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Derivative margin calls: a new driver of MMF flows

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Abstract

During the March 2020 market turmoil, euro area money-market funds (MMFs) experienced significant outflows, reaching almost 8% of assets under management. This paper investigates whether the volatility in MMF flows was driven by investors' liquidity needs related to derivative margin payments. We combine three highly granular unique data sources (EMIR data for derivatives, SHSS data for investor holdings of MMFs and Refinitiv Lipper data for daily MMF flows) to construct a daily fund-level panel dataset spanning from February to April 2020. We estimate the effects of variation margin paid and received by the largest holders of EUR-denominated MMFs on flows of these MMFs. The main findings suggest that variation margin payments faced by some investors holding MMFs were an important driver of the flows of EUR-denominated MMFs domiciled in euro area.

Key words: liquidity risk, money market funds, big data, interconnectedness, non-bank financial intermediaries.

JEL classification: G13, G15, G23.

Non-technical summary

Total net assets of euro area money market funds (MMFs) represented 1.2 trillion euros in Febreruary 2020. During the Covid19-related market turmoil in March 2020, MMFs across the globe experienced significant volatility in flows. For instance, between 13 and 20 March 2020, euro area MMFs experienced outflows of nearly 8% of assets under management. The unprecedented responses by central banks, followed by other public policy responses, helped stabilise the outflows. But the experience raises questions about the potential drivers and amplifiers of such volatility in MMF flows.

While existing studies on MMF outflows during the March 2020 market turmoil focus on drivers related to MMF characteristics such as MMFs' type or riskiness, our paper is the first – to our knowledge – to relate MMF outflows to investors' liquidity needs arising from derivative margin calls. This topic is particularly important in view of the recent regulatory reform in the derivatives market, which reduced the time-frame to exchange margins to a daily base for the vast majority of derivative exposures and thus has profoundly changed the functioning of the derivatives market, with potential repercussions for the whole financial system. The exchange of margin in the form of high-quality collateral reduces counterparty credit risk, but the requirements also increase liquidity risk as counterparties need to meet margin calls with high-quality collateral at short notice.

To study the relationship between margin payments and MMF flows, we combine three unique and very granular data sets. First, we use transaction-by-transaction derivatives data collected under the European Market Infrastructure Regulation (EMIR) to compute margin payments by all types of investors located in the euro area. These data can be classified as *big data* and are also known as trade repository (or TR) data. Second, we use Securities Holdings Statistics at sector level (SHSS) to identify holdings of MMFs by investors (SHSS data are available only at country-sector level, not at an individual holder level). Finally, we use Refinitiv Lipper data to obtain daily MMF flows at fund level.

The resulting dataset contains a daily fund-level panel data where the dependent variable is daily flows in individual MMFs domiciled in France, Ireland, and Luxembourg, while the explanatory variables of interest are variation margin (VM) posted or received by major investor country-sectors holding the respective MMFs. The panel spans over three months, from

February to April 2020. Since margin payments in EUR are the largest, we only focus on EUR-denominated margin payments and EUR-denominated MMF flows. Furthermore, we focus on VM payments (as opposed to initial margin payments) as VM is typically paid in cash, while initial margin payments can also be met by non-cash collateral.

Overall, our results support the hypothesis that some non-bank financial intermediaries investing in MMFs, notably investment funds and pension funds, used MMFs to manage liquidity related to margin calls in the March 2020 market turmoil. In line with expectations, the results are typically more pronounced for MMF investors facing large margin payments than MMF investors facing relatively limited margin payments. Specifically, we distinguish between MMF outflows and inflows, and VM posted and received. We show that VM posted tends to increase MMF outflows, indicating that some MMF investors quickly redeemed MMF shares to meet the margin payments. In addition, margin received is found to increase inflows in MMFs, which suggests that some MMF investors used MMFs to store the liquidity received from VM payments.

Our findings bring about several policy implications. First, in the context of liquidity management of non-bank financial intermediaries, the results highlight the risks of reliance on the cash-like properties of MMF shares as a reliable source of liquidity under stress. In particular, non-banks' liquidity management should account for the fact that the value of MMFs can decline and MMFs can even suspend redemptions, while MMFs should be made more resilient to significant outflows. Second, the results underline the importance of assessing risks arising from interconnectedness across markets, including from relatively small but volatile links, and across borders. This is particularly relevant in view of evaluating the recent regulatory reform in the derivatives market. Specifically, our paper highlights that in the March 2020 market turmoil some non-bank financial intermediaries passed on their liquidity squeeze from VM payments to MMFs. Third, the results also point to a new channel through which unprecedented policy actions by central banks such as the ECB's pandemic emergency purchase programme (PEPP) helped to stabilise MMF outflows: since market volatility significantly decreased after these policy actions and VM payments move mechanically with market volatility, the actions helped reduce VM payments and thus also MMF outflows. Finally, our paper demonstrates that granular (regulatory) data collections are key for analysing interconnectedness, including in relation to regulatory reforms and policy actions, as we could find those links and channels only thanks to the availability of various granular datasets, including trade repository data.

1 Introduction

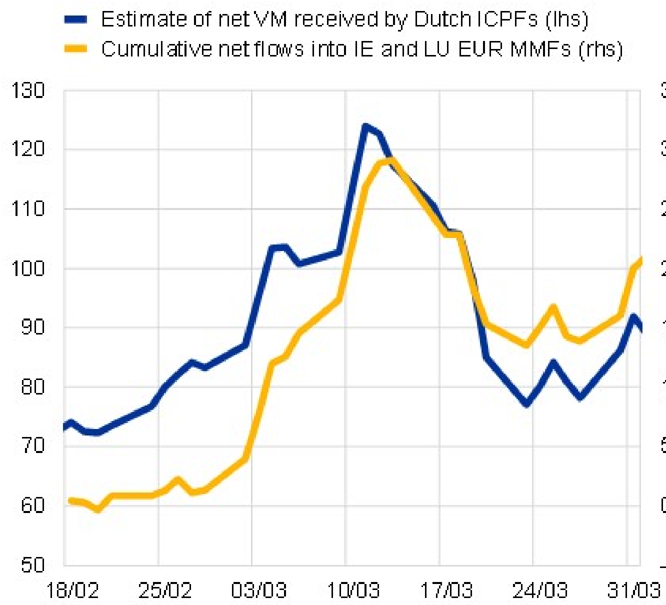
During the Covid19-related market turmoil in March 2020, money market funds (MMFs) across the globe experienced significant volatility in flows. In Europe, euro area MMFs faced outflows of nearly 8% of assets under management within a week from March 13 to 20 2020 (Boucinha et al., 2020), while prime MMFs in the US recorded outflows of 11% of their assets over March 2020 (FSB, 2020). Total net assets (TNA) of money market funds (MMFs) in the largest euro area countries by market capitalization represent more than 1.2 trillion euros, and instability is such market can have important systemic effects. The main risks lie in liquidity, maturity, and credit transformation performed by MMFs that can lead to depositor runs and thus to fire sales and financial instability (Garcia Pascual et al., 2021). In March 2020, central banks' unprecedented response, followed by other public policy responses, helped stabilise the outflows, but the experience raised questions about the potential drivers and amplifiers of such volatility in MMF flows.

In this paper we investigate the reasons behind the MMF flows, paying particular attention to investors, their liquidity needs and the use of MMFs as a source of liquidity in stressed periods. As retail and institutional investors use MMFs to manage their short-term liquidity needs (FSB, 2021), investors' liquidity needs in turbulent times may pose a significant strain on MMFs. We start from a stylized fact in Figure 1, documenting a strikingly strong correlation (over 80%) between variation margin (VM) payments on derivative portfolios of euro area insurance companies and pension funds (ICPFs) and MMF flows held by ICPFs facing these payments (Fache Rousová et al., 2020).[1] We then analyse in more depth whether VM payments of various sectors were one of the drivers of the observed MMF flows. Based on market intelligence and anecdotal evidence, some existing studies suggest that VM payments played a role in MMF flow dynamics during the March 2020 market turmoil (BlackRock, 2020; Bank of England, 2020), but none of them investigates the topic systematically as we do.

