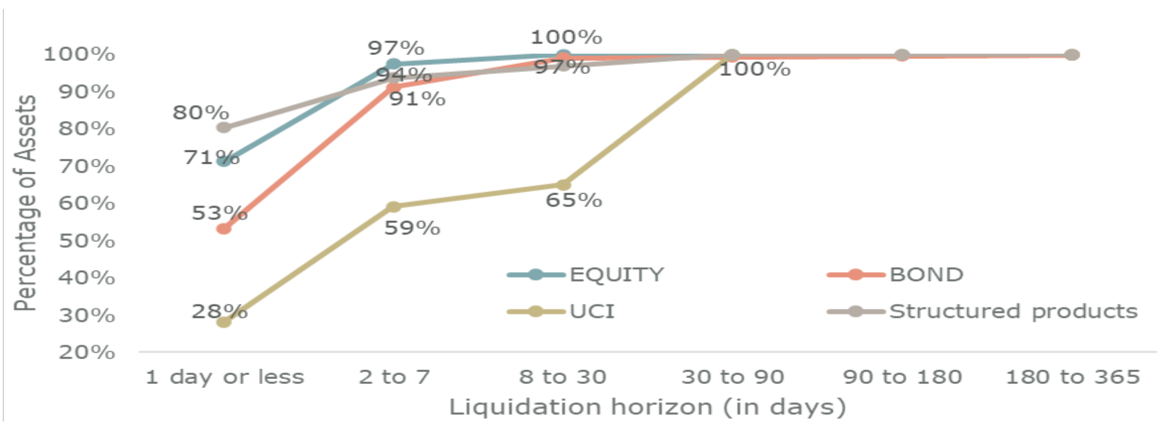
For that purpose, we use for each security position held within the individual funds the time required to meet the defined macro redemption shocks, together with the corresponding liquidation amount. We then allocate these TTL and liquidation amounts across asset categories (equity, bonds, UCIS, structured products) and liquidation horizons (i.e. the different time buckets as referred to in the UCITS Risk Reporting and the AIFM reporting: one day, one week, one month, one quarter, half-year and a year). Then, we determine, per asset category, the percentage of assets that can be liquidated within a given time bucket.

The percentage numbers, cumulated over time up to reaching 100% of the asset liquidations under the macro redemption shocks, are reported per asset category in Figure 11 and per bond category (by rating grade, i.e. AAA, AA, A, BBB, HY) in Figure 12. This outcome allows the assessment of the liquidation dynamics per asset category. Note that this is not the liquidation process of an aggregated portfolio, but one resulting from the aggregation of individual liquidations calculated separately at fund level.

We first note that the speed of liquidation is relatively heterogeneous across asset categories (Figure 11). Based on our sample of funds, the equity asset category shows the lowest liquidation time with 97% of equity positions being able to be liquidated within a week, closely followed by the structured products (94% within a week) and the bond (91% within a week) categories.

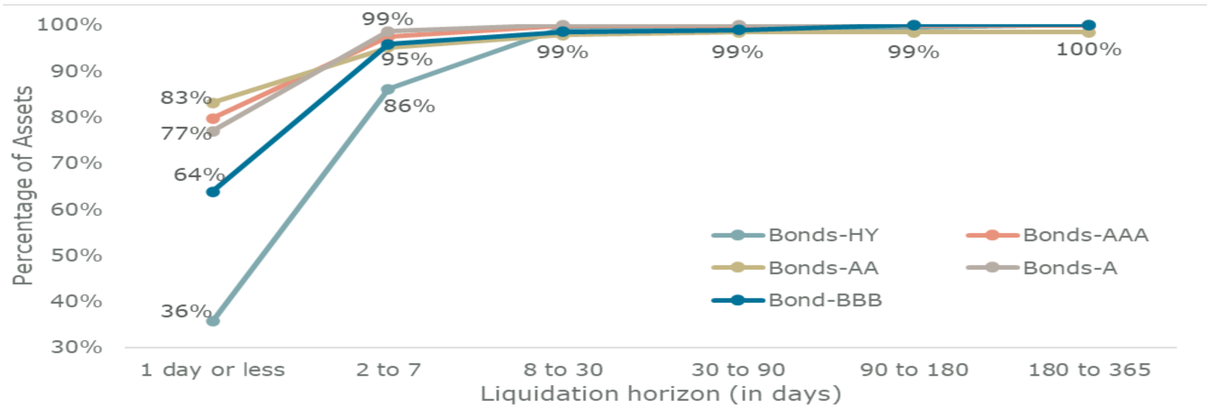
On the contrary, the liquidation time of the shares of UCIs is lower, which results from the conservative liquidation amounts used in the TTL-LSTIF and the fact that some funds have larger holdings of UCIs (fund of funds structures). This partially explains the previous findings for mixed funds (significant proportion of mixed funds were found to take more than 20 days to meet redemption shocks based on the conservative assumption underlying the liquidation amounts – cf. Figures 5 and 7).

