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Asset Price Bubbles and Systemic Risk in Money Market Funds*

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Abstract

We investigate the systemic risk contribution of 3,500 Money Market Funds (MMFs) in normal periods and during asset price bubbles in the US from January 2004 to December 2022. Using state-of-the-art statistical techniques for bubble detection and granular fund-level data, we show that MMF characteristics significantly influence systemic risk. Large MMFs and government MMFs, which invest exclusively in US Treasury securities, are associated with reduced systemic risk, while prime MMFs contribute to higher systemic risk. MMFs denominated in US dollars but domiciled offshore exhibit no significant differences from their US-domiciled counterparts.

Keywords: Financial Crises, Financial Bubbles, Backward Supremum Augmented Dickey-Fuller Test, Systemic Risk Measures, Panel Data.

J.E.L. Classification: C23, G21, G15.

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1 Introduction

While financial crises can occur without a preceding asset price bubble, a significant body of literature has found that crises following a bubble tend to be severe (Borio & Lowe, 2002; Reinhart & Rogoff, 2008). In some cases, bubbles do not merely precede a crisis but directly cause it. However, the overall relationship is complex to disentangle and likely to depend on several factors that vary across time and space. Given the lasting scars financial crises leave on the real economy, it is unsurprising that research has sought to identify patterns that clarify the role of asset price bubbles and systemic risk.

The vast majority of this research, however, focuses on links between bubbles, systemic risk and the macroeconomy (Reinhart & Rogoff, 2008; Guerron-Quintana et al., 2023; Berger & Sedunov, 2024). While macroeconomic factors are undoubtedly important, the microeconomic determinants of the interaction between bubbles and systemic risk have received far less attention. A notable exception is Brunnermeier et al. (2020), who analyze the relationship between asset price bubbles and systemic risk using bank-level data. They highlight the role of bank characteristics, especially bank size, in the build-up of financial fragility, providing the first evidence that individual institutions increase systemic risk during asset price bubbles. In addition, Basse et al. (2021) examine the importance of dividend policy when testing for speculative bubbles in the S&P500 equity index using a long spanning data set from 1871 to 2014.

Banks are the cornerstone of the global financial system and rightly receive significant attention. However, non-bank financial intermediaries (NBFIs) have expanded considerably in recent years (Financial Stability Board (FSB), 2023; International Monetary Fund (IMF), 2023; Tian et al., 2024; Aldasoro et al., 2025; Acharya et al., 2026). Now accounting for nearly 50% of the global financial system, NBFIs have drawn increasing regulatory scrutiny worldwide. Despite their growth and rising importance, no study has examined their role in asset price bubble formation or their interaction with systemic risk measures. Given their growing influence, understanding NBFIs' contribution to systemic risk and financial stability is now paramount.

In this paper, we begin to fill this gap in the literature by focusing on Money Market Funds (MMFs), a core component of the non-bank sector. Several characteristics make MMFs relevant to our analysis. First, they are the most bank-like institution among NBFIs as they effectively guarantee the principal amount invested, much like bank deposits. Indeed, there is evidence that investors do treat MMFs as an alternative to bank deposits (Bouveret et al., 2022). Second, while some jurisdictions have imposed restrictions on MMFs, they remain less regulated than banks, particularly following the 2008 financial crisis. As a result, risks previously borne by banks may have shifted to MMFs, given their perceived substitutability for bank deposits. Third, MMFs have been a source of financial stress in several crises, including the 2008 financial meltdown and the 2020 COVID-19 turmoil, underscoring their importance to financial stability (Kacperczyk & Schnabl, 2013; Schmidt et al., 2016; La Spada, 2018). This paper contributes to the rapidly expanding literature on MMFs, particularly to the strand examining their risk-taking behavior (Baba et al., 2009; McCabe, 2010; Bengtsson, 2013; Chernenko & Sunderam, 2014; Hanson et al., 2015; Strahan & Tanyeri, 2015; Parlatore, 2016; Di Maggio & Kacperczyk, 2017; Li, 2021; Baghai et al., 2022; Lugo, 2021, 2023)[1].

[1]An interesting alternative framework is offered by Kopányi-Peuker and Weber (2021, 2024) who inves-

We begin our analysis by detecting and timing asset price bubbles in the U.S., using the Backward Supremum Augmented Dickey Fuller (BSADF) test on both the stock and real estate markets. We find that the S&P500 and the real estate markets experienced two main bubble periods each, with the only overlap occurring after the COVID-19 crisis. Next, we examine MMFs contribution to systemic risk and their interaction with asset price bubbles. Our primary systemic risk measure is $\Delta CoVaR$ (Adrian & Brunnermeier, 2016) though our results remain robust when using *Marginal Expected Shortfall* (MES) as the measure of systemic risk (Acharya et al., 2017). $\Delta CoVaR$ has a number of appealing features: first, it allows the generation of time-varying estimates of systemic risk contributions from individual MMFs to the entire financial system. Second, it is one of the best performing near-coincident indicators, as it captures potential spillovers and offers policymakers valuable insights about the systemic risk contribution of individual financial institutions (Arsov et al., 2013). Finally, $\Delta CoVaR$ serves as an early warning signal, highlighting both the potential systemic damages that may arise from MMFs distress and their vulnerability to systemic shocks (Zhang et al., 2015).

Given their systemic importance, we focus on MMFs denominated in US dollars. However, we do not limit our analysis to US-domiciled funds, as a significant portion of the US dollar-denominated assets that is managed offshore. Our full sample includes 3,586 MMFs over the period from January 2004 to December 2022. Since MMFs share many of the characteristics of banks, one might expect them to have a similar impact on systemic risk. This is only partially true. Our results show that, like banks, MMFs' systemic risk contributions

tigate the role of investor experience in the formation of asset price bubbles, and Luo et al. (2022) who examine the effect of fund managers' bubble-crash experience on their investment styles.

are significantly influenced by asset price bubbles. However, while MMFs' characteristics also play a crucial role, their effects on systemic risk differ from those observed in banks.

First, unlike banks, large MMFs generally reduce systemic risk in normal times, although this effect varies during bubble periods, when it may either amplify or mitigate systemic risk. In particular, a one-standard-deviation increase in MMFs' log asset size is associated with an 11.7 basis-point decrease in $\Delta CoVaR$, indicating a reduction in their contribution to global financial fragility. By contrast, during periods of equity booms, a one-standard-deviation increase in $\Delta Size$ implies a 5.68 basis-point increase in $\Delta CoVaR$, corresponding to higher systemic risk at the one-month horizon. Overall, these results suggest that MMF growth is generally benign outside bubble periods, but that policymakers should pay close attention to MMF expansion during exuberant market conditions, for instance by explicitly incorporating MMF growth into systemic risk monitoring frameworks.

Second, MMFs with more pronounced maturity mismatches are associated with lower systemic risk, highlighting their limited role in the transformation of credit. Third, riskier funds contribute more to systemic risk overall, but this effect weakens during bubble periods. Finally, USD-denominated MMFs managed offshore behave similarly to the US-domiciled, suggesting they are unlikely to act as a buffer during periods of stress. We also examine the relatively calm period identified by Baghai et al. (2022) and Fricke et al. (2024) and find that regulatory reforms introduced in the United States and Europe influenced MMFs characteristics. In particular, systemic risk for larger government MMFs decreased, reinforcing their role as a potential safe haven.

Our results are robust to several sensitivity checks, including the use of *MES* as an alternative measure of systemic risk; the inclusion of $\Delta CoVaR$ state variables in the estimations; considering the rolling window as an alternative estimation strategy for $\Delta CoVaR$; and excluding the observations during the COVID-19 time period.

The remainder of the paper is structured as follows: Section 2 provides an overview of the USD-denominated MMF industry. Section 3 describes the methodology, while Section 4 reports the empirical analysis. Section 5 discusses robustness tests, and Section 6 concludes.

2 Money market funds and financial stability

Since the 2008 financial crisis, NBFIs have significantly expanded their presence in the global financial system, reaching USD 238 trillion by the end of 2023 (FSB, 2023). This heterogeneous sector includes entities such as open-ended mutual funds, insurance companies, pension funds, special purpose vehicles, and others. While public authorities initially focused on strengthening banks' resilience due to their role in the crisis, efforts to assess and mitigate vulnerabilities in NBFIs gained momentum in subsequent years.

Shadow banking, the term commonly used to refer to non-bank financial institutions prior to 2018, denoted "*the system of credit intermediation involving entities and activities fully or partially outside the regular banking system*" (FSB, 2013, p. ii). The concept focuses on credit intermediation activities conducted by non-bank entities that closely resemble traditional banking functions. To support financial stability analysis, the Financial Stability Board classifies shadow banking activities into five economic functions: (i) collective investment vehicles with features susceptible to runs; (ii) lending activities dependent on short-term funding; (iii) market intermediation reliant on short-term funding; (iv) facilitation of credit intermediation; and (v) securitisation-based credit intermediation.

Interestingly, MMFs were excluded from this initial framework. There was full agreement among policymakers that MMFs performed the bank-like activities described in the first economic function and posed systemic risks. The biggest difference being that MMFs are not leveraged. As a result, the International Organization of Securities Commissions (IOSCO) began work to mitigate these risks in earnest (IOSCO, 2012).

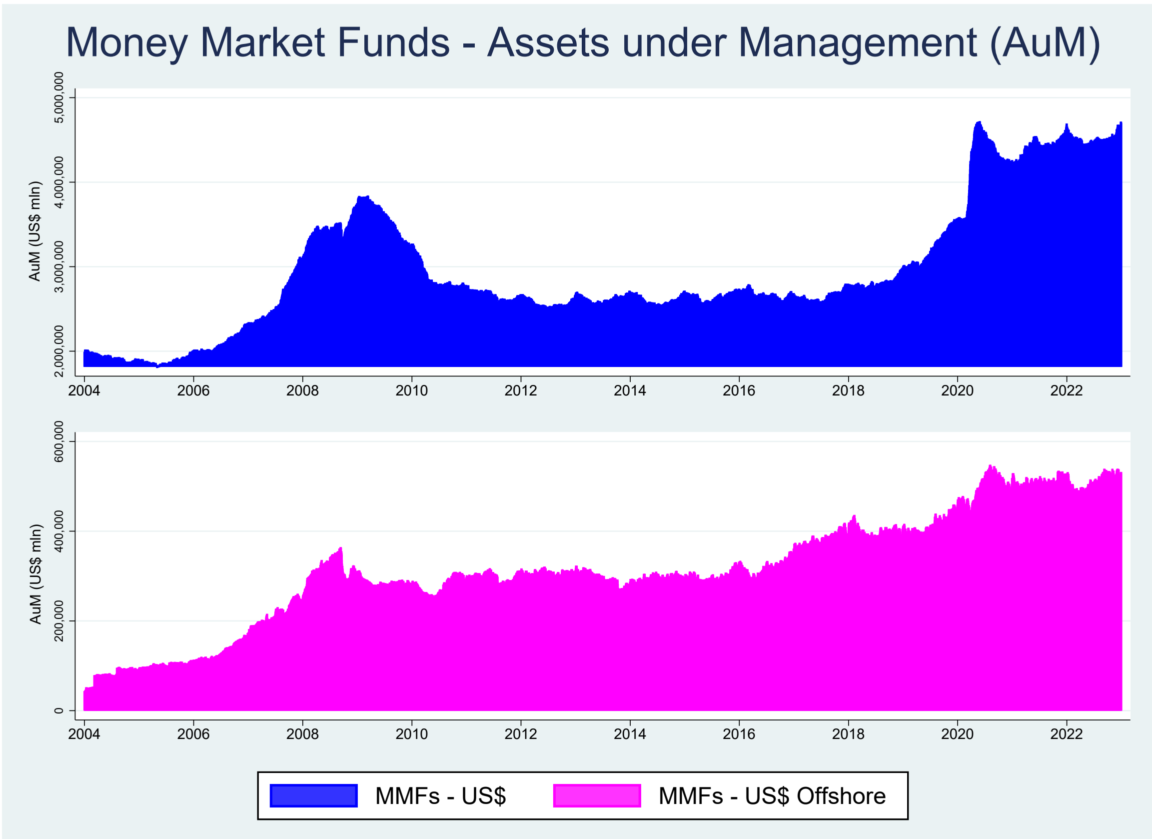
MMFs are open-ended mutual funds designed to offer returns aligned with money market rates. By channeling investments into markets, MMFs provide critical financing to governments, local authorities, and financial and non-financial corporates. MMFs originated in the United States in the 1970s when Regulation Q capped the interest that banks could offer on deposits. MMFs filled this gap by offering higher returns for comparable risks. Since then, MMFs have occupied a space between banking and capital markets. For example, in their early decades, MMFs issued checkbooks to investors, underscoring the deposit-like nature of their liabilities. While checkbooks are no longer offered, MMFs still resemble bank deposits, and MMF shares are often considered cash equivalents for accounting purposes[2].