Studying the effects of margin payments on the financial system in general and MMFs in particular is very important in view of the recent regulatory reform in the derivative market, which introduced mandatory clearing for certain classes of over-the-counter (OTC) derivative

[1] VM is collateral exchanged by two counterparties to a derivative transaction, which reflects the price movement of such a transaction or a portfolio of such transactions.

Figure 1: Co-movement of ICPFs' VM payments and flows in EUR-denominated MMFs domiciled in Ireland and Luxembourg.



Sources: EMIR data, EPFR Global, and authors' calculations.
Notes: Values in EUR bn. "Net VM received" is the difference between the stock variables "VM received" and "VM posted" reported in EMIR. See Section 2 for more details.

contracts, while requiring stricter risk-mitigation practices for the non-centrally cleared ones, implying the posting of initial and variation margins for larger classes of derivative exposures, thus profoundly changing the functioning of the derivative markets. The exchange of margin in the form of high-quality collateral reduces counterparty credit risk, but the requirements also increase liquidity risk as counterparties need to meet margin calls with high-quality collateral at short notice (ECB, 2016, 2020a). In this respect, our paper is the closest to Czech et al. (2021), which shows that UK-based insurance companies and pension funds heavily sold gilts to meet VM calls on their FX hedges. But Czech et al. (2021) does not look at MMFs. A similar recent spiral involving UK LDI funds responding to margin calls on their IR hedges has been documented in Bank of England (2022). Still no direct link to MMFs flows is made. On the other hand, existing studies on MMF outflows during the March market turmoil mainly focus on drivers related to MMF characteristics. In particular, de Guindos and Schnabel (2020) and Boucinha et al. (2020) suggest that the outflows from USD-denominated MMFs domiciled in the euro area were driven by flight-to-safety reasons as investors withdrew particularly from riskier low-volatility net asset value (LVNAV) funds and moved investments into safer USD-denominated constant net asset value (CNAV) funds. Furthermore, Capotă et al. (2022) underlined the role of a number of weaknesses in European MMF regulatory framework related to non-public debt funds, the LVNAV structure and MMF liquidity requirements.

To study the relationship between VM payments and MMF flows, we estimate the effects of VM paid and received by the largest holders of EUR-denominated MMFs on flows of these MMFs. We combine three granular data sources: (i) transaction-by-transaction derivatives data collected under the European Market Infrastructure Regulation (EMIR), which can be classified as *big data* (also known as trade repository (or TR) data), (ii) Securities Holdings Statistics by Sector (SHSS) and (iii) Refinitiv Lipper data. The resulting dataset contains a daily fund-level panel where the dependent variable is daily flows in individual MMFs domiciled in France, Ireland and Luxembourg, and the explanatory variables of interest are VM posted or received by major investor country-sectors holding the respective MMFs. The panel spans over three months: February, March and April 2020.

Since margin payments in EUR (as opposed to USD or GBP) are the largest in our dataset, we focus on these margin payments and EUR-denominated MMF flows. Furthermore, we study the effects of VM payments (as opposed to initial margin payments) as VM is typically paid in cash, while inital margin payments can also be met with non-cash collateral (e.g. high-quality government debt). Focusing on VM payments is also in line with the results of the ECB's June 2020 SESFOD survey that indicate that VM payments led to strained liquidity situation in some insurance companies, hedge funds and investment funds, while initial margin had almost no impact on their liquidity situation (ECB, 2020b, special question 6).

Our results suggest that VM payments experienced by some investors holding MMFs were an important driver of the flows of EUR-denominated MMFs domiciled in the euro area. In line with expectations, the results are typically more pronounced for MMF investors facing large margin payments, notably investment funds and pension funds, than MMF investors facing relatively limited margin payments. Specifically, we distinguish between MMF outflows and inflows and VM posted and received. We show that margin posted tends to increase MMF outflows, indicating that some MMF investors quickly redeemed MMF shares to meet the margin payments. By the same token, margin received is found to increase inflows in MMFs.

Overall, the results indicate that some non-bank financial intermediaries investing into MMFs such as investment funds and pension funds used MMFs to manage liquidity related to margin calls in the March 2020 market turmoil. The results are robust across all three countries where EUR-denominated MMFs are domiciled (i.e. France, Ireland and Luxembourg) and various model specifications. Moreover, we find these results despite the fact that the unavailability of the data does not allow us to conduct the analysis on firm-to-MMF level but only at less accurate country-sector-to-MMF level.

In addition to the literature on MMFs, our paper contributes to the emerging literature on liquidity risk stemming from derivative exposures (Bardoscia et al., 2021; Paddrik et al., 2020; Bardoscia et al., 2019; Glasserman and Wu, 2018; de Jong et al., 2019; Jensen and Achord, 2019; Fache Rousová et al., 2020). However, these papers rely on margin simulations rather than actual data or consider a limited number of derivative contract types and/or simplistic market shocks. They also tend to compare the simulated margin demands to static (e.g. pre-crisis) liquidity buffers and thus do not capture the evolving market dynamics and the actual impact on MMFs such as our paper does.

The rest of the paper is structured as follows. Section 2 describes the data and provides some key descriptive statistics with focus on the March 2020 market turmoil. Section 3 presents the empirical model. Section 4 discusses the results, while Section 5 briefly concludes.

2 Data

In this paper, we combine three highly granular, voluminous and unique data sets. First, we use transaction-by-transaction EMIR data on derivatives to compute VM payments of investors. We further enrich these data using sector classification developed by Lenoci and Letizia (2021). Second, we use Refinitiv Lipper data to obtain daily MMF flows at the fund level. We then link the VM payments and MMF flows data using Securities Holdings Statistics by Sector (SHSS) data, which provide information on sectors that hold individual MMFs. Since SHSS data include investor information only at country-sector level (e.g., holding of funds A, B and C by the whole German investment fund sector), we aggregate VM at country-sector level.

2.1 VM payments from EMIR data

EMIR data are transaction-by-transaction data on derivatives collected through trade repositories. They have been reported by entities resident in the EU since February 2014 and include the details of each individual derivative transaction conducted by these counterparties. For each derivative transaction more than 120 data fields are available. The collected information includes the type of derivative, the underlying security, the price, the amount outstanding, the execution and clearing venues of the contract, the valuation, the collateral (margin) and life-cycle events. Owing to their volume, high frequency and variety, the EMIR data can be classified as *big data*.

In this paper, we work with EMIR data that are accessible to the ECB, focusing on a subsample that is restricted to the trades reported by counterparties located in the euro area. We enrich the reported data with sector of the reporting entity applying the classification algorithm of Lenoci and Letizia (2021), which combines information from four official lists (ECB's lists of monetary financial institutions and investment funds, EIOPA's list of insurance undertakings and ESMA's list of CCPs) and four other data sources (ECB's RIAD, Orbis, Refinitiv Lipper and Bank Focus). Since EMIR data are highly granular and complex, we also extensively manipulate and clean them. In particular, the data are initially reported by both counterparties to a trade and, therefore, we pair the two legs of the trade (where possible and applicable). Furthermore, we run various quality checks and remove outliers.[2]

While EMIR data are reported at transaction level, VM is reported at portfolio level. This implies that for all trades belonging to the same collateral portfolio, the reporting counterparty is required to provide one value for VM *received* and one value for VM *posted* (i.e., one value for each of the two VM variables, where one of these typically equals 0). These two variables are required to be reported in *stocks*, reflecting the cumulative margin payments since the starting date of the contract. For paired trades, when one counterparty receives (posts) VM, the other counterparty sharing the same portfolio will post (receive) the same amount (see an illustrative example in Table 1).

To compute margin from transaction-level data, we first define a reliable and unique collateral portfolio code for each pair of counterparties sharing a portfolio of derivatives by concatenating

[2] Despite this processing, the final data are still subject to some data quality limitations such as missing values, residual unpaired transactions or possible under-reporting.

Table 1: Illustrative example of VM stock reporting in EMIR data after pairing of the two legs of a trade for a given portfolio.