FIGURE 11 – Macro redemption shocks: Cumulated percentage of assets that can be liquidated over time per asset category



We further note that the liquidation speed of the bonds depends on their ratings. HY and BBB bonds show the lowest liquidation dynamics (Figure 12).

FIGURE 12 – Macro redemption shocks: Cumulated percentage of assets that can be liquidated over time per bond category



The results for the 20% redemption shock, which are in line but more severe than the ones associated to the macro redemption shocks as above, are available on request (graphs).

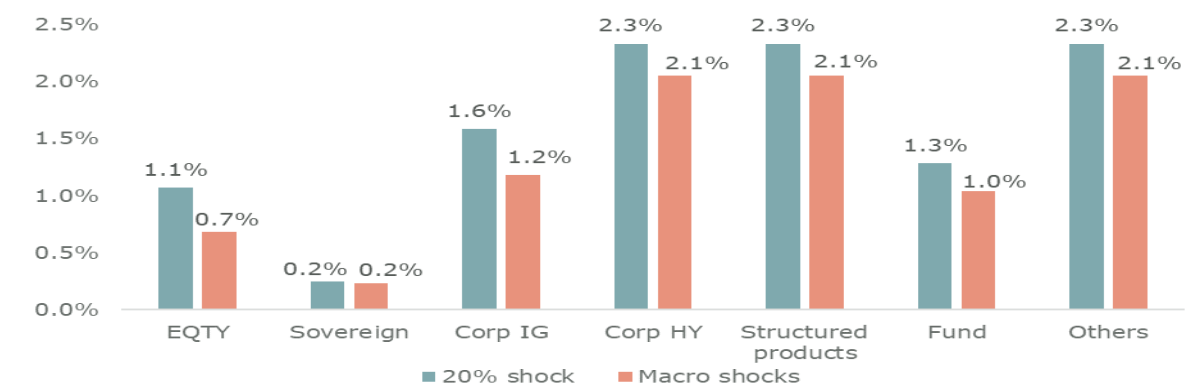
4.3 Contagion and amplification channels

Due to the price impact of the asset liquidations, the redemption shocks are assumed to result in direct losses for the funds.

Following the redemption shock, funds will perform a pro rata liquidation of assets in the portfolios according to the level of the shock. The price impact results from the application of the price (semi-)elasticities (see the parameters in Table 4) to the aggregated amount of asset liquidations (aggregation by asset class and across all funds). Finally, the price impact is computed for each fund (according to the portfolio composition) and for each fund category.

As reported in Figure 13, we see that the price impacts go up to 2.1% for the macro redemption shocks and up to 2.3% for the uniform 20% redemption shock. The relatively moderate rise for the 20% redemption shock can be explained by the higher TTL induced by the larger redemptions, which partially smooths the price effect (with the dilution of large sales over time being an inherent feature of the TTL approach). We find that the price impact is smallest for sovereign bonds and equity given the price impact assumptions set out in Table 4 above.