Overall there are more than USD 9 trillion invested in MMFs globally (Bouveret et al., 2022). Of these, slightly less than two thirds are denominated in US dollars. MMFs denominated in US dollars are unsurprisingly mostly domiciled in the US (USD 4.7 trillion at the end of 2022) as they are used by domestic investors to manage their cash needs (see Figure 1). However, there is a substantial market for USD-denominated MMFs outside of the US (USD 590bn at the end of 2022), the overwhelming majority of which are based in the European Union and serve the need of European issuers and investors. The former can

[2]International Accounting Standard 7 suggests that MMF units do not strictly qualify as cash equivalents, as they are equity instruments with no maturity. However, they can be considered *in-substance* cash equivalents since the cash receivable is known at the time of investment.

raise funds in US dollars from both European and US investors; the latter can get exposure to dollar-denominated money markets.

Figure 1: Money Market Funds (MMFs) US$ and US$ Offshore - Assets under Management (AuM - daily).



Source: Authors elaboration on iMonyNet database.

MMFs are not a homogeneous category. In the US, they can be divided into three main groups: *government* MMFs, which invest exclusively in short-term debt issued by the US government (including federal agencies) and repurchase agreements collateralised by such securities, representing the safest category with essentially no credit risk; *prime* MMFs, which invest in instruments issued by both public and private entities (e.g., commercial paper and negotiable certificates of deposit), making them the riskiest category; and *tax-exempt* MMFs, which invest in short-term state, local government, and municipal securities.

In Europe, for USD-denominated funds, while the nomenclature differs slightly, the biggest difference is that there is no *tax-exempt* category, but both *government* and *prime* MMFs exist. These funds invest either in US government securities or USD-denominated paper issued by European and US entities.

Government MMFs in both the US and Europe maintain a stable net asset value (NAV), meaning one unit remains constant at one dollar, regardless of fluctuations in the value of underlying assets. Except for rare instances where a fund *breaks the buck*, one unit can typically be redeemed for cash within a day. The situation for *prime* funds is more complex. In the US, *prime* funds offered to retail investors can also maintain a stable NAV, while those offered to institutional investors have a floating NAV. However, fluctuations in the NAV are usually minimal, so one unit is effectively worth a dollar. In Europe, *prime* funds often maintain a low-volatility NAV. They can offer a stable NAV but must switch to a floating NAV if the mark-to-market value of their assets deviates by more than 20 basis points from the stable NAV - a rare occurrence in practice.

Recent financial history has highlighted the fragility of MMFs during periods of stress. During the 2009 financial crisis, a major MMF *broke the buck* (i.e., failed to trade at par) due to losses on Lehman Brothers' paper, reflecting their higher risk-taking (Kacperczyk & Schnabl, 2013). More recently, the market turmoil triggered by COVID-19 in March 2020 caused significant outflows from *prime* MMFs, which only ceased following substantial public intervention (FSB, 2020). Fragility in MMFs has also been observed in other jurisdictions, such as Japan and South Africa[3].

[3]Several Japanese MMFs *broke the buck* during the Enron scandal in 2001, while a similar event occurred in South Africa in 2014 following the collapse of a bank.

Policymakers have identified three main vulnerabilities of MMFs (FSB, 2021), arising from the interaction of their features. First, MMFs engage in liquidity transformation, as their daily redemption terms are misaligned with the trading cycle of their underlying assets. This is particularly concerning for *prime* funds, whose assets are infrequently traded. Consequently, investors may prefer selling MMFs shares over other assets, especially during periods of low market liquidity. Second, MMFs are widely used as a cash management tool. Investors expect MMFs to maintain their cash-like characteristics under all circumstances. This exposes MMFs to the risk of sudden, large-scale redemption, for example, when investors face increased margin calls on derivatives positions. Additionally, a loss of confidence in a fund's ability to maintain its value can trigger disruptive runs (Schmidt et al., 2016). Finally, MMFs are exposed to credit risk, which became particularly evident during the 2008 financial crisis following the default of Lehman Brothers, and which can undermine their ability to maintain a stable net asset value (NAV). Across all three vulnerabilities, exposure to less liquid and longer-maturity assets amplifies the overall riskiness of MMFs.

The risk transmission channels for MMFs therefore display both similarities and differences compared with those of banks. Starting with the differences, MMFs are not leveraged entities and, as such, their solvency is not directly threatened by losses on their assets. Moreover, they do not have creditors who would be directly affected if a fund came under stress. MMFs are also not directly exposed to one another, since they do not purchase each other's shares and do not maintain credit relationships among themselves. The most likely channel through which MMFs can affect the financial system as a whole is their role in short-term funding markets. If a large subset of MMFs were to experience redemption pressure from investors, they might be unable to roll over their purchases of commercial paper and certificates of deposit and, *in extremis*, could be forced to liquidate existing holdings. This could lead to a significant reduction in activity in short-term funding markets, with knock-on effects on the ability of banks and corporations to finance their operations.

However, MMFs and banks also share important similarities. First, the effects on short-term funding markets described above resemble the credit contraction effects typically associated with banking crises. Admittedly, banks provide credit to a broader range of borrowers - including households and smaller corporations - and the maturity of such lending is often considerably longer than that associated with MMFs. Nevertheless, the macroeconomic consequences can be similar. In both cases, the overall amount of credit available to borrowers may decline substantially, generating spillover effects on real economic activity. A second similarity arises from the fact that both banks and MMFs may benefit from explicit or implicit support from public authorities when facing significant distress. Financial history provides numerous examples of governments intervening to rescue or support banks. Comparable interventions, while less frequent, have also occurred in the case of MMFs. For example, in March 2020, when prime MMFs experienced substantial redemption pressure, the Federal Reserve established the Money Market Mutual Fund Liquidity Facility (MMLF). This facility enabled financial institutions to obtain loans from the Federal Reserve in order to purchase assets from MMFs.

Overall, the activities of banks and MMFs exhibit important functional similarities, even though their business models and regulatory frameworks differ. Hence, notwithstanding certain methodological implications discussed below, it is natural to analyse MMFs from a systemic risk perspective.

3 Methodology

3.1 Defining and detecting asset prices bubbles

The first building block of our methodology requires identifying asset price bubbles, episodes in which asset prices experience dramatic increases followed by significant reductions (Blanchard, 1979; Diba & Grossman, 1988; Evans, 1991; Lee & Phillips, 2016; Chen et al., 2023). A number of technical definitions have been proposed in the literature, but they all underline that the main characteristic of bubbles is the deviation of the price of an asset from its fundamental value. This deviation could be the result of a number of underlying reasons. Brunnermeier (2009) highlights that a potential explanation is the belief of current owners that they will be able to resell the asset for an even higher value, while Shiller (2015) focuses on the role of buyers' behavior rather than fundamental information about value. In the history of financial markets and economic development, bubbles are fairly common occurrences and are well documented in the literature (Quinn & Turner, 2020; Vogel, 2022; Barlevy, 2025). But while the identification of asset prices bubbles is relatively straightforward after their occurrence, it is considerably more difficult to identify bubbles in *real time*. From a practical perspective, as the fundamental value of many assets is almost always not observable, it is difficult to assess if large price changes are justified by changes in fundamentals while the trend is upward. In their seminal analysis Reinhart & Rogoff (2008) always refer to large increases in asset prices rather than bubbles, although some authors argue that in a fully efficient market, bubbles should not exist (Fama, 2014).

3.2 Timing asset bubbles

A number of statistical procedures have been developed to detect episodes of exuberance and explosive behavior in financial time series. Tests that use the full amount of data available date back decades (see Gurkaynak (2008) and Skrobotov (2023) for a review), but substantial advances have been made in recent years. These new tests are not simple ex-post rationalisations of the observed behavior of time series, but tools that rely only on information available up to the point in which the test is carried out. These tools can therefore be used to date when the explosive behavior started to manifest. An important contribution in this respect is the work of Phillips et al. (2011), which was subsequently expanded in Phillips et al. (2015a,b) to accommodate the potential presence of multiple bubbles in a time series.

In these papers, the authors propose a recursive test procedure based on a right-tailed unit root test to identify bubbles. The procedure involves the following steps. First, conduct an Augmented Dickey Fuller (ADF) regression to test the null hypothesis of a unit root against the alternative of explosive behavior. Second, compute the Supremum Augmented Dickey Fuller (SADF) statistics using a forward-expanding sample and test whether it exceeds the critical value on the right-tail. Similar to the standard ADF test, the rejection of the unit root hypothesis in the SADF test indicates exuberant behavior. However, in contrast to the standard ADF test, the alternative hypothesis of the SADF test suggests exuberance dynamics in specific parts of the sample. Finally, compute the Generalized SADF (GSADF) (Phillips et al., 2015a,b), which has the same alternative hypothesis as the SADF but which covers a larger number of sub samples.

In comparison to the SADF, the GSADF test shows more flexibility on the estimation window and it is consistent with multiple bubble periods, while the SADF test is consistent only with a single episode. If the null hypothesis of a unit root is rejected, then the SADF and the GSADF tests can provide a sequence of episodes of exuberance. The inference for the ADF, SADF and GSADF statistics requires critical values computed using Monte Carlo simulations[4]. Consequently, Phillips et al. (2015a,b) introduce the Backward Supremum Augmented Dickey Fuller (BSADF) statistic, which allows identifying episodes of multiple bubbles more effectively. Appendix A describes the estimation approach.