LEI 1	LEI 2	Trade ID	Portfolio code	Notional value	VM stock received 1	VM stock posted 1	VM stock received 2	VM stock posted 2
ABC	DEF	111	ABCDEF00	100	200	0	0	200
ABC	DEF	222	ABCDEF00	500	200	0	0	200

Notes: The representative portfolio (identified by the collateral portfolio code ABCDEF000) consists of two contracts (identified by trade IDs 111 and 222 with notional values of 100 and 500 respectively) between two counterparties (identified by their LEIs ABC and DEF respectively). While the two contracts have different trade IDs and notional values, they belong to the same collateral portfolio and thus share the same values for *VM stock received* by ABC from DEF and *VM stock posted* by DEF to ABC (200). By the same token, *VM stock posted* by ABC to DEF has the same value as *VM stock received* by DEF from ABC (0). The total notional value of this portfolio equals 600.

the legal entity identifiers (LEIs) of the two counterparties with the reported collateral portfolio codes. If one of the latter does not exist, then it is replaced by the reported VM value. To filter out potential outliers with suspiciously high VM values, we drop portfolios for which the value of either *VM stock posted* or *VM stock received* exceeds 80% of the total notional value of the portfolio (computed as the sum of the notional values of all contracts in the portfolio). We make two considerations for the choice of this threshold. First, since the stock of VM reflects the market value of a portfolio, it should not exceed the total notional value of all contracts in a portfolio. Second, as VM is set to 0 at the beginning of the contract and it is rather unlikely that it approaches 100% of the total notional value, we opt in our cleaning procedure for a more conservative threshold than 100% and choose a threshold of 80%. The difference between the use of the two thresholds is rather minor: the choice of the 80% threshold drops less than 0.1% of notional value as compared to the use of the 100% threshold.

Having cleaned the reported VM data, we compute *net VM stock posted* (V_t) as the difference between the reported *VM stock posted* (V_t^P) and *VM stock received* (V_t^R) on each day and for each collateral portfolio ($V_t = V_t^P - V_t^R$). The value of the *flow* of margin payments exchanged on a given day t, call it $flow_t$, can then be derived by taking the difference between the value of *net VM stock posted* on day t and on day $t-1$, i.e. $flow_t = V_t - V_{t-1}$. $flow_t$ can take both positive and negative values, indicating respectively a liquidity outflow (margin call) or liquidity inflow. We isolate the positive part, signalling a net outflow of cash, by defining it as the value of $flow_t$ if it is positive and zero otherwise, and denote it as *VM flow posted*. Similarly, we define the negative part, signalling a net inflow of cash, as the absolute value of $flow_t$ if $flow_t$ is negative and zero otherwise, and denote it as *VM flow received*. As a result, the positive and negative parts are always non-negative (see Table 2).

Table 2: Definition of *net VM flow posted* and the separation of its positive and negative parts using two types of portfolios: with an increasing and decreasing *net VM stock posted* (Case 1 and 2 respectively).

Time	Net VM stock posted	Portfolio	Flow	Sign	VM flow posted		VM flow received	
					Value	Sign	Value	Sign
$t-1$ t	$V_{t-1} = V_{t-1}^P - V_{t-1}^R$ $V_t = V_t^P - V_t^R$	Case 1: $V_t > V_{t-1}$	$flow_t = V_t - V_{t-1}$	+	$flow_t$	+	0	None
$t-1$ t	$V_{t-1} = V_{t-1}^P - V_{t-1}^R$ $V_t = V_t^P - V_t^R$	Case 2: $V_t < V_{t-1}$	$flow_t = V_t - V_{t-1}$	-	0	None	$-flow_t$	+

Notes: V_t^P and V_t^R stand respectively for *VM stock posted* and *VM stock received* at time t. The *net VM stock posted* at time t, denoted as V_t, is computed as the difference between V_t^P and V_t^R. The margin flow at time t, denoted as $flow_t$, is the difference between V_t and V_{t-1}.

Having isolated the positive and negative parts of $flow_t$, we aggregate each of them (separately) from individual counterparty to country-sector level. Such aggregation leads to a significant information loss but it is the only feasible way for us to build our panel data as SHSS data are only available at sector level (see Section 2.3). At the same time, the separation of positive and negative values of VM flows mitigates this information loss somewhat. If the aggregation to country-sector level were done before the separation, the positive and negative values of margin flows by different entities within a sector would often offset each other, so that more variability in the data would be lost.

To each portfolio, we also assign a currency for the VM posted/received to filter out only portfolios where margins are posted/received in EUR. Since, in principle, it is possible to receive or post margins in multiple currencies for contracts belonging to the same portfolio, we use values converted to EUR and define that a portfolio receives (posts) margin in a given currency if the outstanding notional of the contracts receiving (posting) margin in that currency exceeds an 80% threshold of the total outstanding notional of the portfolio. Overall, around 60% of the VM flows over the three-months period is in EUR.

Figure 2 shows that during the March 2020 market turmoil, the daily VM payment flows of euro area non-bank entities increased more than fivefold, from around €5 bn in the first half of February 2020 to more than €20 bn in March 2020, with peaks of over €30 bn.[3] We exclude from the chart VM of CCPs and banks, since CCPs positions are fully balanced (VM received equals VM paid) and banks/large dealers usually pay VM not only for their own trading purposes but also on behalf of their clients, which complicates the analysis. Banks are also not

[3]See also Fache Rousová et al. (2020) for similar evidence on VM faced by investment funds.

large holders of MMFs (see Section 2.3).

Figure 2: VM flows of euro area non-bank entities.

Source: EMIR data and authors' calculations.
Notes: The figures are obtained by aggregating VM flows posted and received where the flows are derived from the reported VM stocks (see also Table 2).

2.2 MMF flows from Refinitiv Lipper data

According to Lipper data from Refinitiv, the euro area MMF sector hold assets with a total value of around €1.2 trillion in early 2020. MMFs domiciled in Ireland, Luxembourg and France represent the lion's share of the sector in the euro area. The sector is highly diverse. Funds are available in different currencies (EUR, GBP or USD) and are of three types: public debt CNAV, LVNAV and short-term variable net asset value (VNAV). Each category has different regulatory requirements in terms of pricing, shares of public debt and shares of weekly liquid assets among others. [4]

Since the majority of VM payments by euro area investors are done in EUR, we focus on MMFs denominated in EUR. These represent around 46% of the euro area MMF total net assets (TNAs) with respective TNAs of MMFs in France, Luxembourg and Ireland being equal to €335

[4]For more information on the requirements, see Capotă et al. (2022).

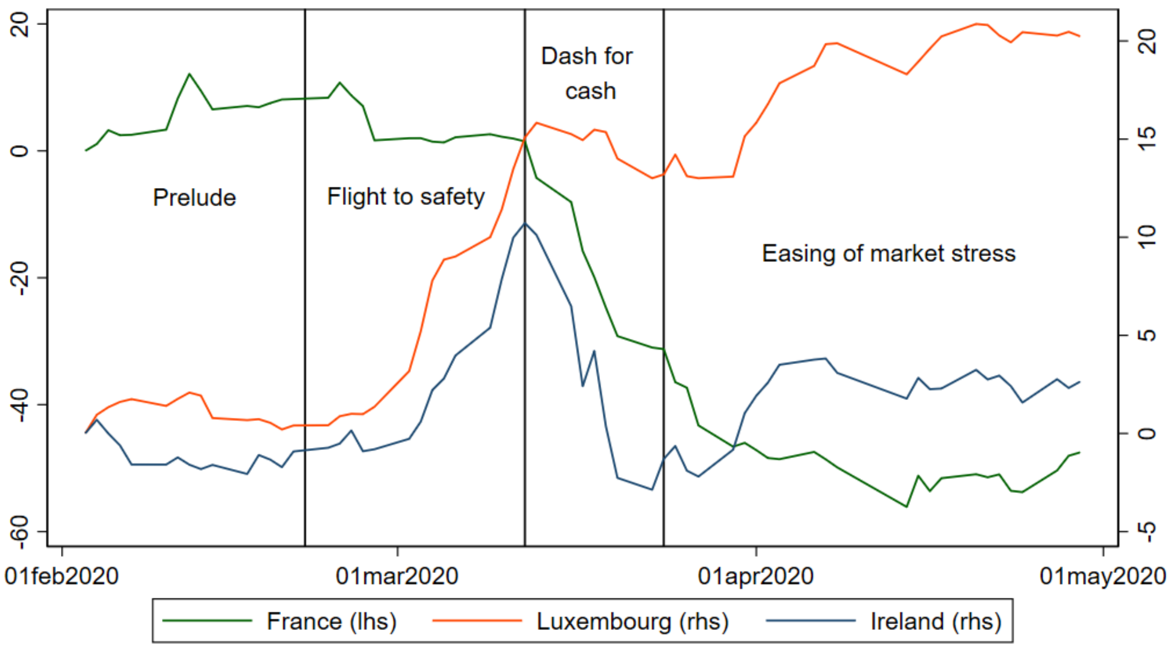
bn, €99 bn and €118 bn respectively. Overall, French MMFs thus make up almost two thirds of the EUR-denominated MMF assets.