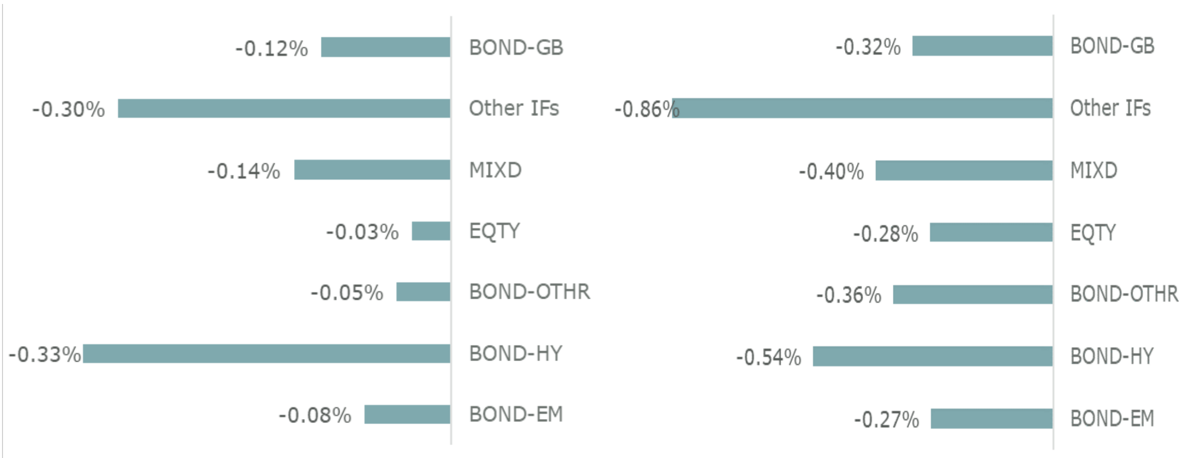
FIGURE 13 – Total asset class price impacts resulting from the liquidation scenarios



The price impacts per asset category set out in Figure 13, as derived from the redemption shocks, are assumed to give rise to losses at the level of Luxembourg investments funds depending on the portfolio weights of these asset categories (the contagion effect). Of course, these total losses will reflect the (very) conservative assumption that the shocks are fully synchronous on all funds which leads to an aggregation of the sales with a substantial price impact.

These losses are expressed in negative NAV variations varying widely between -0.03% for EQTY and -0.33% for HY bond funds for the macro redemption shocks (Figure 14 – left panel) and from -0.27% for Bond-EM up to -0.86% for the Other IFs for the 20% redemption shock (Figure 14 – right panel).

FIGURE 14 – Direct losses for funds (% NAV): average price impacts resulting from the macro redemption shocks (left panel) and the 20% redemption shock (right panel)



Having determined the price impact per asset category, and the resulting losses per investment fund category, we now extrapolate this impact at the level of the total Luxembourg investment fund sector (at EUR 5.5 trillion total net assets in June 2021), by assuming that the price impact will affect by contagion all funds through market revaluation effects. The market-wide impact, that is, a loss would be of around EUR 12 bn for the macro redemption shocks and EUR 30 bn for the 20% redemption shock.

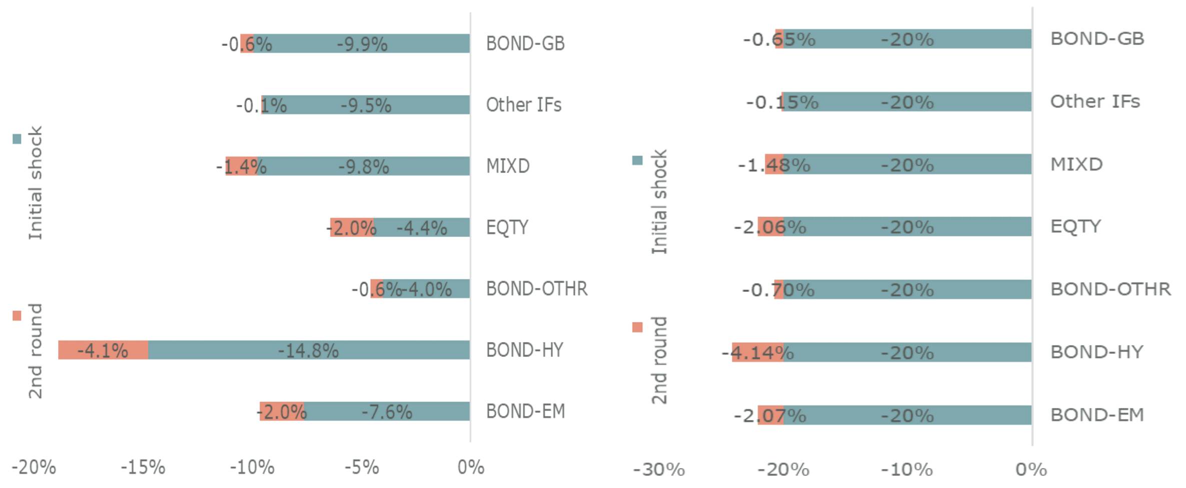
These numbers are to be interpreted as the direct liquidity costs associated to the synchronous and stressed sales assumed under the TTL-LSTIF scenarios.