In our empirical analysis, we employ the BSADF approach to identify multiple bubble episodes in the S&P 500 and Case-Shiller index, the latter deflated using the Personal Consumption Expenditures (PCE) index (Pavlidis et al., 2016), for stock and real estate markets, respectively. We then construct four binary variables to indicate episodes where a real estate or stock market bubble emerges or collapses (*Section 4.1*).

3.3 Quantifying systemic risk at the MMF level

Benoit et al. (2017, p. 110) identify two main strands of research on systemic risk: the "*source-specific approach*" and the "*global approach*". Within the latter, several global measures of systemic risk have been proposed over the past decade, including the $\Delta CoVaR$ of Adrian & Brunnermeier (2016), the *SRISK* of Brownlees & Engle (2016), and the Marginal Expected Shortfall (*MES*) of Acharya et al. (2017). In particular, $\Delta CoVaR$ is particularly

[4]The finite sample critical values for 90%, 95% and 99% confidence levels are obtained from Monte Carlo simulations with 2,000 replications (see Phillips et al., 2015a,b and Vasilopoulos et al., 2022). The window size is given by $r_0 = \left(0.01 + 1.8/\sqrt{T}\right)$ as recommended by Phillips et al. (2015a,b). For both S&P 500 and Case-Shiller index, the time period is 2001:1 - 2022:4 (monthly frequency) and $T = 264$ observations.

well suited for assessing the systemic risk contribution of financial institutions. Its ability to capture changes in the financial system's Value at Risk (VaR), conditional on a financial institution being in distress, makes it a powerful indicator for studying how systemic risk propagates through the financial system. Moreover, $\Delta CoVaR$ provides time-varying estimates of systemic risk contributions of individual financial institutions to the financial system as a whole, and ranks among the best performing near-coincident indicators, as it captures potential spillovers and offers policymakers valuable insights into the systemic risk contributions of individual financial institutions (Arsov et al., 2013). Finally, $\Delta CoVaR$ provides early warning signals concerning both the potential systemic damages that may arise from MMFs distress and their vulnerability to the onset of a systemic shock (Zhang et al., 2015).

However, a methodological challenge arises when applying the $\Delta CoVaR$ framework to MMFs. Unlike banks, MMFs do not have publicly traded equity but distribute their performance through yields, and they seek to maintain a stable NAV at $1.00 as required under Rule 2a-7. As a consequence, equity returns - the standard input in the original $\Delta CoVaR$ - are not observable for MMFs. To address this limitation, we follow the empirical literature on MMFs and we use daily gross yields as the main proxy for fund-level returns, thus making $\Delta CoVaR$ well-suited to capture risk spillovers both within individual MMFs and between MMFs and the financial system as a whole.

We now outline the $\Delta CoVaR$ methodology as adapted to the MMF setting. The *CoVaR* is an indicator of systemic risk defined as the *VaR* for the entire financial system, conditional on another financial institution, exceeding its specific *VaR*, the threshold loss that will not be exceeded at a given level of confidence. The $CoVaR_q^{system|C(X^i)}$ is defined by the *q-th* quantile of the conditional probability distribution:

$$Prob(X^{system|C(X^i)} \leq CoVaR_q^{system|C(X^i)}) = q\% \tag{1}$$

In the original framework of Adrian & Brunnermeier (2016), X^i is the market-valued asset return of institution i, while X^{system} is the return of the financial system, computed as the average of the X^i's weighted by the lagged market value assets of the institutions. In our adaptation to MMFs, X^i corresponds to the *daily gross yield* of MMF i, which we use as a proxy for fund-level returns. The choice is motivated by the following considerations. First, *economic meaning*: the gross yield captures the economic return generated by MMFs and distributed to investors, reflecting changes in portfolio valuation and interest rate conditions. Second, *risk transmission channel*: the gross yield incorporates exposure to market liquidity, credit, and rate risks, the same channels through which systemic risk materializes in the MMF sector (this is consistent with the notion of systemic risk underlined by $\Delta CoVaR$). Third: *consistency with existing empirical literature*: several influential papers use MMF yields as the canonical measure of MMF performance and risk sensitivity, such as Duygan-Bump et al. (2013), Kacperczyk & Schnabl (2013), La Spada (2018), Cipriani & La Spada (2020), where yields are treated as the key indicator of MMF performance and risk sensitivity.

It is worth noticing that daily gross yields should not be interpreted as a direct real-time measure of acute MMF distress. Rather, they should be viewed as a high-frequency proxy for time-varying portfolio vulnerability. This interpretation is consistent with the MMF literature, which shows that higher gross yields are informative about fund risk-taking and predictive of adverse outcomes during periods of stress (McCabe, 2010; Kacperczyk &

Schnabl, 2013). At the same time, we acknowledge that gross yields are backward-looking and mechanically smooth measures, and therefore do not capture in real time shadow NAV deviations, redemption pressures, or fire-sale dynamics. Accordingly, the $\Delta CoVaR$ estimates should be interpreted as linking systemic stress to MMF vulnerability, rather than to acute realised MMF distress of the type typically observed in the banking sector (McCabe, 2010; Kacperczyk & Schnabl, 2013)[5].

There are several possible approaches to defining the appropriate system-wide variable X^{system}. One possibility would be to employ an aggregate measure of MMF returns. However, such a measure would fail to account for the interconnectedness between MMFs and the broader financial system, including their links with banks, dealers, and short-term funding markets.

Our baseline measure is therefore the S&P 500 equity index, which offers several advantages. First, it provides a broad representation of U.S. financial conditions, reflecting aggregate market dynamics that are highly relevant for U.S. MMFs, whose portfolios mainly consist of short-term instruments issued by U.S. financial and corporate entities. Second, the index adjusts instantaneously to episodes of market-wide stress, thereby providing a timely indicator of the systemic environment in which MMFs operate. Third, it is conceptually well aligned with the ΔCoVaR framework: although MMFs do not issue publicly traded equity, systemic risk in the MMF sector is transmitted through market-wide channels that are likely to be reflected in aggregate equity returns.

Nevertheless, recognising that MMFs play a particularly important role in short-term

[5]To assess the informational content of gross yields, we estimate predictive panel regressions in which future changes in monthly $\Delta CoVaR$ over the next 12, 14, 16, 16, and 18 months are sensitive to lagged gross yields, controlling for the current level of $\Delta CoVaR$ and MMFs' predictors. The results are available upon request.

funding markets, and that their systemic effects may be especially pronounced in this segment, we also conduct a robustness analysis in which the X^{system} variable is defined as the spread between commercial paper yields and the federal funds rate.

We measure the contribution of each MMF to systemic risk by the Δ*CoVaR*, namely the difference between *CoVaR* conditional on the MMF being in distress and *CoVaR* in the median state of the MMF. Formally, the $\Delta CoVaR_q^i$, i.e., the contribution to systemic risk of MMF i during the q quartile, is defined as follows:

$$\Delta CoVaR_q^i = CoVaR_q^i - CoVaR_{50}^i = \hat{\beta}_q^i (VaR_q^i - VaR_{50}^i) \tag{2}$$

where the q is set to be 5%, so that $CoVaR^i$ identifies the system losses predicted on the 5% loss of MMF i, while $\Delta CoVaR^i$ identifies the deterioration in the system losses, when the MMF i moves from its median state to its 5% worst scenario. *VaRs* and *CoVaRs* estimations are obtained using quantile regressions (q) (Koenker & Bassett, 1978).

To obtain the time-varying VaR_t and $CoVaR_t$, we estimate the following quantile regressions on daily data:

$$X_t^i = \alpha_q^i + \gamma_q^i \mathbf{M}_{t-1} + \varepsilon_{q,t}^i \tag{3a}$$

$$X_t^{system|i} = \alpha_q^{system|i} + \beta_q^{system|i} X_t^i + \gamma_q^{system|i} \mathbf{M}_{t-1} + \varepsilon_{q,t}^{system|i} \tag{3b}$$

where $\mathbf{M}_t$ includes the set of US state variables. We then use the predicted values from these regressions to obtain:

$$VaR^i_{q,t} = \hat{\alpha}^i_q + \hat{\gamma}^i_q \mathbf{M}_{t-1} \tag{4a}$$

$$CoVaR^i_{q,t} = \hat{\alpha}^{system|i}_q + \hat{\beta}^{system|i}_q VaR^i_{q,t} + \hat{\gamma}^{system|i}_q \mathbf{M}_{t-1} \tag{4b}$$

Regarding the US financial system, we consider the following daily state variables: *Liquidity Spread*, the difference between the 3-month US repo rate and the 3- month US T-bill yield; *Credit Spread*, the difference between the 10-year Moody's seasoned Baa corporate bond and the 10-year US Treasury bond; *Yield slope*, the first difference curve (yield spread between the US Treasury benchmark 10-year bonds and the US 3-month T-bill); *T-Bill change*, the first difference of the US Treasury bill secondary market 3-month rate; *VIX*, the volatility index of the Chicago Board Options Exchange (CBOE)[6].

Table 1 reports the 1-daily gross yields, the system variables, and the $\Delta CoVaR$ state variables. We notice that the daily gross yields report time-series and cross-section variation, with higher volatility for *prime* MMFs rather than *government* MMFs, in line with their greater exposure to credit and liquidity risk. $\Delta CoVaR$ shows slightly higher volatility for Prime MMFs rather than Government MMFs, supporting the validity of the proxy[7].

Figures 2 and 3 report the $\Delta CoVaR$ trend for MMFs US$ and MMFs US Offshore. The figures show that the $\Delta CoVaR$ of US and offshore MMFs moves together over the period of analysis. The contribution to systemic risk by all US MMFs (Figures 2 and 3, black

[6]Table B1 in Appendix B reports the correlation matrix between $\Delta CoVaR$ and the full set of US state variables.

[7]We also compute an additional summary statistic, which indicates that although the unconditional difference in the average $\Delta CoVaR$ between *prime* and *government* MMFs is small, it increases during stress periods. In particular, $\Delta CoVaR$ is 0.09 for *prime* MMFs and 0.06 for *government* MMFs during the 2008-2009 global financial crisis, compared with 0.11 and 0.09, respectively, during the COVID-19 and post-pandemic recovery period. The results are available upon request.

Table 1: Summary statistics for MMF returns, system conditions, and $\Delta CoVaR$ - daily frequency.