We use Refinitiv Lipper daily data on MMFs' TNAs to compute daily flows at fund level by taking the difference between the TNAs on two consecutive days. We do not take into account funds' performance as MMFs are supposed to have a very stable net asset value. For instance, according to Capotă et al. (2022), for the majority of the USD-denominated LVNAV funds, the deviation in net asset value was typically less than 10 basis points (i.e. less than 0.1%) during the February-April 2020 market turmoil. As for the EUR-denominated LVNAVs that constitute the majority of MMFs in Ireland and Luxembourg, "no LVNAV breached the 20 bps collar in March, a few funds were close to the threshold, with one fund having an 18 bps deviation" (ESMA, 2021). We consider these valuation effects to be small in comparison with the effect from flows on TNAs (almost 8% outflows for euro area MMFs).

Figure 3 shows cumulative flows into EUR-denominated MMFs domiciled in France, Ireland and Luxembourg over our period of interest, i.e. from February to April 2020. Despite some differences, the flows across the three types of MMFs, particularly across Irish and Luxembourgish MMFs, reflect the four different stages of market developments over February to April 2020 as classified by FSB (2020).

First, during the 'prelude', markets were relatively calm, which was reflected by fairly flat MMF flows. After the first lockdowns in Italy on 21 February 2020, markets reacted by 'flying to safety', with Irish and Luxembourgish MMFs experiencing strong inflows. On 11 March, World Health Organization declared Covid-19 a pandemic, which triggered the highly-volatile 'dash for cash' period, during which investors scrambled for cash and redeemed shares from all three types of MMFs. After significant interventions by central banks around the globe, the market stress eased towards the end of March and during April. In line with these overall market developments, inflows in Irish and Luxembourgish MMFs resumed, while the outflows from French MMFs decreased and came to halt around mid-April 2020. The dynamics for French MMF towards the end of March 2020 differs somewhat from that of Irish and Luxembourgish MMFs as it reflects not only the pandemic-related market dynamics but also significant redemption flows at the end of each quarter. This is because (French non-financial) companies regularly withdraw cash from French MMFs at the end of each quarter to settle expenses and structure their balance sheets (AMF, 2020, Figure 80).

Figure 3: Cumulative flows into EUR-denominated MMFs



Source: Refinitiv Lipper and authors' calculations.
Notes: Values in EUR bn. To derive cumulative flows, we compute daily changes in TNAs (daily flows) for each fund and accumulate them over time starting from 1 February 2022. The cumulative flows are aggregated across all funds in a given domicile. Value at each specific date shows how much flows entered/left funds domiciled in a country since 1 February 2022. The vertical lines are drawn on 22 February, 12 March and 24 March 2020 and refer to the ends/beginnings of the four distinct periods (prelude, flight to safety, dash for cash and easing of market stress) defined in FSB (2020).

2.3 Investors' holdings of MMF shares from SHSS

To link the VM data to the MMF data, we use information on euro area sector holdings of MMFs from the Securities Holdings Statistics by Sector (SHSS). SHSS data provide quarterly information on investor holdings of individual funds, where investors are aggregated at country-sector level. Since there are 19 euro area countries and 10 sectors, the sector-country combinations provide us with 190 different investor groups.[5]

Since not all MMFs are held by euro area investors, merging MMF flows data with SHSS data somewhat reduces our sample of EUR-denominated MMF funds. The final sample of MMFs still remains representative for Luxembourg and France, where it represents more than

[5]The countries include Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovenia, Slovakia and Spain. The sectors are banks, national central banks (NCBs), central clearing houses (CCPs), non-financial corporations (NFCs), government, insurance corporations (ICs), pension funds (PFs), investment funds (IFs), other financial institutions (OFIs) and others.

90% of TNAs of all EUR-denominated MMFs domiciled in these countries, €327 bn and €89 bn respectively. Irish funds in our final sample make up around 30% (€35 bn) of TNAs of all EUR-denominated MMFs domiciled in Ireland. The share of non-euro area investors investing in Irish MMFs is particularly high as there is a strong link between Irish MMFs and British financial institutions.[6]

3 Empirical model

Compiling all the data together, we obtain a daily fund-level panel over the three months period from February to April 2020. In our model, the dependent variable is the daily flows in individual MMFs and the explanatory variables of interest are VM flows of sectors in different euro area countries, which hold the individual MMFs. Since we expect that VM flows posted (received) drive MMF outflows (inflows), we run separate regressions for MMF outflows and inflows.

Specifically, we estimate the following empirical specifications:

$$Outflows_{i,t,q} = \sum_{g} \beta_g * VM\ flows\ posted_{g,t,q} * MMF\ held_{g,i,q-1} + I_i + T_{t,q} + \epsilon_{i,t,q} \quad (1)$$

$$Inflows_{i,t,q} = \sum_{g} \beta_g * VM\ flows\ received_{g,t,q} * MMF\ held_{g,i,q-1} + I_i + T_{t,q} + \epsilon_{i,t,q} \quad (2)$$

where i denotes the MMF, g the investor group at sector-country level, t the date and q the quarter. $VM\ flows\ posted_{g,t,q}$ refers to VM flows posted by investor group g at date t belonging to quarter q, while $VM\ flows\ received_{g,t,q}$ is VM flows received.[7] $MMF\ held_{g,i,q-1}$ is a dummy equal to one if the investor group g holds MMF i at the end of the previous quarter $q-1$ (i.e., for dates in February and March 2020, the end of the previous quarter is the end of December 2019, while for dates in April 2020, it is the end of March 2020).[8] To control for any MMF-specific characteristics such as fund age and type, we also include fund fixed effects (FEs), denoted as I_i. Similarly, to control for market volatility over time, we include daily time fixed effects and denote them as $T_{t,q}$. The variable $Outflows_{i,t,q}$ equals to MMF outflows when

[6] For statistics on holdings of MMFs by the largest investor sectors (investor groups), see Section 3.1. In that section, we also provide information on VM flows experienced by these largest MMF investor groups.

[7] More specifically, $VM\ flows\ posted_{g,t,q}$ is the positive part of the net margin flows posted and $VM\ flows\ received_{g,t,q}$ is the negative part, as described in Section 2.1.

[8] Put differently, we filter the explanatory variables to include only those investor groups, which held MMF i at the end of the previous quarter.

they are positive and to zero when they are negative (that is, when there are inflows). The same applies to the variable $Inflows_{i,t,q}$. β_g are the coefficients of interest that capture the effect of VM flows on MMF in-/outflows, while $\epsilon_{i,t,q}$ is the error term.

Since it could be plausible to assume that the individual fund effects and VM payments faced by investors into these MMFs are uncorrelated, we don't estimate only FE models but run also random effect (RE) models. We report the results of the Hausman tests, which indicate the more preferable model specification (i.e., RE or FE model). To further check the robustness of the results, we also estimate a model in which we include the lagged dependent variable (i.e., lagged MMF in-/outflows) as an explanatory variable to control for potential autocorrelation in MMF flows. In this specification, we however exclude fund FEs to avoid biased estimates (Wooldridge, 2010).