Furthermore, based on the flow-performance model reported in Section 3.5.2 where flows depend on fund past performance and on the VIX variation, we can compute the second-round effects of redemptions.

These additional redemptions are calculated at individual fund level by incorporating in the estimated flow-performance model a performance value based on the daily price impact (calculated at fund level by using the asset class price impact reported in Figure 13) with the coefficients in Figure 3 and on a stressed value for the VIX index (set at +100%).

As reported in Figure 15 below, we find that the additional redemptions are relatively moderate, which suggests that second-round effects do not fundamentally change the main outcomes presented (being also a standard result in the empirical literature). The relatively moderate differences of the second-round redemptions between the macro and the 20% redemption shocks can be explained by the large influence of the VIX in the model and the relatively small size of the price impact on past performance.

FIGURE 15 – Average second-round redemptions (percent NAV): flow-performance model based on (initial) macro redemption shocks (left panel) and 20% redemption shock (right panel)



5. Conclusions

We present in this working paper a liquidity stress testing framework applied by the CSSF for Luxembourg investment funds with a liquidation process using a time to liquidation (TTL) approach. The approach provides for a complement to the frameworks developed by ESMA, the IMF, other national competent authorities and/or other academic contributors.

By allowing liquidation speed to depend on the market liquidity of the assets, the time to liquidation approach allows the assessment of, more precisely than standard tiered/static approaches, the liquidity risk of funds with less liquid assets in their portfolio, such as EM and HY bond funds. More particularly, the binary "pass-or-fail" test is replaced in the framework by a view on the liquidation dynamics, enabling the assessment of, by considering the market liquidity of the assets, the time required for funds to meet pre-defined redemptions shocks. The macroprudential perspective is further supported by the contagion and amplification mechanisms embedded in the liquidation process.

The presented approach also has caveats, as it requires a set of assumptions on the size of the redemption shocks, on liquidity haircuts, on participation rates and on asset-specific liquidation features, but it also requires granular data on portfolio holdings, notably average historical daily trading volumes and outstanding amounts of the assets held in the fund portfolio and is therefore more demanding from a data perspective than the ones relying on tiered approaches: a large number of securities' and market data is required for the implementation of this framework, while final results are then sensitive to the availability and accuracy of such input data.

Nevertheless, the TTL-LSTIF is robust enough to allow for an assessment of the liquidity risk across investment funds. Such stress testing is not only deemed to be a very important and helpful risk management tool at individual investment fund level but also a powerful supervisory tool for regulators to implement cross-sectional analyses and allowing supervisory follow-up with identified individual fund outliers.

As to the results, we show that 96% of the funds can honour the macro-based redemption shocks (whose magnitude provides for an extra layer of stress when compared with the redemption levels observed at fund level during the March 2020 episode) in five days or less, and 84% a 20% redemption shock (which is significantly more severe than the macro-based shock). The results differ across fund sectors as it reaches only 73% for HY bond funds under the 20% redemption shock. Some mixed funds would also need more than five days because of their larger size. The results also show that across all sectors, small and middle-sized well-diversified funds are generally able to liquidate their portfolios in shorter time, while larger funds or less diversified funds are more likely to have a longer liquidation horizon. The price impact resulting from a 20% redemption shock applied to the full Luxembourg fund industry would amount to EUR 30 bn, while the second-round effects are found to amplify moderately only the initial shocks.

These figures show that some funds are more vulnerable in the case of larger liquidity shocks than others and confirm the relevance of the international efforts in addressing the liquidity risk of open-ended funds, especially the ongoing work of the IOSCO and the FSB on structural liquidity mismatches and the use of fund and system-wide stress testing.