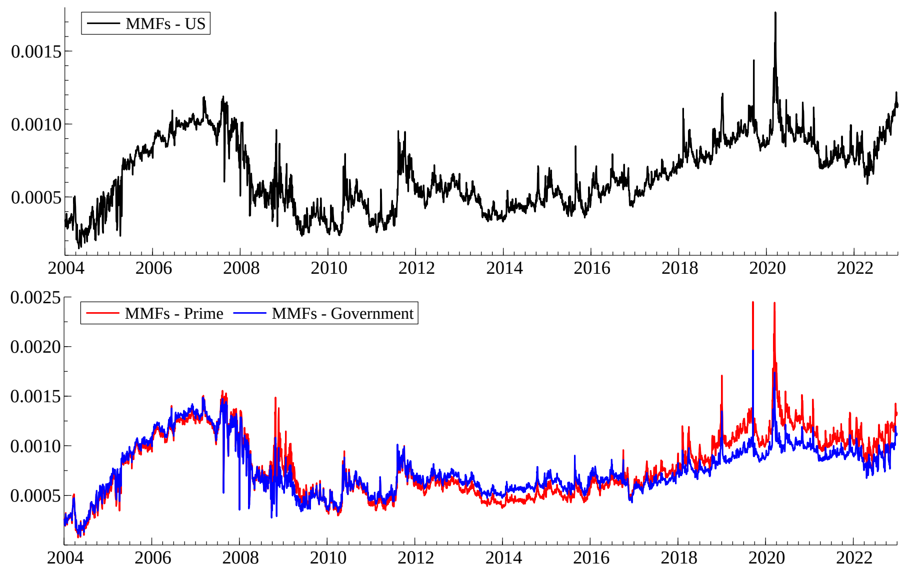
Variable	Mean	Std. Dev.	5^{th} percentile	Median	95^{th} percentile
Panel A: MMF returns (1-day gross yield)					
X_t^i: 1-day gross yield (%)	1.21	1.84	0.01	0.70	4.07
X_t^i: 1-day gross yield (%) - MMFs Prime	1.28	1.65	0.01	0.37	4.85
X_t^i: 1-day gross yield (%) - MMFs Government	1.03	1.43	0.00	0.24	4.51
Panel B: System variables					
X_t^{system}: S&P500 (%)	0.03	1.20	-1.80	0.07	1.65
Liquidity Spread	0.11	0.33	-0.14	0.03	0.74
T-Bill change	0.00	0.19	-0.13	0.00	0.13
VIX	19.38	8.79	11.08	16.92	34.69
Yield Slope	1.69	1.08	-0.12	1.71	3.43
Credit Spread	2.53	0.76	1.67	2.38	3.51
Panel C: $\Delta CoVaR$ estimates					
$\Delta CoVaR$ - (daily %)	0.07	0.02	0.03	0.06	0.10
$\Delta CoVaR$ - (daily %) - MMFs Prime	0.08	0.03	0.03	0.07	0.11
$\Delta CoVaR$ - (daily %) - MMFs Government	0.07	0.02	0.04	0.07	0.09

The table reports summary statistics (mean, standard deviation, 5^{th} percentile, median, and 95^{th} percentile) for the variables that enter in the $\Delta CoVaR$ computation at the daily frequency. Panel A reports 1-day gross yields (%) for the full sample of MMFs and separately for *prime* and *government* MMFs. Panel B shows system variables, *Liquidity Spread*, the difference between the 3-month US repo rate and the 3- month US T-bill yield; *T-Bill change*, the first difference of the US Treasury bill secondary market 3-month rate; *VIX*, the volatility index of the Chicago Board Options Exchange (CBOE); *Yield slope*, the first difference curve (yield spread between the US Treasury benchmark 10-year bonds and the US 3-month T-bill); *Credit Spread*, the difference between the 10-year Moody's seasoned Baa corporate bond and the 10-year US Treasury bond. Panel C reports daily $\Delta CoVaR$ estimates (daily %) for the overall MMF sector and for *prime* and *government* MMFs.

lines) started increasing before the onset of the 2008-2009 global financial crisis and during systemic events that occurred from September 2008 onwards. In addition to the Lehman bankruptcy and the rescue of the American International Group (AIG), one of the most notable fact is the *breaking of the buck* (i.e., the value of the fund going below $1 per share) by the Reserve Primary Fund in September 2008. This occurred due to exposure to Lehman Brothers' debt. In response to the crisis in the money market sector, the U.S. Treasury and the Federal Reserve intervened to stabilize the financial markets. Systemic events of 2008 also prompted regulatory reforms to enhance the resilience and the stability of MMFs. The Treasury established the Temporary Guarantee Program for Money Market Funds, providing a temporary guarantee to prevent runs on MMFs.

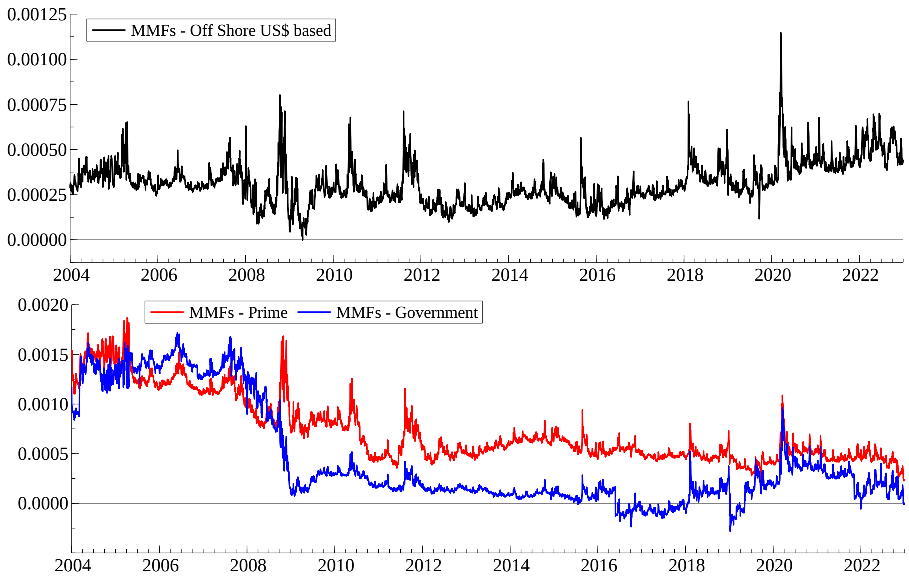
Monetary policy and a broad range of central bank activities initially alleviated issues

Figure 2: $\Delta CoVaR$ (daily) - US$ MMFs.



Source: Authors elaboration.

Figure 3: $\Delta CoVaR$ (daily) - US Off Shore MMFs.



Source: Authors elaboration.

with the two funding channels, including the interbank and wholesale funding markets (which had dried up during the summer of 2008). The system was then stable for a number of years, but instability resurfaced with full force only during the spread of COVID-19 pandemic, during which the mean of $\Delta CoVaR$ increased dramatically. The heightened market volatility and economic uncertainty likely prompted investors to prioritize liquidity. Overall, MMFs experienced substantial inflows, but investors rotated out of *prime*, which experienced large outflows, and into *government* funds.

Figures 2 and 3 also report the $\Delta CoVaR$ for *prime* (red line) and *government* (blue line), respectively. The measure for *prime* MMFs consistently remains higher throughout the entire period, with a notable increase during the pandemic, in line with the large outflows that these funds experienced. Indeed, *prime* MMFs are generally riskier than *government* MMFs due to their broader range of securities, including those issued by private entities. This increased risk encompasses credit risk associated with the issuers of the securities.

3.4 MMF predictors as determinants of $\Delta CoVaR$

In this section, we move onto determining the contribution of MMFs to systemic risk as well as their interaction with periods of stock and real estate bubbles using $\Delta CoVaR$ (Adrian & Brunnermeier, 2016) as our systemic risk measure. To align with the time frequency of the MMFs predictors, which are available only at the monthly level, the daily estimates of $\Delta CoVaR$ are aggregated by month through summation, following López-Espinosa et al. (2012), Adrian & Brunnermeier (2016), and Brunnermeier et al. (2020). We begin with a basic regression linking the characteristics of MMFs to systemic risk, controlling for the macroeconomic environment as follows:

$$\Delta CoVaR_{i,t} = \alpha_i + \beta_1 * MMFs\ Char._{\cdot i,t-1} + \lambda_1 * Macro_{t-1} + \\ [or\ \ \lambda_2 * \Delta CoVaR\ Macro_{t-1}\ or\ Time\ Dummies_t] + \varepsilon_{i,t} \tag{5}$$

where $MMFs\ Char._{\cdot i,t-1}$ contains the following MMF-specific predictors: [i] *Size* - indicates the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions) for MMF i at month *t-1.* [ii] *Weighted average maturity* (*Wam*) indicates the asset-weighted time (in days) until the securities in the portfolio mature for MMF i at month *t-1.* [iii] *Weighted average life* (*Wal*) is the weighted average life (in days), for MMF i at month *t-1*, based on a security's stated final maturity date or, when relevant, the date of the next demand feature when the fund may receive payment of principal and interest (such as a put feature); *Wal* reflects how a portfolio would react to deteriorating credit (e.g., widening spreads) or tightening liquidity conditions. [iv] $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF i at month *t-1*, included in accordance of the extant literature such as Jordà et al. (2015b), Brunnermeier & Schnabel (2016), and Brunnermeier et al. (2020). As macroeconomic controls, we consider: [v] ΔGDP as the monthly growth rate of real GDP, [vi] ΔCPI is the monthly percentage change in the US Consumer Price Index, [vii] *10-year Government Bond* refers to the monthly rate of 10-year Government Bond, [viii] *Investment-to-GDP* as the monthly ratio between investment and real GDP[8]. We also control for market conditions by using the US [ix] *Money Market MCI* indicator developed by Aldasoro et al. (2022).

[8]Bank and macroeconomic variables are stationary. The full set of results of the Im et al. (2003) and Pesaran (2007) panel unit root tests is not reported but available upon request.

We then analyse whether the effects change in bubble periods, and include in our regression the four binary variables indicating booms and busts in real estate and stock markets (I_t^{Bubble}) at time t, and their interaction with the MMF characteristics as described in Equation (6) below:

$$\Delta CoVaR_{i,t} = \alpha_i + \beta_1 * I_t^{Bubble} + \beta_2 * MMFs\ Char._{i,t-1} + \beta_3 * I_t^{Bubble} * MMFs\ Char._{i,t-1} + \lambda_1 * Macro_{t-1}\ [or\ \ \lambda_2 * \Delta CoVaR\ Macro_{t-1}\ or\ Time\ Dummies_t] + \varepsilon_{i,t} \tag{6}$$

Table 2 provides summary statistics for the $\Delta CoVaR$, MMFs characteristics, macroeconomic variables and $\Delta CoVaR$ macro variables. The frequency of $\Delta CoVaR$ is monthly. The mean of $\Delta CoVaR$ equals 1.32%, which implies that, on average, distress at one MMF is associated with an increase in the conditional VaR of the financial system by 1.32 percentage points per month. By splitting the sample by MMFs categories, *prime* MMFs report a mean size of 11,649 (monthly $mils), while *government* MMFs are larger on average, with a mean size of 16,605 (monthly $mils). *Prime* MMFs show slightly higher *Wam* (38.71 days), than *government* MMFs (36.07 days). In contrast, *government* MMFs report longer *Wal* on average (72.75 days), compared to *prime* MMFs (60.28 days). Macroeconomic variables report wide variation over the sample period. In particular, ΔGDP ranges from -38.90 (5^th percentile) to 51.40 (95^th percentile), while ΔCPI varies between -0.002 and 0.007. The *10-year Government Bond* ranges from 1.26 to 4.72, the *Investment-to-GDP* from 6.03 to 7.83, and the *Money Market MCI* from -0.55 to 1.88. The $\Delta CoVaR$ state variables similarly span different financial conditions: the *Liquidity Spread* ranges from -0.12 to 0.59, *T-Bill* *change* from -0.20 to 0.15, and the *VIX* from 10.85 to 34.74. In addition, the *Yield Slope* varies between -0.12 and 3.55, and the *Credit Spread* between 1.67 and 3.52.