In addition to the simultaneous effects of VM payments on MMF flows, we also run regressions with lead (forward) and lagged values of VM flows to capture the potential dynamics over time. If margin is called today, it is to be posted today, tomorrow or the day after tomorrow, so we expect margin posted today or in the next few days to have an impact on MMF outflows today.[9] Therefore, we add two leads (forwards) of VM flows posted to regression 1. For margin received, we expect a different timing: investors receiving margins may deposit the funds to MMFs not only on the same day but also later on, so we add one and two lags of VM flows received to regression 2.

Positive and significant coefficients for contemporaneous/lead margin flows posted and contemporaneous/lagged margin flows received would confirm our hypothesis that investors use MMFs for liquidity purposes to pay margin calls. When investors receive margins, they would buy MMF shares, while when they have to pay margins, they would redeem MMF shares.

We run all the regressions separately for each MMF domicile. We have two reasons for that. First, it helps us further control for the potential differences in the type of MMFs including the underlying regulatory framework. In particular, most EUR-denominated MMFs domiciled in Ireland and Luxembourg are LVNAV funds, while French MMFs are typically VNAV funds

[9] The exact timing when margin is to be posted depends on whether the portfolio is cleared or uncleared by a CCP. Furthermore, the EMIR reporting may also not allow for the exact identification of the date when margin are posted/received.

(ESMA, 2021). Second and more importantly, the largest investor groups for each domicile are different.

3.1 Reducing the high data dimension in the model

As mentioned in Section 2.3, we classify investors into groups that reflect all possible combinations of 10 sectors in 19 countries, i.e., 190 investor groups. But to reduce the high dimension of the data, in the regressions we focus on the most important investor groups for each MMF domicile and among them on those that are subject to large VM payments.[10] We consider the combination of these two aspects (i.e., investment into a MMF and the size of VM payments) in selecting the sectors because the two aspects are not necessarily related to each other. In particular, the size of VM payments does not depend only on the size of the sector but also on the extent the sector uses derivatives and the volatility in the market value of these derivatives.

Specifically, for each MMF domicile, we rank investor groups according to the share of MMFs' TNAs that they hold and restrict them to the top ten investor groups (see Table 3). Given that we are interested in the effect of VM flows on MMFs' flows, we then select five sectors with the largest VM flows among the top ten investor groups for each domicile. Since some sectors with large VM payments appear among the top ten investor groups for more than one domicile (notably Luxembourgish IFs, German IFs and Dutch PFs), we end up with nine investor sectors of interest. These nine sectors are listed in Table 4, which also provides statistics on VM flows faced by these sectors.

In Table 3 we also report statistics for the sample of MMFs used in the regressions, i.e. for MMFs that are held (at least partially) by euro area investors. Most MMFs in our sample (262) are domiciled in Luxembourg and they represent about 90% of TNAs of all EUR-denominated MMFs from Luxembourg (or €89 bn out of €99 bn). While the number of French MMFs in our sample (250 funds) is slightly lower than that of Luxembourgish MMFs, French MMFs stand

[10]We have also considered the opposite approach, in which we first select the sectors with the largest VM payments and among them those with large investment into MMFs. This alternative approach, however, results in the selection of several banking sectors whose holdings of MMFs are almost negligible. Moreover, banks tend to have many more options to obtain liquidity than non-banks and, therefore, we do not expect them to rely on MMFs for their own liquidity management. In particular, in the March 2020 market turmoil, banks often sourced liquidity from central banks, which introduced various measures to provide banks with immediate liquidity support. See Daskalova and Weißler (2020) for more information on the ECB's liquidity support to euro area banks.

Table 3: Top 10 holders of EUR-denominated MMFs by domicile

Luxembourgish MMFs (262 funds, TNAs: EUR 89 bn)	Share of TNA held	French MMFs (250 funds, TNAs: EUR 327 bn)	Share of TNA held	Irish MMFs (50 funds, TNAs: EUR 35 bn)	Share of TNA held
1. IT IC	9.1%	1. FR IC	24.4%	**1. LU IF**	8.4%
2. LU IF	7.5%	**2. FR IF**	18.3%	**2. IE IF**	7.2%
3. IE IC	5.1%	3. FR NFC	15.3%	3. IE IC	3.6%
4. NL IF	4.3%	**4. LU IF**	2.4%	**4. NL PF**	3.5%
5. DE IF	3.3%	**5. DE IF**	1.8%	5. IT IC	2.5%
6. NL PF	2.2%	6. IT IC	1.4%	**6. IT IF**	0.7%
7. DE IC	2.0%	7. LU IC	0.9%	7. NL IF	0.6%
8. FR IC	1.6%	**8. FR Bank**	0.7%	**8. DE IF**	0.5%
9. LU IC	1.5%	9. NL NFC	0.6%	9. ES NFC	0.4%
10. ES IF	1.2%	10. **ES IF**	0.6%	10. IE PF	0.3%

Sources: SHSS, Refinitiv Lipper and authors' calculations.
Note: MMFs holdings are as of end of December 2019. TNAs are computed as an average of daily values over February 2020. Statistics are computed for the sample of MMFs, for which holdings data from SHSS are available. The top five groups in terms of largest VM payments among the top ten largest investor groups are in bold.

out for their large TNAs (almost €330 bn). Finally, Irish MMFs in our sample are small in terms of both the number of funds (50) and their TNA (€35 bn).

To identify from these descriptive statistics candidate sectors that could be particularly strong drivers of MMF flows, we look at the most important euro area investors into MMFs in our sample, which also experienced large VM flows. Three sectors stand out in this respect: Luxembourgish IFs, Dutch PFs and German IFs. More specifically, Luxembourgish IFs are among the top five investors into MMFs in all three domiciles, while they also experienced large VM flows (both mean and median exceeding €1 bn). Second, VM flows faced by Dutch PFs were even greater (with mean and median over €1.5 bn) and Dutch PFs also belong to the top ten investors into both Luxembourgish and Irish MMFs. Third, German IFs belong to the top ten investors into MMFs in all three domiciles, while they also experienced substantial VM flows (mean around €900 mn and €800 mn for VM flows posted and received respectively). Other sectors seem less suitable candidates. For instance, French banks experienced exceptionally large VM flows but their holding of MMFs are very limited. On the other hand, French insurers represent by far the top holder sector of French MMFs but their VM flows are fairly small (ranking last in Table 4).

Table 4: VM flows posted and received by the top ten sectors in terms of investment into EUR-denominated MMFs

VM flow posted

	5th percentile	Median	95th percentile	Mean	Std. dev.
1. FR Bank	5,170	10,712	27,361	13,351	7,189
2. NL PF	424	1,626	4,134	1,852	1,206
3. LU IF	491	1,073	2,337	1,175	582
4. DE IF	206	722	2,636	900	729
5. FR IF	198	366	1,350	468	328
6. IE IF	84	241	708	310	224
7. ES IF	20	123	742	222	342
8. IT IF	43	97	497	151	146
9. FR IC	26	70	300	118	93

VM flow received

	5th percentile	Median	95th percentile	Mean	Std. dev.
1. FR Bank	3,862	10,099	29,125	13,376	8,611
2. NL PF	366	1,783	3,831	1,862	1,171
3. LU IF	427	1,150	1,928	1,140	485
4. DE IF	122	621	1,957	805	688
5. FR IF	156	364	1,017	446	305
6. IE IF	100	219	751	310	201
7. ES IF	16	97	1,119	215	396
8. IT IF	28	98	461	145	139
9. FR IC	12	114	321	137	108

Sources: EMIR data and authors' calculations.
Notes: Values in EUR mn. Based on VM flows from the beginning of February to the end of April 2020. Sorted by mean of VM flow posted and received.

4 Empirical results

We estimate equations 1 and 2 using panel regressions with standard errors clustered at fund level. We start with the contemporary effects of VM flows on MMF flows over February to April 2020 and report the results in Tables 5 and 6 respectively. Across all three model specifications (i.e., FE, RE and lagged dependent variable models) and the three MMF domiciles as well as for both MMF outflows and inflows, we estimate positive and significant effects of VM payments faced by some sectors on MMF flows. The signs of the coefficients are as expected: we estimate that investors withdraw funds from MMFs to post VMs (see Table 5), while VM flows received increase MMF inflows (see Table 6).