This standard liquidity stress testing framework is a first step and could be improved and expanded in several directions, for example by replacing the partial equilibrium macroeconomic model by a general equilibrium one, by relying on finer measures of the price impact or by using alternative measures, by incorporating the derivatives in the perimeter or by recalibrating the parameters underlying the asset specific liquidation rates to better fit the stress test predictions with the liquidity difficulties faced by some funds during the COVID-19 episode.

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Appendix 1 – Time to liquidation calibration

The nominal amount of a security that a fund can liquidate per day is

- measured/capped by the corresponding average historical daily trading volume;
- calculated at the level of asset sub-categories;
- reduced by a participation rate to estimate the share that can be traded by a fund without materially impacting the market price in normal times.

1) The 3M-ATV (3-month **average historical daily trading volume**) provides for a first proxy of the market liquidity. This figure is obtained for each individual security position ("line-by-line") from the data collection exercise.

   a. For each fixed income security position, this figure is then divided by the total issue size corresponding to the portfolio position to determine the ratio of the 3M-ATV to the total issue size (or "relative 3M-ATV").

   b. For the other securities, the 3M-ATV is not divided by the total issue size due to data limitations and can be viewed as the "absolute 3M-ATV".

   Both approaches are valid, the relative approach being more precise as the ultimate proxies will be closer to the genuine market size of the specific securities positions/lines.

2) For handling extreme values at the individual security position level, the (relative/absolute) 3M-ATV, as derived from 1) is then averaged at the level of **asset sub-categories.** The following asset sub-categories are used in the framework:

   a. Fixed income: ratings (from AAA to HY); issuer sector (corporate/financial/government); size of the issue
   b. Structured products: by rating grade
   c. Equity: small, middle and large caps
   d. UCIs: 1 category

   To preserve monotonicity/smoothness, the (relative/absolute) 3M-ATV measures per asset sub-category are adjusted linearly by applying smoothing factors to ensure that the nominal amount of a security that a fund can liquidate per day decreases monotonically with the risk factors considered in this analysis.

3) The average 3M-ATV is then discounted by a factor called the **participation rate**. The participation rate represents how much of the average 3M-ATV could reasonably be expected to be traded by a fund in one day without significantly impacting the market price in normal times.

   Different participating rates can be applied. We set the rate at 20% and assess the sensitivity of the results by using other rates (10% and 30%).

At the end of this process, we have the amount that can be liquidated per day, expressed in euros (**absolute approach** for structured products, equity and UCIs) or expressed as a ratio of the security position/line-specific total issue size (**relative approach** for fixed income securities positions).

Appendix 2 – Macroeconomic model

The macroeconomic model – see Equation (1), duplicated below for convenience - is a time series econometric model relating the percentage of net flows (in terms of TNA) to a set of macro-financial variables, namely equity prices (monthly variations in percent of EuroStoxx600), equity volatility (monthly changes in percent of VIX), industrial production of the eurozone (monthly variation in percent) and interest rates (monthly changes of EONIA).

$$Net\ flows_{j,t} = c_i + \beta_{1,j} * VIX_t + \beta_{2,j} * STX600_t + \beta_{3,j} * IndProd_t + \beta_{4,j} * STX600_{t-1} + \beta_{5,j} * IndProd_{t-1} + \beta_{6,j} * EONIA_t + \varepsilon_{j,t} \qquad \text{j = Equity, Mixed ...} \qquad (A.1)$$

Similarly to IMF (2018), we include a lag to equity prices and industrial production to account for inertia, as investors might respond with some delay to the change of the macroeconomic environment.

The data are sourced from the FRED[9] (EONIA and VIX) and ECB (IndProd and EuroStoxx600) databases. The window covers the period from January 2008 to June 2021 at a monthly frequency. The results are reported in Table A.1.