Table 2: Descriptive statistics.

Variable	Mean	Std. Dev.	5^{th} percentile	Median	95^{th} percentile
Dependent variable					
ΔCoVaR (monthly %)	1.32	1.75	-1.92	1.40	4.01
MMFs characteristics					
Size (monthly $mils)	11,592.68	24,153.26	109.10	2,572.40	54,163.40
Size (ln)	7.83	1.95	4.69	7.85	10.90
Wam (in days)	34.94	14.27	9.00	36.00	56.00
Wam (ln)	3.42	0.61	2.20	3.58	4.03
Wal (in days)	60.03	28.38	13.00	58.00	107.00
Wal (ln)	3.93	0.67	2.56	4.06	4.67
ΔSize (%)	0.04	1.42	-1.13	-0.01	0.85
Prime - MMFs characteristics					
Size (monthly $mils)	11,649.03	19,723.39	157.10	3,698.90	49,633.70
Size (ln)	8.12	1.83	5.06	8.22	10.81
Wam (in days)	38.71	13.48	15.00	40.00	58.00
Wam (ln)	3.56	0.51	2.71	3.69	4.06
Wal (in days)	60.28	22.03	20.00	60.00	95.00
Wal (ln)	3.99	0.57	3.00	4.09	4.55
ΔSize (%)	0.06	1.26	-0.78	-0.02	0.79
Government - MMFs characteristics					
Size (monthly $mils)	16,605.33	30,895.94	164.90	4,760.50	79,843.10
Size (ln)	8.32	1.91	5.11	8.47	11.29
Wam (in days)	36.07	14.36	9.00	38.00	56.00
Wam (ln)	3.44	0.67	2.20	3.64	4.03
Wal (in days)	72.75	25.91	29.00	74.00	111.00
Wal (ln)	4.20	0.50	3.37	4.30	4.71
ΔSize (%)	0.14	1.21	-0.64	0.04	0.94
Macroeconomic variables					
ΔGDP	16.11	48.85	-38.90	19.80	51.40
ΔCPI	0.002	0.003	-0.002	0.002	0.007
10-year Government Bond	2.86	1.12	1.26	2.71	4.72
Investment-to-GDP	6.99	0.49	6.03	7.00	7.83
Money Market MCI	0.06	1.05	-0.55	-0.29	1.88
ΔCoVaR macro variables					
Liquidity Spread	0.11	0.26	-0.12	0.05	0.59
T-Bill change	0.02	0.19	-0.20	0.00	0.15
VIX	19.23	8.78	10.85	16.50	34.74
Yield Slope	1.63	1.06	-0.12	1.63	3.35
Credit Spread	2.52	0.78	1.67	2.34	3.52

The table reports the mean, standard deviation, 5^{th} percentile, median, and 95^{th} percentile, respectively, for ΔCoVaR, and MMF-specific predictors: *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions) for MMF; *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature; *Weighted average life* (Wal) is the weighted average life (in days), based on a security's stated final maturity date or, when relevant, the date of the next demand feature when the fund may receive payment of principal and interest (such as a put feature). *Wal* reflects how a portfolio would react to deteriorating credit (widening spreads) or tightening liquidity conditions. $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. As $\Delta CoVaR$ controls, we consider: *Liquidity Spread*, the difference between the 3-month US repo rate and the 3- month US T-bill yield; *T-Bill change*, the first difference of the US Treasury bill secondary market 3-month rate; *VIX*, the volatility index of the Chicago Board Options Exchange (CBOE); *Yield slope*, the first difference curve (yield spread between the US Treasury benchmark 10-year bonds and the US 3-month T-bill); *Credit Spread*, the difference between the 10-year Moody's seasoned Baa corporate bond and the 10-year US Treasury bond. The MMFs variables enter the regressions winsorized at the 1% and 99% levels and we apply cubic spline interpolations to obtain monthly observations.

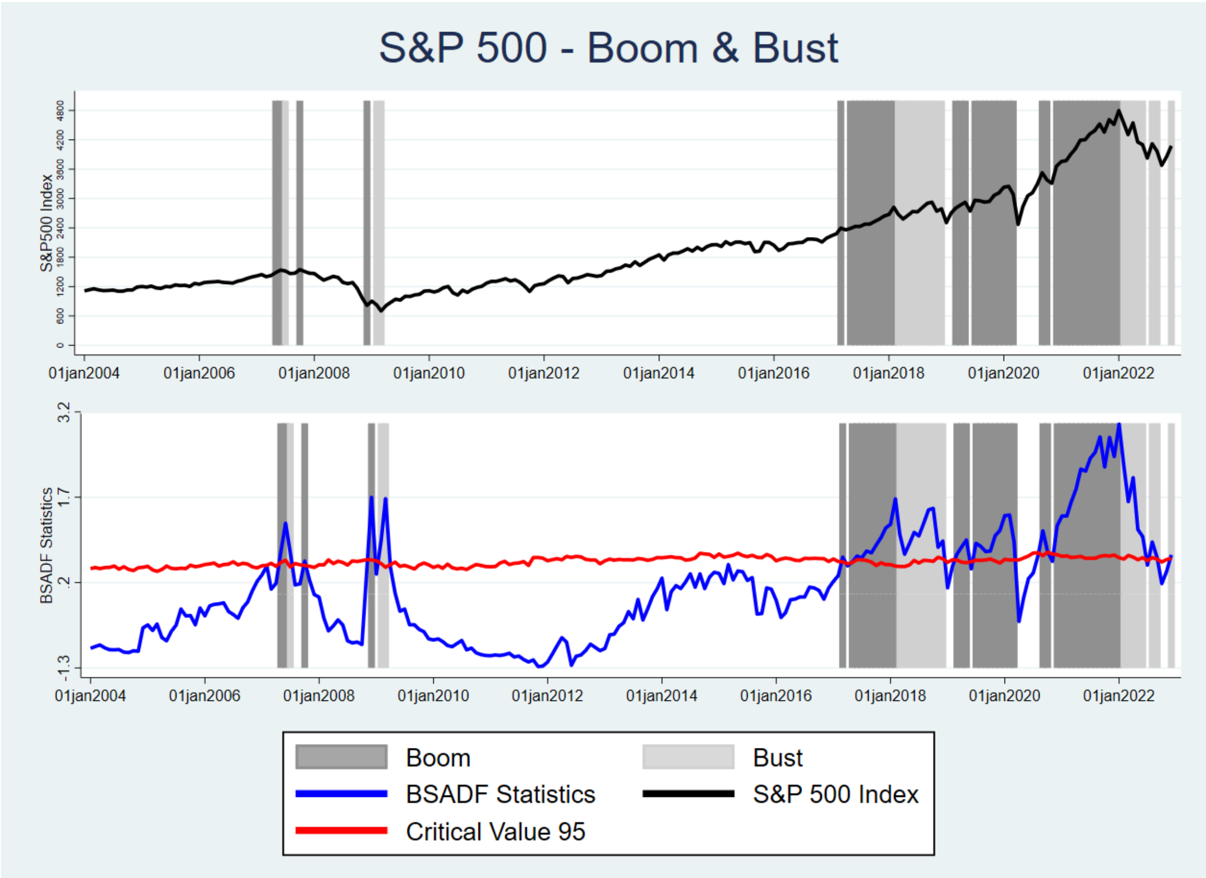
4 Results

4.1 Asset price bubbles in the US

Figures 4 and 5 show the bubble episodes we identify in the S&P 500 and the Case-Shiller indexes through the implementation of the BSADF test of Phillips et al. (2015a,b), as described in Section 3.2. The test identifies the beginning of a bubble episode as the point in time in which the sequence of BSADF test statistics (blue line) first exceeds its critical value (red line). The end of a bubble episode is reached once the test statistics falls below its critical value without exceeding it again within a minimum break length. The switch between the boom and bust phases of an identified bubble takes place when the statistics peaks.

In the S&P 500 index, the test identifies four bubble periods. The first and the second are clearly associated with the 2008-2009 global financial crisis. The test identifies a bubble period starting in May 2007 which is followed by a period in which the index declined substantially. Indeed, from October 2007 to March 2009 the index lost more than 50% of its value. The test then does not identify any period of bubbles for eight years as the index continued stay below the watermark it reached in 2007 until 2013. Starting in March 2017 two more bubble episodes are highlighted, and indeed the statistics is persistently below its critical value only between May and June 2020, as the economy paused in the uncertain phases associated with the COVID-19 pandemic. Euphoria took over once again in the late summer of that year following the manifestation of the effects of the substantial central bank interventions of the previous months, a substantial fiscal package from the US government and optimism about a vaccine. Indeed, the test continued to identify a bubble period up

Figure 4: BSADF test for S&P 500 index.



The Figure reports the Case-Shiller bubble episodes and boom and phase phases. To identify asset price bubbles, we apply the BSADF test of Phillips et al. (2015a,b) (as described in Section 3.2). The test identifies the beginning of a bubble episode as the point in time at which the sequence of BSADF test statistics (blue line) first exceeds its critical value (red line). It thus signals that the price data (black line) is on an explosive trajectory. The end of a bubble episode is reached once the test statistics fall below their critical values without exceeding it again within a minimum break length. The finite sample critical values for 90%, 95% and 99% confidence levels are obtained from Monte Carlo simulations with 2,000 replications (see Phillips et al. (2015a,b) and Vasilopoulos et al. (2022)). The window size is given by $r_0 = \left(0.01 + 1.8/\sqrt{T}\right)$ as recommended by Phillips et al. (2015a,b). The time period is 2004:1 - 2022:4 (monthly frequency) and $T = 228$ observations.

until the end of our time series in December 2022 (see Table 3).