Table 5: Regression results for MMF outflows and VM flows posted

	Dependent variable: MMF outflows										
	Luxembourgish MMFs				French MMFs				Irish MMFs		
*Independent variables: VM flows posted * MMF held*											
	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)
LU IF	**0.002***	**0.002***	0.001	FR IF	-0.004	-0.003	-0.005	LU IF	0.000	0.001	-0.000
	[0.054]	[0.066]	[0.163]		[0.513]	[0.593]	[0.307]		[0.900]	[0.843]	[0.950]
DE IF	0.002	0.002	**0.003***	LU IF	**0.011*****	**0.011*****	**0.007*****	IE IF	-0.003	-0.003	-0.007
	[0.303]	[0.423]	[0.082]		[0.000]	[0.000]	[0.000]		[0.620]	[0.704]	[0.129]
NL PF	**0.009****	**0.008****	**0.011****	DE IF	**0.024****	**0.020****	**0.037*****	NL PF	**0.011*****	**0.011*****	**0.010*****
	[0.023]	[0.030]	[0.010]		[0.011]	[0.026]	[0.003]		[0.004]	[0.009]	[0.001]
FR IC	0.002	0.001	0.003	FR Bank	0.000	0.000	0.000	IT IF	-0.013	-0.012	-0.004
	[0.809]	[0.905]	[0.694]		[0.143]	[0.117]	[0.638]		[0.210]	[0.227]	[0.674]
ES IF	0.005	0.005	0.005	ES IF	-0.010	-0.009	-0.011	DE IF	-0.001	-0.002	0.001
	[0.332]	[0.332]	[0.314]		[0.217]	[0.233]	[0.279]		[0.729]	[0.724]	[0.819]
Fund effects	RE	FE	No	Fund effects	RE	FE	No	Fund effects	RE	FE	No
Lagged dep.	No	No	Yes	Lagged dep.	No	No	Yes	Lagged dep.	No	No	Yes
Date FE	Yes	Yes	Yes	Date FE	Yes	Yes	Yes	Date FE	Yes	Yes	Yes
Observations	15,803	15,803	15,535	Observations	15,218	15,218	14,953	Observations	3,055	3,055	2,986
R-squared	0.069	0.221	0.129	R-squared	0.079	0.301	0.162	R-squared	0.065	0.263	0.153
Hausman test	p-value: 0.08			Hausman test	p-value: 0.00			Hausman test	p-value: 0.67		

Notes: The table shows regression results of MMFs' outflows against the interaction between VM flows posted by investor groups and a dummy equal to one when the investor groups hold the MMF. Investor groups included in the regressions are the five groups with the largest VMs among the top ten largest investor groups. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6: Regression results for MMF inflows and VM flows received

Dependent variable: MMF inflows											
Luxembourgish MMFs				French MMFs				Irish MMFs			
*Independent variables: VM flows received * MMF held*											
	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)
LU IF	**0.002***	**0.002***	0.001	FR IF	0.002	0.002	0.001	LU IF	0.002	0.003	-0.001
	[0.003]	[0.004]	[0.272]		[0.336]	[0.456]	[0.811]		[0.492]	[0.398]	[0.768]
DE IF	0.002	0.001	**0.004***	LU IF	**0.004*****	0.000	**0.006*****	IE IF	-0.002	-0.001	-0.009
	[0.179]	[0.463]	[0.024]		[0.006]	[0.968]	[0.002]		[0.770]	[0.901]	[0.153]
NL PF	**0.013***	0.011	**0.14***	DE IF	0.002	-0.007	**0.025*****	NL PF	0.005	0.005	**0.010*****
	[0.091]	[0.136]	[0.025]		[0.725]	[0.412]	[0.000]		[0.117]	[0.193]	[0.000]
FR IC	0.012	0.011	0.016	FR Bank	0.000	0.000	-0.000	IT IF	0.002	0.003	-0.002
	[0.229]	[0.248]	[0.240]		[0.627]	[0.608]	[0.696]		[0.678]	[0.480]	[0.839]
ES IF	0.001	0.001	0.004	ES IF	**0.009***	**0.010***	0.005	DE IF	0.003	0.003	0.003
	[0.753]	[0.848]	[0.171]		[0.069]	[0.058]	[0.371]		[0.524]	[0.522]	[0.531]
Fund effects	RE	FE	No	Fund effects	RE	FE	No	Fund effects	RE	FE	No
Lagged dep.	No	No	Yes	Lagged dep.	No	No	Yes	Lagged dep.	No	No	Yes
Date FE	Yes	Yes	Yes	Date FE	Yes	Yes	Yes	Date FE	Yes	Yes	Yes
Observations	15,803	15,803	15,535	Observations	15,218	15,218	14,953	Observations	3,055	3,055	2,986
R-squared	0.085	0.293	0.221	R-squared	0.015	0.162	0.043	R-squared	0.036	0.241	0.080
Hausman test	p-value: 0.00			Hausman test	p-value: 0.00			Hausman test	p-value: 0.81		

Notes: The table shows regression results of MMFs' inflows against the interaction between VM flows received by investor groups and a dummy equal to one when the investor groups hold the MMF. Investor groups included in the regressions are the five groups with the largest VM flows among the top ten largest investor groups. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Overall, the estimated coefficients are found to be fairly stable across the three model specifications both in terms of size and significance, suggesting that our results are by and large robust to the choice of the model.[11] The results of the Hausman test differ by domicile: they indicate that Irish MMF flows can be estimated using the RE model, while the FE model is preferable for modelling Luxembourgish and French MMF flows.

As expected, investors with larger holdings of MMFs and larger exposures to derivatives tend to have a significant effect on MMF outflows. In particular, the regressions confirm that the top three non-bank sectors in terms of the largest derivative exposures (as measured by VM flows) stand out in this respect: Dutch PFs, Luxembourgish IFs and German IFs (see ranking in Table 4 and related discussion). In addition, we find that these sectors typically use MMFs for both purposes: as a source of liquidity to meet VM payments and as a storage of liquidity when VM is received.

More specifically, VM flows of all these three sectors are found to have significant effects on Luxembourgish MMF flows (both in- and outflows). In addition to their large derivative exposures, these sectors also belong to the top six sectors in terms of holdings of Luxembourgish MMFs (see ranking in Table 3). VM flows of Luxembourgish and German IFs are also found to have significant effects on French MMF flows (again both in- and outflows). The two sectors belong to the top five holders of French MMFs.[12] Finally, it is Dutch PFs whose VM payments are found to have a significant effect on both Irish MMF inflows and outflows. Dutch PFs rank fourth in terms of Irish MMF holdings and first in terms of the size of non-bank VM payments.

The estimated effects are not only statistically but also economically significant. In particular, the significant coefficients range between 0.002 and 0.037, which implies that if a sector faced VM flows of the size of €1 bn, the corresponding MMFs are estimated to have experienced flows from around €2 mn to €37 mn. For instance, for Irish MMFs, the estimated coefficients for VM paid by Dutch PFs are found to be around 0.010, which means that when Dutch PFs post €1 bn in VM, Irish MMFs held by them are estimated to have suffered outflows of around €10 mn.

[11] We have also estimated dynamic panel models such as the Arellano-Bond model. For Luxembourgish and French MMFs, this estimator yielded qualitatively similar results as those obtained by the model with lagged dependent variable. For Irish MMFs, standard errors could not be estimated due to a low number of observations.

[12] There is some tentative evidence that VM received flows by Spanish IFs increase French MMF inflows as the RE and FE models suggest so. But this result is not further confirmed by the lagged dependent variable model and the VM posted by this sector is also not found significant in the regressions for French MMF outflows.