Table A.1 – Macroeconomic model

	Dependent variable: Net flows						
	EQTY	MIXD	BOND-HY	BOND-EM	BOND-GB	BOND-OTHR	Other IFs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VIX_t	0.0014	0.005	-0.011*	-0.0145	-0.0032	0.0018	-0.0059
	(0.001)	(0.009)	(0.0062)	(0.0102)	(0.0081)	(0.0041)	(0.0194)
EuroStoxx_t	0.112***	0.146***	0.3617***	0.2058***	0.1750*	0.1066*	0.2638*
	(0.027)	(0.043)	(0.0487)	(0.07)	(0.100)	(0.0567)	(0.1374)
EuroStoxx_t-1	0.017	-0.108*	-0.055	0.081	0.0841**	-0.0191	0.1580
	(0.028)	(0.058)	(0.048)	(0.06)	(0.0364)	(0.0277)	(0.1635)
IndProd_t	0.013	-0.058	-0.0231	0.02	-0.0522	-0.0241	0.0044
	(0.026)	(0.072)	(0.066)	(0.136)	(0.077)	(0.0661)	(0.2000)
IndProd_t-1	-0.02	0.033	-0.131**	0.0337	-0.112**	-0.0827	0.1033
	(0.026)	(0.09)	(0.056)	(0.147)	(0.0486)	(0.0514)	(0.2057)
EONIA	-0.001	0.003	-0.0089	-0.008	-0.0079	-0.0023	0.0214**
	(0.003)	(0.003)	(0.007)	(0.0052)	(0.0045)	(0.0047)	(0.0100)
Constant	0.006***	0.017***	0.01***	0.016***	0.0130***	0.008***	0.0260***
	(0.001)	(0.002)	(0.002)	(0.003)	(0.0022)	(0.0013)	(0.0080)
Observations	153	153	153	153	153	153	153
R2	0.117	0.076	0.382	0.15	0.0942	0.097	0.0295
Adj. R2	0.082	0.04	0.36	0.12	0.0587	0.0619	-0.0085

Note: *p<0.1; **p<0.05; ***p<0.01.

The redemption shocks resulting from the econometric model are then obtained by injecting into the above model the values set in the adverse scenario for the coefficients that are found to be significant at 10% and to set them to zero otherwise, similarly to IMF (2018). As an illustration, a 1% decrease in the variable "EuroStoxx_t" (i.e. the performance of the index Eurostoxx) will give rise to a net redemption of 0.112% in the EQTY fund category.

[9] FRED stands for Federal Reserve Economic Data.

Appendix 3 – Second-Round Effects

The flow-performance relationship model – see Equation (2), duplicated below for convenience - is estimated by panel regressions with fixed effects at fund level (meaning that the intercept c_i is fixed across time, but varies across funds) and carried out separately for each fund strategy to measure strategy specific flow-performance relationships.

$$Net\ flows_{i,j,t} = c_i + \beta_{1,j} * VIX_t + \beta_{2,j} * Return_{i,t-1} + \varepsilon_{i,t} \qquad \text{j = Equity, Mixed ...} \quad \text{i = Fund i} \qquad (A.2)$$

Monthly net flows (in percent of NAV) are explained by past fund performance (monthly NAV variation in percent - adjusted for the net flows) and by risk variations (monthly VIX variations in percent) over 2008-2021.

Monthly net flows are based on the CSSF U1.1 reporting as per Circular CSSF 15/627 and VIX information is sourced from the FRED database. The estimation results are reported in Table A.2.

TABLE A.2 – Second-round effects

	Dependent variable: Net flows						
	BOND-HY	BOND-EM	BOND-GB	BOND-OTHR	EQTY	MIXD	Other IFs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VIX_t	-0.04 ***	-0.02 ***	-0.00	-0.01	-0.02 **	-0.01 *	0.00
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
Return_t-1	0.25 ***	0.24 ***	0.17 ***	0.39 ***	0.20 ***	0.16 ***	0.17
	(0.04)	(0.03)	(0.04)	(0.10)	(0.02)	(0.05)	(0.10)
N	6674	6396	6889	8328	5488	3919	1370
R2	0.01	0.01	0.00	0.00	0.02	0.00	0.00
Adj. R2	0.01	0.00	-0.01	-0.01	0.01	-0.00	-0.01

Note: *p<0.1; **p<0.05; ***p<0.01.

We find that the VIX index coefficient is negative and significant in most specifications, meaning that increasing volatility is associated with negative net flows (net redemptions).

A 1% increase of the VIX will give rise to net flows of -0.04% of the BOND-HY NAV (in other words, a net redemption of 0.04%). A -1% negative fund performance will give rise to a net redemption of 0.25% of the BOND-HY NAV (in other words, negative net flows of -0.25%). The return coefficient for the fund category Other IFs is not significant, which might be partially due to the smaller sample and to larger heterogeneity of the category.