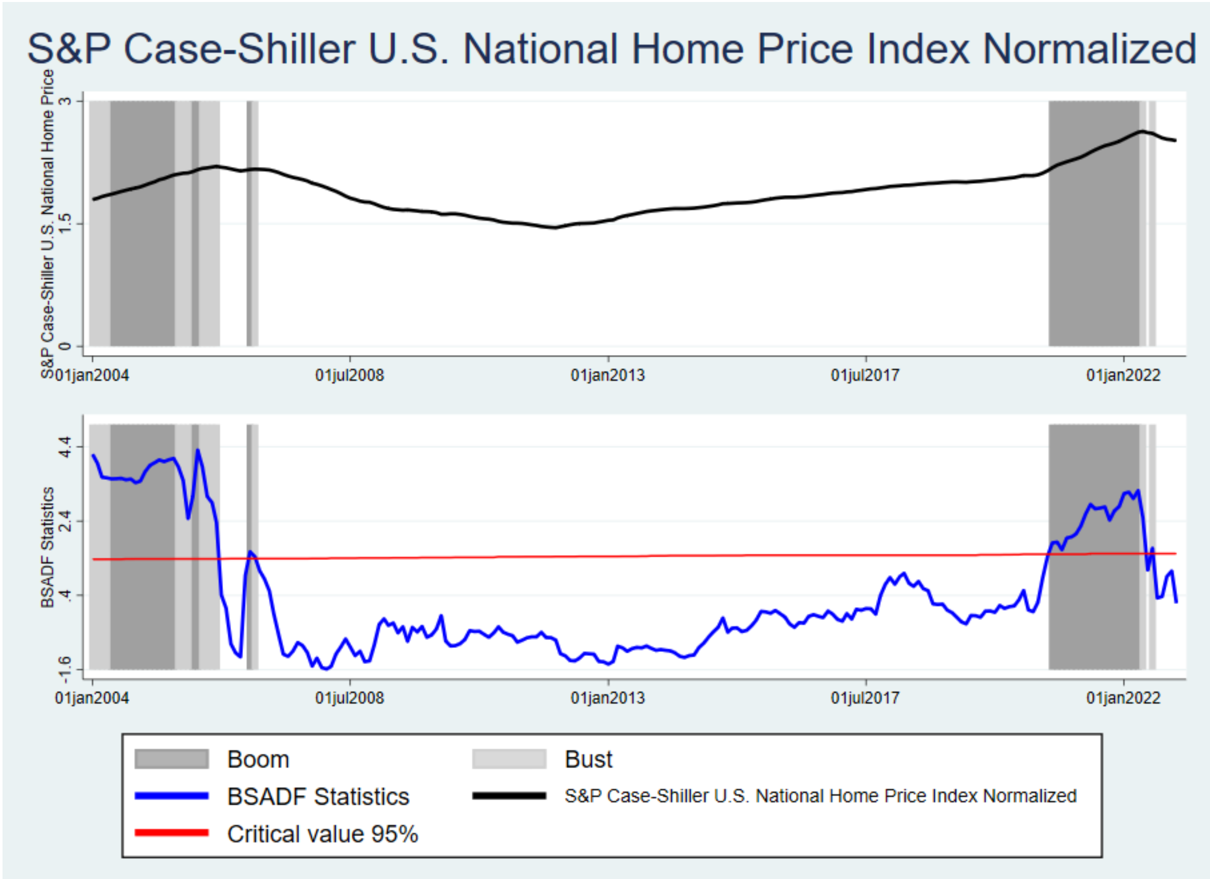
Table 3: S&P 500 Index - Periods of Boom and Bust.

S&P 500 Index					
Time (Monthly)	Boom	Bust	Time (Monthly)	Boom	Bust
01/05/2007	1	0	01/01/2020	1	0
01/06/2007	1	0	01/02/2020	1	0
01/07/2007	0	1	01/03/2020	1	0
01/10/2007	1	0	01/09/2020	1	0
			01/10/2020	1	0
01/12/2008	1	0	01/12/2020	1	0
01/02/2009	0	1	01/01/2021	1	0
01/03/2009	0	1	01/02/2021	1	0
			01/03/2021	1	0
01/03/2017	1	0	01/04/2021	1	0
01/05/2017	1	0	01/05/2021	1	0
01/06/2017	1	0	01/06/2021	1	0
01/07/2017	1	0	01/07/2021	1	0
01/08/2017	1	0	01/08/2021	1	0
01/09/2017	1	0	01/09/2021	1	0
01/10/2017	1	0	01/10/2021	1	0
01/11/2017	1	0	01/11/2021	1	0
01/12/2017	1	0	01/12/2021	1	0
01/01/2018	1	0	01/01/2022	1	0
01/02/2018	1	0	01/02/2022	0	1
01/03/2018	0	1	01/03/2022	0	1
01/04/2018	0	1	01/04/2022	0	1
01/05/2018	0	1	01/05/2022	0	1
01/06/2018	0	1	01/06/2022	0	1
01/07/2018	0	1	01/08/2022	0	1
01/08/2018	0	1	01/09/2022	0	1
01/09/2018	0	1	01/12/2022	0	1
01/10/2018	0	1			
01/11/2018	0	1			
01/12/2018	0	1			
01/03/2019	1	0			
01/04/2019	1	0			
01/05/2019	1	0			
01/07/2019	1	0			
01/08/2019	1	0			
01/09/2019	1	0			
01/10/2019	1	0			
01/11/2019	1	0			
01/12/2019	1	0			

The Table reports the periods of boom and bust for the S&P 500 index through the implementation of the BSADF test of Phillips et al. (2015a,b). The test identifies the beginning of a bubble episode as the point in time in which the sequence of BSADF test statistics first exceeds its critical value. The end of a bubble episode is reached once the test statistics falls below its critical value without exceeding it again within a minimum break length. The switch between the boom and bust phases of an identified bubble takes place when the statistics peaks.

The BSADF test applied to the Case-Shiller index of house prices, deflated using the personal consumption expenditure index, reveals that the series exhibits explosive behavior

Figure 5: BSADF test for S&P/Case-Shiller U.S. National Home Price Index - Revised.



The Figure reports the Case-Shiller U.S. National Home Price Index, normalized for the personal consumption expenditure deflator, bubble episodes and boom and phase phases. To identify asset price bubbles, we apply the BSADF test of Phillips et al. (2015a,b) (as described in Section 3.2). The test identifies the beginning of a bubble episode as the point in time at which the sequence of BSADF test statistics (blue line) first exceeds its critical value (red line). It thus signals that the price data (black line) is on an explosive trajectory. The end of a bubble episode is reached once the test statistics fall below their critical values without exceeding it again within a minimum break length. The finite sample critical values for 90%, 95% and 99% confidence levels are obtained from Monte Carlo simulations with 2,000 replications (see Phillips et al. (2015a,b) and Vasilopoulos et al. (2022)). The window size is given by $r_0 = \left(0.01 + 1.8/\sqrt{T}\right)$ as recommended by Phillips et al. (2015a,b). The time period is 2004:1 - 2022:4 (monthly frequency) and $T = 228$ observations.

for in essentially two periods. The first is in the initial part of our sample and predate the global financial crisis: the test highlights periods of exuberance from the beginning of 2004 to mid 2006. The second bubble period identified is afer the onset of the COVID-19. The statistics is above the critical value from October 2020 up to July 2022 (see Figure 5).

Table 4: Case-Shiller Index - Periods of Boom and Bust.

S&P Case-Shiller U.S. National Home Price Index Normalized					
Time (Monthly)	**Boom**	**Bust**	**Time (Monthly)**	**Boom**	**Bust**
01/01/2004	0	1	01/10/2020	1	0
01/02/2004	0	1	01/11/2020	1	0
01/03/2004	0	1	01/12/2020	1	0
01/04/2004	0	1			
01/05/2004	1	0	01/01/2021	1	0
01/06/2004	1	0	01/02/2021	1	0
01/07/2004	1	0	01/03/2021	1	0
01/08/2004	1	0	01/04/2021	1	0
01/09/2004	1	0	01/05/2021	1	0
01/10/2004	1	0	01/06/2021	1	0
01/11/2004	1	0	01/07/2021	1	0
01/12/2004	1	0	01/08/2021	1	0
			01/09/2021	1	0
01/01/2005	1	0	01/10/2021	1	0
01/02/2005	1	0	01/11/2021	1	0
01/03/2005	1	0	01/12/2021	1	0
01/04/2005	1	0			
01/05/2005	1	0	01/01/2022	1	0
01/06/2005	1	0	01/02/2022	1	0
01/07/2005	0	1	01/03/2022	1	0
01/08/2005	0	1	01/04/2022	1	0
01/09/2005	0	1	01/05/2022	0	1
01/10/2005	1	0	01/07/2022	0	1
01/11/2005	1	0			
01/12/2005	0	1			
01/01/2006	0	1			
01/02/2006	0	1			
01/03/2006	0	1			
01/10/2006	1	0			
01/11/2006	0	1			

The Table reports the periods of boom and bust for the Case-Shiller index through the implementation of the BSADF test of Phillips et al. (2015a,b). The test identifies the beginning of a bubble episode as the point in time in which the sequence of BSADF test statistics first exceeds its critical value. The end of a bubble episode is reached once the test statistics falls below its critical value without exceeding it again within a minimum break length. The switch between the boom and bust phases of an identified bubble takes place when the statistics peaks.

Overall, our results show that stock price and real estate bubbles are relatively common in the US market and that there are strong commonalities in the latter part of the sample (see Table 4).

Table 5 presents the descriptive statistics for S&P500 and Real Estate bubble episodes, the distribution of both indices and the associated BSADF statistics, including also a detailed description of the duration (number of months) for both boom and bust periods. The

S&P500 shows substantial dispersion over the sample period, while the S&P/Case-Shiller U.S. National Home Price Index varies more smoothly. The duration of boom and bust periods is heterogeneous across equity and real estate: boom episodes last up to 43 months for the S&P500 and 36 months for S&P/Case-Shiller index, whereas bust episodes are comparatively shorter, reaching up to 21 and 14 months, respectively.

Table 5: Descriptive statistics for S&P500 and Real Estate bubble episodes.

Type of index	Variable	Mean	Std. Dev.	Min.	Max
Equity index - S&P 500	S&P Index	2,021.49	991.18	700.82	4,796.56
	BSADF Statistics	0.09	0.93	-1.28	2.98
	Boom (n. of months)	-	-	1	43
	Bust (n. of months)	-	-	1	21
Real Estate - S&P/Case-Shiller U.S. National Home Price Index	Case-Shiller Index Normalized	1.91	0.29	1.45	2.63
	BSADF Statistics	0.32	1.60	-1.58	4.31
	Boom (n. of months)	-	-	1	36
	Bust (n. of months)	-	-	1	14

The table reports the number (n. of months) for Real Estate and the number (n. of months) for S&P500 index bubble episodes.

4.2 MMFs, systemic risk and asset price bubbles

Table 6 reports the results of regressions using the characteristics of MMFs considering the full sample but without considering the periods of equity and real estate bubbles. We focus on characteristics that mimic some of the features of banks, mainly to understand whether MMFs exhibit similar features as banks. We focus on *Size*, measured as the total amount of assets under management in each MMF, weighted average maturity (*Wam*) and weighted average life (*Wal*). The *Wam* is the asset-weighted number of days until the securities in each fund mature. We use it to measure maturity mismatches. The *Wal* of a fund is the average number of days for which each dollar of the fund's assets remain outstanding. The *Wal* therefore reflects how the portfolio of assets reacts to deteriorating credit or liquidity conditions. We use it to measure the overall riskiness of a fund. In addition, we consider the role of MMFs size growth, as the Δln(Size) based on a twelve-month rolling window.

Table 6 shows that the only MMF characteristic that predicts MMFs' contribution to systemic risk is size and that it enters the regression with a negative sign, suggesting that larger MMFs are associated with a reduction in systemic risk. Our results suggest that an increase in log asset size of one standard deviation (1.95 in Table 2) and the coefficients in specifications [ii] and [iii] of -0.0006 imply a 11.7 basis points decrease in the $\Delta CoVaR$ or (equivalently) a decrease in systemic risk at the 1-month horizon. Adding macroeconomic controls, however, reveals that MMF characteristics are important determinants of overall systemic risk. The size variable is no longer significant but changes in size are associated with increases in systemic risk of MMFs and are marginally statistically significant. The *Wam* of a fund is associated with a reduction in systemic risk while the opposite is true for *Wal*. In particular, higher values of *Wal* imply that portfolio cash flows mature more slowly and thus may lead daily redemptions harder to meet without asset sales under stress.