These effects are estimated using the whole period from February to April 2020 and as such represent average effects over this period, whereby it could be expected that the effects were larger in the most acute phase of the market stress such as during the 'dash for cash' period.More importantly, the fact that we can use in the regressions only country-sector level data on VM flows (instead of VM flows for each individual investor) means that our results are likely to suffer from measurement error downwards bias, because the individual firm-level variability in the data is dampened by the aggregation. For all these reasons, our estimates can be interpreted as a lower bound for the actual effects during the March 2020 market turmoil.

4.1 Regressions with leads and lags of VM flows

We now turn to estimating the model with leads (forward values) of VM flows posted and lags of VM flows received. To limit the number of the coefficients in the model, we keep in the regressions only those sectors whose estimates of the simultaneous VM payments are found significant and positive. We report the results of the lagged dependent variable model in Tables 5 and 6 as this model is likely to account the best for potential autocorrelation in error terms and thus might be the most suitable for estimating the lead/lagged effects of VM flows. At the same time, we show in Annex A that these results are by and large consistent to the results from other model specifications (i.e. FE and RE models).

When investors learn about the need to post VM, the actual VM payment can occur today, tomorrow or the day after tomorrow. Therefore, we also expect the investors to withdraw liquidity from MMFs within this timeframe. The results in Table 7 are in line with this expectation, even if we detect only one sector, German IFs, whose forward values of VM flows posted have a significant impact on (French) MMF outflows.

Regarding VM flows received and MMF inflows, we find evidence that German and Luxembourgish IFs deposit the funds received from VM payments into (Luxembourgish and French) MMFs with one day delay (see Table 8). This suggest that investors may not immediately reinvest the VM flows received into MMFs. One reason could be that they expect a market reversal amid stressed markets. In addition, investors may invest the VM flows received into MMFs only partially as they may aim to diversify the storing of liquidity across different asset types.

The results for leads/lags are also economically significant. The significant coefficients range

Table 7: Regression results for MMF outflows and VM flows posted - including leads (model specification with lagged dependent variable)

	Dependent variable: MMF outflows					
	Luxembourgish MMFs		French MMFs		Irish MMFs	
*Independent variables: VM posted flows * MMF held*						
LU IF (t)	**0.002****	**0.002****	**0.008****	**0.009*****		
	[0.014]	[0.013]	[0.016]	[0.009]		
LU IF (t+1)	-0.001	-0.001	-0.002	0.000		
	[0.492]	[0.633]	[0.547]	[0.979]		
LU IF (t+2)		-0.001		-0.003		
		[0.493]		[0.490]		
DE IF (t)	0.003	0.003	**0.024****	**0.020***		
	[0.247]	[0.295]	[0.024]	[0.081]		
DE IF (t+1)	0.001	0.000	**0.015*****	0.002		
	[0.417]	[0.715]	[0.004]	[0.787]		
DE IF (t+2)		0.001		**0.021***		
		[0.718]		[0.089]		
NL PF (t)	**0.010****	**0.011****			**0.009****	**0.009*****
	[0.018]	[0.022]			[0.014]	[0.009]
NL PF (t+1)	0.001	0.000			0.002	-0.000
	[0.614]	[0.974]			[0.542]	[0.978]
NL PF (t+2)		0.001				0.002
		[0.337]				[0.365]
Lagged dep. var.	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,997	14,459	14,423	13,893	2,861	2,736
R-squared	0.129	0.130	0.164	0.169	0.138	0.150

Notes: The table shows regression results of MMFs' outflows against the interactions between simultaneous and future VM flows posted by investor groups and a dummy equal to one when the investor groups hold the MMF. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8: Regression results for MMF inflows and VM flows received - including lags (model specification with lagged dependent variable)

	Dependent variable: MMF inflows					
	Luxembourgish MMFs		French MMFs		Irish MMFs	
*Independent variables: VM flows received * MMF held*						
LU IF (t)	0.001	0.002	-0.000	-0.001		
	[0.279]	[0.130]	[0.890]	[0.805]		
LU IF (t-1)	-0.000	0.001	**0.005****	0.005		
	[0.887]	[0.537]	[0.037]	[0.237]		
LU IF (t-2)		-0.002		0.001		
		[0.156]		[0.762]		
DE IF (t)	0.002	0.001	0.011	0.010		
	[0.377]	[0.456]	[0.105]	[0.130]		
DE IF (t-1)	**0.005****	**0.004***	**0.020****	**0.017***		
	[0.048]	[0.067]	[0.039]	[0.096]		
DE IF (t-2)		0.001		0.005		
		[0.424]		[0.163]		
NL PF (t)	**0.007****	**0.007***			**0.007****	**0.006****
	[0.026]	[0.058]			[0.031]	[0.036]
NL PF (t-1)	**0.010***	0.008			0.002	0.000
	[0.055]	[0.208]			[0.538]	[0.905]
NL PF (t-2)		0.002				0.003
		[0.541]				[0.505]
ES IF (t)			0.004	0.006		
			[0.413]	[0.243]		
ES IF (t-1)			-0.002	0.001		
			[0.594]	[0.729]		
ES IF (t-2)				-0.009		
				[0.125]		
Lagged dep. var.	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,527	15,254	14,938	14,665	2,980	2,905
R-squared	0.226	0.225	0.049	0.048	0.091	0.100

Notes: The table shows regression results of MMFs' inflows against the interactions between simultaneous and past VM flows received by investor groups and a dummy equal to one when the investor groups hold the MMF. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

from 0.004 to 0.021, which suggest that VM payments of around €1 bn can trigger MMF flows between €4 mn and €21 mn. For instance, for French MMFs, the estimated coefficient for 2-day forward value of VM flow posted by German IFs (t+2) equals 0.021. Hence, using the French MMFs as an example, German IFs are estimated today to withdraw around €20 mn for €1 bn of VM to be posted today and another €21 mn for €1 bn of VM to be posted in two days.

5 Conclusions

In this paper we investigate whether the significant volatility in MMF flows in the March 2020 market turmoil was driven by investors' liquidity needs related to derivative margin payments. We combine three highly granular unique data sets to construct a daily fund-level panel data spanning from February to April 2020 and estimate the effects of VM flows posted and received by the largest holders of EUR-denominated MMFs on flows of these MMFs.

Overall, the results support the hypothesis that some non-bank financial intermediaries investing into MMFs - in particular investment funds and pension funds - used MMFs to manage liquidity related to VM calls in the March 2020 market turmoil. These results are by and large robust for all EUR-denominated MMFs domiciled in the euro area as they apply across all three countries, in which such MMFs are domiciled (i.e., France, Ireland and Luxembourg). The results are also robust to different model specifications. Moreover, we find these results despite the fact that the unavailability of the data does not allow us to conduct the analysis at firm-to-MMF level but only at less accurate country-sector-to-MMF level. Since significant variability in the margin payments data is lost by aggregation to a sector level, the estimates can be considered as providing a lower bound to the actual size of the effects.

The findings suggest several policy implications. First of all, in the context of liquidity management of non-bank financial intermediaries, they highlight the risks of reliance on the cash-like properties of MMF shares as a reliable source of liquidity under stress. Although no MMF had to suspend redemptions in the March 2020 market turmoil, non-banks' liquidity management should account for the fact that the value of MMFs can sometimes decline and MMFs can suspend redemptions in exceptional circumstances. As emphasized in ECB (2021), MMFs should also be made more resilient to significant outflows and the structure of their investor base should also be taken into account.

Second, the results underline the importance of unearthing and monitoring interconnectedness across markets, including from relatively small but volatile links, and across borders. This is particularly relevant in view of the recent regulatory reform in the derivatives market, which has introduced the daily exchange of margin for the vast majority of derivative exposures. While the exchange of margin in the form of high-quality collateral reduces counterparty credit risk, our results suggest that it can also increase liquidity risk in the financial system and create spillovers across different markets.

In particular, our paper highlights that in the March 2020 market turmoil some non-bank financial intermediaries passed on their liquidity squeeze from margin calls to MMFs, which in turn largely stopped providing funding to banks and NFCs. By the same token, our paper points at a new channel of the ECB's unprecedented policy actions enacted during the March 2020 market turmoil including the pandemic emergency purchase programme (PEPP). This program was announced on 18th March 2020 and market volatility and thus also VM payments (which move mechanically with market volatility) significantly declined after its announcement. While PEPP did not directly target MMFs, the unearthed link between VM payments and MMF flows in our paper suggests that the PEPP also helped stabilise the outflows faced by some MMFs.