Moving to the macroeconomic controls themselves reveals that the signs of the estimated coefficients for these controls are aligned with prior expectations. Periods of high GDP growth are associated with a reduction in risk. Increases in the stress indicator in the money markets developed by Aldasoro et al. (2022) are associated with higher measures of systemic risk and so are periods of high inflation. Increases in government bond yields are associated with reductions in systemic risk.

In Table 7, we provide evidence of the correlation between our measure of systemic risk for MMFs and asset price bubbles. First, we regress the $\Delta CoVaR$ of both US-domiciled and offshore MMFs on the bubble indicators, fund fixed effects, macroeconomic controls (column

Table 6: MMFs US$ and US$ Off Shore without periods of bubbles.

Dependent variable: ΔCoVaR$_{i,t}$	**[i]**	**[ii]**	**[iii]**
Size$_{i,t-1}$	-0.0002	-0.0006***	-0.0006***
	(0.0001)	(0.0001)	(0.0001)
Wam$_{i,t-1}$	-0.0026***	0.0000	-0.0005**
	(0.0002)	(0.0002)	(0.0002)
Wal$_{i,t-1}$	0.0012***	-0.0002	-0.0001
	(0.0002)	(0.0002)	(0.0002)
ΔSize$_{i,t-1}$	0.0029*	-0.0019	0.0000
	(0.0011)	(0.0010)	(0.0010)
ΔGDP$_{t-1}$	-0.0005***		
	(0.0000)		
ΔCPI$_{t-1}$	0.0875***		
	(0.0093)		
10-year Government Bond$_{t-1}$	-0.0019***		
	(0.0001)		
Investment-to-GDP$_{t-1}$	0.0037***		
	(0.0002)		
Money Market MCI$_{t-1}$	0.0011***		
	(0.0001)		
Constant	0.0024	0.0278***	0.0259***
	(0.0018)	(0.0013)	(0.0016)
Fixed Effects	YES	YES	YES
Time Dummy	NO	NO	YES
Macro Controls	YES	NO	NO
ΔCoVaR state variables	NO	YES	NO
N. Obs.	134,083	134,083	134,083
Adjusted R^2 *within*	0.10	0.26	0.26
F-Test	79.52***	136.34***	80.22***

The table reports the results between systemic risk and MMFs characteristics. The dependent variable is ΔCoVaR. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ of both US-domiciled and US-Off shore MMFs on the bubble indicators, fund fixed effects, macroeconomic controls (column [i]), $\Delta CoVaR$ state variables (column [ii]) and monthly dummies (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

[i]), $\Delta CoVaR$ state variables (column [ii]) and monthly dummies (column [iii]).

The results show that bubble periods are associated with significant changes in $\Delta CoVaR$. The first two columns highlight that, overall, systemic risk increases during bubble period but declines substantially during periods of real estate busts. In the third column, which includes time dummies, some of the signs are reversed, suggesting that systemic risk is lower during bubble periods, as most of the positive association between bubbles and systemic risk is captured by time dummies. However, as most of the bubble periods we identify in our analysis took place from 2017 onward and coincide with a general increase in $\Delta CoVaR$, it is possible that this contemporaneous correlation influences our estimates. Overall, the econometric analysis confirms that the strong association between bubble indicators and measured systemic risk which Brunnermeier et al. (2020) documented for banks, carries over when looking at MMFs.

The last three columns of Table 7 combine MMF characteristics and bubble periods as described in Equation (6). A number of interesting results emerge. First of all, the relationship between bubbles and $\Delta CoVaR$ remains strong and statistically significant when we include MMFs characteristics in the regressions. In the regression with macroeconomic controls the coefficients associated with these variables do not change their magnitude and remain highly statistically significant, but the coefficients on inflation and on the investment to GDP ratio change sign compared to the regressions without bubbles. While the systemic risk decreases with MMFs' $\Delta Size$, the relationship vanishes during bubble episodes. In particular, during periods of equity boom, we find that an increase in $\Delta Size$ (1.42 in Table 2) of one standard deviation and on the basis of 0.04 [an average of the coefficients in specifications [iv], [v] and [vi] in Table 7], implies a 5.68 basis points increase in the $\Delta CoVaR$ or (equivalently) an increase in systemic risk at the 1-month horizon. This corresponds to roughly 3.24% of the unconditional monthly standard deviation of $\Delta CoVaR$, ([0.0568/1.75 (std. dev. $\Delta CoVaR$)]*100 in Table 2).

Focusing on MMFs characteristics reveals that the size of MMFs is still negatively associated with systemic risk, but that this association is less prevalent in periods of real estate busts. Changes in size also reduce systemic risk, but with one exception: if these changes take place during equity booms, then the systemic risk of MMFs increases. The size of the coefficients for this interaction term in various specifications is also particularly large, suggesting that MMFs may contribute to increasing systemic risk in periods of exuberance in the stock market. Moving to discussing other MMFs characteristics *Wam*, our measure of maturity mismatch is negatively associated with our measure of systemic risk in general in the regression with macroeconomic controls, but the effect is completely reversed at times of real estate bubbles. More specifically, during real estate bust, an increase in *Wam* of one standard deviation (0.61 in Table 2) and 0.0011 [the average of the coefficients in specifications [iv], [v] and [vi]], implies a 0.0671 basis points increase in the $\Delta CoVaR$ or (equivalently) an increase in systemic risk.

The opposite behavior is present for *Wal*: it increases systemic risk overall, but its contribution is significantly reduced during bubble periods. In particular, during periods of equity bust, we find that an increase in *Wal* of one standard deviation (0.67 in Table 2) and 0.0011 [the average of the coefficients in specifications [iv], [v] and [vi]], implies a 0.0715 basis points decrease in the $\Delta CoVaR$ or (equivalently) a decrease in systemic risk. Overall, our analysis confirms that MMFs characteristics are important for systemic risk measures.

4.2.1 The varying impact of the different types of MMFs

As discussed above, MMFs are not a homogeneous category and given the varying focus of their investments it would not be surprising to find that their contribution to systemic risk differs substantially depending on their type. We therefore repeat the analysis described above using Equation (6) but separate out the two most important categories of MMFs: *prime* and *government* MMFs. We include a triple interaction term in our regression speci-

Table 7: MMFs US$ and US$ Off Shore during 2004:1-2022:12 time period.

Dependent variable: ΔCoVaR$_{i,t}$	**Bubbles: Boom & Bust**			**Bubbles with MMF characteristics**		
	[i]	**[ii]**	**[iii]**	**[iv]**	**[v]**	**[vi]**
Real Estate Boom$_t$	0.0003**	0.0003***	-0.0007***	0.0019**	0.0044***	0.0017**
	(0.0001)	(0.0001)	(0.0001)	(0.0007)	(0.0007)	(0.0006)
Real Estate Bust$_t$	-0.0010***	-0.0003**	-0.0023***	-0.0032***	(0.0006)	-0.0034***
	(0.0001)	(0.0001)	(0.0001)	(0.0008)	(0.0008)	(0.0008)
Equity Boom$_t$	0.0044***	0.0009***	-0.0008***	0.0065***	0.0032**	0.0027**
	(0.0002)	(0.0001)	(0.0001)	(0.0012)	(0.0011)	(0.0011)
Equity Bust$_t$	0.0070***	0.0014***	0.0016***	0.0118***	0.0041***	0.0053***
	(0.0003)	(0.0001)	(0.0001)	(0.0014)	(0.0012)	(0.0012)
Size$_{i,t-1}$				-0.0003**	-0.0006***	-0.0006***
				(0.0002)	(0.0002)	(0.0002)
Size$_{i,t-1}$*Real Estate Boom$_t$				-0.0002**	0.0001	0.0001
				(0.0001)	(0.0001)	(0.0001)
Size$_{i,t-1}$*Real Estate Bust$_t$				0.0002**	0.0002**	0.0002**
				(0.0001)	(0.0001)	(0.0001)
Size$_{i,t-1}$*Equity Boom$_t$				0.0001	0.0001	0.0001
				(0.0001)	(0.0001)	(0.0001)
Size$_{i,t-1}$*Equity Bust$_t$				-0.0001	-0.0001	-0.0001
				(0.0001)	(0.0001)	(0.0001)
Wam$_{i,t-1}$				-0.0010***	-0.0001	-0.0003
				(0.0002)	(0.0002)	(0.0003)
Wam$_{i,t-1}$*Real Estate Boom$_t$				0.0007**	-0.0005**	0.0001
				(0.0002)	(0.0002)	(0.0002)
Wam$_{i,t-1}$*Real Estate Bust$_t$				0.0017***	0.0007**	0.0009***
				(0.0002)	(0.0002)	(0.0002)
Wam$_{i,t-1}$*Equity Boom$_t$				0.0001	-0.0002	-0.0007**
				(0.0003)	(0.0003)	(0.0003)
Wam$_{i,t-1}$*Equity Bust$_t$				0.0001	0.0008**	0.0004
				(0.0004)	(0.0003)	(0.0004)
Wal$_{i,t-1}$				0.0007**	0.0003	0.0003
				(0.0002)	(0.0002)	(0.0002)
Wal$_{i,t-1}$*Real Estate Boom$_t$				-0.0007***	-0.0003	-0.0005**
				(0.0002)	(0.0002)	(0.0002)
Wal$_{i,t-1}$*Real Estate Bust$_t$				-0.0012***	-0.0008***	-0.0009***
				(0.0002)	(0.0002)	(0.0002)
Wal$_{i,t-1}$*Equity Boom$_t$				-0.0006*	-0.0003	-0.0001
				(0.0003)	(0.0003)	(0.0003)
Wal$_{i,t-1}$*Equity Bust$_t$				-0.0011**	-0.0011**	-0.0010**
				(0.0004)	(0.0004)	(0.0004)
ΔSize$_{i,t-1}$				0.0005	-0.0031**	-0.0022**
				(0.0012)	(0.0011)	(0.0011)
ΔSize$_{i,t-1}$*Real Estate Boom$_t$				-0.0083**	-0.0056**	-0.0076**
				(0.0029)	(0.0027)	(0.0027)
ΔSize$_{i,t-1}$*Real Estate Bust$_t$				0.0046	0.0006	0.0018
				(0.0063)	(0.0061)	(0.0061)
ΔSize$_{i,t-1}$*Equity Boom$_t$				0.0461***	0.0372**	0.0374**
				(0.0132)	(0.0125)	(0.0125)
ΔSize$_{i,t-1}$*Equity Bust$_t$				0.0149	0.0236*	0.0234
				(0.0162)	(0.0138)	(0.0143)
ΔGDP$_{t-1}$	-0.0004***			-0.0004***		
	0.0000			0.0000		
ΔCPI$_{t-1}$	-0.1167***			-0.1154***		
	(0.0054)			(0.0057)		
10-year Government Bond$_{t-1}$	-0.0020***			-0.0023***		
	(0.0001)			(0.0001)		
Investment-to-GDP$_{t-1}$	-0.0021***			-0.0014***		
	(0.0002)			(0.0002)		
Money Market MCI$_{t-1}$	0.0014***			0.0013***		
	(0.0001)			(0.0001)		
Constant	0.0345***	0.0192***	0.0185***	0.0338***	0.0238***	0.0235***
	(0.0012)	(0.0002)	(0.0010)	(0.0020)	(0.0014)	(0.0018)
Fixed Effects	YES	YES	YES	YES	YES	YES
Time Dummy	NO	NO	YES	NO	NO	YES
Macro Controls	YES	NO	NO	YES	NO	NO
ΔCoVaR state variables	NO	YES	NO	NO	YES	NO
N. Obs.	135,291	135,291	135,291	134,083	134,083	134,083
Adjusted R^2 *within*	0.17	0.25	0.27	0.19	0.27	0.27
F-Test	152.23***	151.44***	101.75***	66.59***	70.49***	67.88***