Finally, we could investigate those links only thanks to the availability of various granular datasets, including trade repository data that started to be collected as a part of the global derivatives market reform. Overall, this suggests that granular (regulatory) data collections are key for analysing interconnectedness.

While our paper is the first - to our knowledge - to empirically and systematically assess the role of derivative margin for MMF flows, it also opens the door and calls for further research in the area of interconnectedness between the derivatives market and other markets. In particular, BCBS, CPMI, IOSCO (2022) suggests that to meet margin payments, non-bank financial intermediaries used not only MMFs but also bank deposits, the repo market and credit or liquidity lines, while some of them even liquidated assets (e.g. bonds). Furthermore, non-banks are subject not only to VM payments but can face also other liquidity needs during periods of market stress, notably initial margin payments and redemptions (the latter in the case of investments funds). We leave both these areas for further research.

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A Robustness of regression results with leads and lags of VM flows

Table 9: Regression results for MMF outflows and VM flows posted - including leads (FE specification)

	Dependent variable: MMF outflows					
	Luxembourgish MMFs		French MMFs		Irish MMFs	
*Independent variables: VM flows posted * MMF held*						
LU IF (t)	**0.002****	**0.003****	**0.011*****	**0.012*****		
	[0.021]	[0.030]	[0.001]	[0.001]		
LU IF (t+1)	-0.000	-0.000	-0.000	0.001		
	[0.697]	[0.896]	[0.994]	[0.780]		
LU IF (t+2)		-0.001		-0.004		
		[0.407]		[0.404]		
DE IF (t)	0.002	0.002	**0.016***	0.017		
	[0.470]	[0.461]	[0.089]	[0.132]		
DE IF (t+1)	0.000	-0.000	**0.010***	0.003		
	[0.787]	[0.908]	[0.071]	[0.649]		
DE IF (t+2)		0.000		0.014		
		[0.810]		[0.229]		
NL PF (t)	**0.009****	**0.010****			**0.010****	**0.011****
	[0.031]	[0.034]			[0.021]	[0.020]
NL PF (t+1)	-0.001	-0.001			0.004	0.002
	[0.812]	[0.687]			[0.301]	[0.653]
NL PF (t+2)		-0.000				0.003
		[0.796]				[0.286]
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,265	14,727	14,688	14,158	2,930	2,805
R-squared	0.223	0.227	0.302	0.305	0.256	0.245

Notes: The table shows regression results of MMFs' outflows against the interactions between simultaneous and future VM flows posted by investor groups and a dummy equal to one when the investor groups hold the MMF. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10: Regression results for MMF inflows and VM flows received - including lags (FE specification)

	Dependent variable: MMF inflows					
	Luxembourgish MMFs		French MMFs		Irish MMFs	
*Independent variables: VM flows received * MMF held*						
LU IF (t)	**0.002****	**0.002***	-0.003	-0.004		
	[0.047]	[0.078]	[0.197]	[0.146]		
LU IF (t-1)	0.001	0.002	**0.004***	0.006		
	[0.579]	[0.223]	[0.091]	[0.204]		
LU IF (t-2)		-0.002		0.000		
		[0.238]		[0.976]		
DE IF (t)	0.000	0.000	-0.007	-0.005		
	[0.874]	[0.972]	[0.419]	[0.514]		
DE IF (t-1)	**0.003***	**0.003***	0.002	0.003		
	[0.089]	[0.090]	[0.804]	[0.684]		
DE IF (t-2)		0.001		-0.010*		
		[0.560]		[0.084]		
NL PF (t)	0.006	0.006			0.005	0.005
	[0.171]	[0.167]			[0.123]	[0.131]
NL PF (t-1)	0.013	0.010			0.001	0.001
	[0.136]	[0.213]			[0.816]	[0.899]
NL PF (t-2)		**0.007*****				0.001
		[0.000]				[0.700]
ES IF (t)			**0.008***	**0.008***		
			[0.088]	[0.094]		
ES IF (t-1)			0.005	**0.006***		
			[0.126]	[0.096]		
ES IF (t-2)				-0.004		
				[0.416]		
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,530	15,257	14,945	14,672	2,980	2,905
R-squared	0.304	0.304	0.162	0.159	0.249	0.243

Notes: The table shows regression results of MMFs' inflows against the interactions between simultaneous and past VM flows received by investor groups and a dummy equal to one when the investor groups hold the MMF. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 11: Regression results for MMF outflows and VM flows posted flows - including leads (RE specification)

	Dependent variable: MMF outflows					
	Luxembourgish MMFs		French MMFs		Irish MMFs	
*Independent variables: VM flows posted * MMF held*						
LU IF (t)	**0.002****	**0.003****	**0.011*****	**0.012*****		
	[0.013]	[0.024]	[0.001]	[0.001]		
LU IF (t+1)	-0.000	-0.000	-0.000	0.001		
	[0.659]	[0.893]	[0.889]	[0.789]		
LU IF (t+2)		-0.001		-0.004		
		[0.409]		[0.399]		
DE IF (t)	0.002	0.002	**0.018***	0.018		
	[0.397]	[0.407]	[0.057]	[0.104]		
DE IF (t+1)	0.001	0.000	**0.012****	0.004		
	[0.516]	[0.947]	[0.018]	[0.470]		
DE IF (t+2)		0.001		0.016		
		[0.649]		[0.165]		
NL PF (t)	**0.010****	**0.010****			**0.010****	**0.011****
	[0.027]	[0.031]			[0.013]	[0.013]
NL PF (t+1)	0.000	-0.000			0.004	0.002
	[0.825]	[0.902]			[0.286]	[0.660]
NL PF (t+2)		0.000				0.003
		[0.723]				[0.313]
Fund RE	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,265	14,727	14,688	14,158	2,930	2,805
R-squared	0.069	0.07	0.086	0.095	0.071	0.077

Notes: The table shows regression results of MMFs' outflows against the interactions between simultaneous and future VM flows posted by investor groups and a dummy equal to one when the investor groups hold the MMF. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 12: Regression results for MMF inflows and VM flows received - including lags (RE specification)

	Dependent variable: MMF inflows					
	Luxembourgish MMFs		French MMFs		Irish MMFs	
*Independent variables: VM flows received * MMF held*						
LU IF (t)	**0.002****	**0.002***	-0.002	-0.002		
	[0.037]	[0.058]	[0.509]	[0.379]		
LU IF (t-1)	0.001	0.002	**0.005****	0.006		
	[0.598]	[0.249]	[0.027]	[0.180]		
LU IF (t-2)		-0.002		0.001		
		[0.231]		[0.723]		
DE IF (t)	0.001	0.000	-0.001	0.001		
	[0.627]	[0.757]	[0.919]	[0.939]		
DE IF (t-1)	**0.004***	**0.003***	0.008	0.009		
	[0.055]	[0.060]	[0.276]	[0.303]		
DE IF (t-2)		0.001		-0.003		
		[0.404]		[0.355]		
NL PF (t)	0.007	0.006			**0.005***	**0.005***
	[0.104]	[0.114]			[0.088]	[0.099]
NL PF (t-1)	0.014	0.011			0.001	0.001
	[0.105]	[0.192]			[0.742]	[0.850]
NL PF (t-2)		**0.007*****				0.002
		[0.000]				[0.632]
ES IF (t)			0.007	0.008		
			[0.108]	[0.103]		
ES IF (t-1)			0.003	0.005		
			[0.199]	[0.135]		
ES IF (t-2)				-0.006		
				[0.290]		
Fund RE	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,530	15,257	14,945	14,672	2,980	2,905
R-squared	0.103	0.105	0.024	0.023	0.037	0.047

Notes: The table shows regression results of MMFs' inflows against the interactions between simultaneous and past VM flows received by investor groups and a dummy equal to one when the investor groups hold the MMF. The time period used is from the beginning of February to the end of April 2020. Standard errors are clustered at fund level. P-values are in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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