The table reports the results between the measure of systemic risk for MMFs and asset price bubbles. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ of both US-domiciled and US-Off shore MMFs on the bubble indicators, fund fixed effects, macroeconomic controls (column [i]), $\Delta CoVaR$ state variables (column [ii]) and monthly dummies (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

fication and estimate the following specification:

$$\Delta CoVaR_{i,t} = \alpha_i + \beta_1 I_t^{Bubble} + \beta_2 MMFs\, Char._{i,t-1} + \beta_3 I_t^{Bubble} * MMFs\, Char._{i,t-1} + \beta_4 I_t^{Bubble} * MMFs\ Cat._i * MMFs\ Char._{i,t-1} + \lambda_1 * Macro_{t-1}\ [or\ \ \lambda_2 * \Delta CoVaR\ Macro_{t-1}\ or\ Time\ Dummies_t] + \varepsilon_{i,t} \quad (7)$$

where $MMFs\ Cat._i$ is a dummy for MMFs categories, such as *prime*, *government*, and *tax free*. As further step, this dummy is split into *prime* MMFs (a dummy variable equal to 1 for *prime* MMFs, and 0 elsewhere) and *government* MMFs (a dummy variable equal to 1 for *government* MMFs, and 0 elsewhere). We interact the dummy with all MMF-specific predictors (see Section 3.4). Initially, we restrict our sample to MMFs domiciled in the US while in the next subsection we include offshore funds. The results are summarized in Table 8. The coefficients should be interpreted in relation to the third category of MMFs, namely *tax free* funds, which act as a benchmark. The results suggest that the effect of the *Size* of MMFs on systemic risk is the result of different contributions of *government* and *prime* MMFs. The negative overall effect is almost completely eliminated for *prime* MMFs, suggesting that they contribute significantly more to systemic risk than *government* ones. A possible explanation is that *prime* MMFs typically invest in a broader range of short-term securities, including those issued by private corporations, potentially resulting in higher yields. Instead, *government* MMFs primarily invest in short-term securities issued or guaranteed by the U.S. government or its agencies.

The fact that *government* MMFs contribute less to systemic risk compared to *prime* ones holds when looking at the estimates of the effects of MMFs characteristics. The *Wam* and *Wal* coefficients mostly lose significance when they are not interacted with the various categories of MMFs suggesting no overall contribution. However, we find that $\Delta CoVaR$ is sensitive to *Wam* for *prime* and *government* MMFs during real estate bubble periods, particularly during boom phases. A real estate boom may coincide with periods of economic growth and changing interest rate expectations. If interest rates are expected to rise during the real estate boom, *prime* and *government* MMFs with a higher *Wam* may be more exposed to interest rate risk, and thus leading to higher value of systemic risk. Moreover, during a real estate boom, *prime* MMFs may seek to enhance yields to attract investors. A higher *Wam* enables funds to invest in longer-term securities, typically offering higher yields. However, this comes with increased exposure to interest rate fluctuations and heightened financial instability.

For both *prime* and *government* MMFs, systemic risk remains unaffected by their *Wam* during a real estate bust, while is sensitive during equity bubble periods. We find that, for *government* MMFs, an increase in *Wam* of one standard deviation (0.67 in Table 2) and 0.0082 [the average of the coefficients in specifications [i], [ii] and [iii], implies a 0.55 basis points decrease in the $\Delta CoVaR$ or (equivalently) a decrease in systemic risk. Instead, for *prime* MMFs, an increase in *Wam* of one standard deviation (0.51 in Table 2) and 0.007 [the average of the coefficients in specifications [i], [ii] and [iii]], implies a 0.36 basis points decrease in systemic risk. While a higher *Wam* may expose MMFs to longer-term securities, it could also allow for better credit risk management. During equity boom, investing in longer-term securities may provide opportunities for higher-quality issuers, potentially reducing credit risk, and thus leading to lower systemic risk.

We also observe sensitivity in $\Delta CoVaR$ to both *prime* and *government* MMFs' *Wal* during an equity boom. A possible explanation is that if a significant number of MMFs have higher *Wal* and interest rates increase rapidly, it could lead to potential losses, impacting the stability of the financial system. In addition, from a market liquidity perspective, longer-term securities may have reduced liquidity, especially during periods of market stress. If a large number of investors seek redemptions from MMFs with higher *Wal*, it could lead to liquidity challenges and contribute to systemic risk. Moreover, higher *Wal* values may expose MMFs to longer-term securities, including corporate debt. In the event of economic downturns or credit events, the credit quality of these securities could deteriorate, affecting the broader financial system and thus leading to higher values of systemic risk.

Interestingly, MMFs growth ($\Delta Size$) is highly significant with a negative sign. This implies that higher MMFs growth is associated with lower systemic risk in normal times. This finding suggests healthy MMFs growth outside of bubble periods. However, the relationship changes during bubble episodes, particularly during equity boom. For both *prime* and *government* MMFs, during an equity boom, investors may be tempted by higher returns in riskier assets, such as corporate debt with slightly elevated yields. MMFs, aiming to deliver competitive returns, may invest in slightly riskier assets to attain higher yields. This "*reach for yield*" can expose MMFs to increased credit and liquidity risks. We also noticed that systemic risk is more sensitive to the $\Delta Size$ for *government* MMFs. One possible explanation is that these funds are often perceived as safer during times of crisis, given their primary focus on government-backed securities. Consequently, investors frequently seek the safety of government debt during turbulent times. Our results suggest that, for *government* MMFs, an increase in $\Delta Size$ of one standard deviation (1.21 in Table 2) and 0.14 [the average of the

Table 8: MMFs US$ by categories during 2004:1-2022:12 time period.

Dependent variable: ΔCoVaR$_{i,t}$	**[i]**	**[ii]**	**[iii]**	**Marginal Effects for MMFs Prime**			**Marginal Effects for MMFs Government**		
				[i]	**[ii]**	**[iii]**	**[i]**	**[ii]**	**[iii]**
Size$_{i,t-1}$	0.0007	-0.0009**	-0.0008*	0.0009*	0.0008	0.0007	0.0002	0.0000	-0.0003
	(0.0005)	(0.0005)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Size$_{i,t-1}$*Real Estate Boom$_t$	-0.0001***	-0.0000***	0.0002***	-0.0006***	-0.0004***	-0.0005***	-0.0001	0.0000	-0.0001*
	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Size$_{i,t-1}$*Real Estate Bust$_t$	0.0003	-0.0005*	0.0004	-0.0002	0.0000	0.0000	0.0003	0.0005*	0.0004
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Size$_{i,t-1}$*Equity Boom$_t$	-0.0003	-0.0002	-0.0003	0.0005	0.0002	0.0002	0.0006**	0.0005*	0.0006**
	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Size$_{i,t-1}$*Equity Bust$_t$	0.0002	0.0002	0.0001	0.0002	-0.0001	-0.0001	-0.0001	-0.0001	0.0000
	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Wam$_{i,t-1}$	0.0018	-0.0022	-0.002	0.0018	0.0032	0.0031	0.0001	0.0018	0.0018
	(0.0023)	(0.0023)	(0.0023)	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0023)	(0.0023)
Wam$_{i,t-1}$*Real Estate Boom$_t$	-0.0091***	-0.0048**	-0.0057**	0.0108***	0.0044**	0.0063***	0.0110***	0.0044**	0.0058**
	(0.0022)	(0.0018)	(0.0018)	(0.0022)	(0.0018)	(0.0019)	(0.0022)	(0.0018)	(0.0018)
Wam$_{i,t-1}$*Real Estate Bust$_t$	0.0011	0.0003	0.0004	0.0017	0.0000	-0.0001	0.0036	0.001	0.0017
	(0.0023)	(0.0021)	(0.0021)	(0.0024)	(0.0022)	(0.0022)	(0.0023)	(0.0021)	(0.0021)
Wam$_{i,t-1}$*Equity Boom$_t$	0.0092***	0.0074**	0.0066**	-0.0073**	-0.0068**	-0.0069**	-0.0098***	-0.0074**	-0.0074**
	(0.0027)	(0.0026)	(0.0026)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wam$_{i,t-1}$*Equity Bust$_t$	0.0058**	0.0052*	0.0051*	-0.0064**	-0.0037	-0.0046	-0.0063**	-0.0045	-0.0054*
	(0.0028)	(0.0027)	(0.0028)	(0.0030)	(0.0029)	(0.0029)	(0.0029)	(0.0028)	(0.0028)
Wal$_{i,t-1}$	0.0012	0.0017	0.0017	-0.0012	-0.0024	-0.0026	-0.0016	-0.0021	-0.0024
	(0.0024)	(0.0024)	(0.0024)	(0.0025)	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)
Wal$_{i,t-1}$*Real Estate Boom$_t$	0.0082***	0.0039**	0.0051**	-0.0091***	-0.0029	-0.0048**	-0.0088***	-0.0043**	-0.0055**
	(0.0022)	(0.0018)	(0.0018)	(0.0023)	(0.0018)	(0.0019)	(0.0022)	(0.0018)	(0.0018)
Wal$_{i,t-1}$*Real Estate Bust$_t$	-0.0003	-0.0013	-0.0011	-0.0003	0.0012	0.0013	-0.0007	0.0007	0.0004
	(0.0024)	(0.0022)	(0.0022)	(0.0025)	(0.0023)	(0.0023)	(0.0024)	(0.0022)	(0.0022)
Wal$_{i,t-1}$*Equity Boom$_t$	-0.0072**	-0.0057**	-0.0055**	0.0055*	0.0047*	0.0053*	0.0087**	0.0069**	0.0069**
	(0.0027)	(0.0027)	(0.0027)	(0.0029)	(0.0028)	(0.0028)	(0.0028)	(0.0027)	(0.0027)
Wal$_{i,t-1}$*Equity Bust$_t$	-0.0035	-0.0025	-0.0027	0.0043	0.0025	0.0032	0.0044	0.0031	0.0036
	(0.0028)	(0.0027)	(0.0028)	(0.0029)	(0.0028)	(0.0029)	(0.0028)	(0.0028)	(0.0028)
ΔSize$_{i,t-1}$	-0.0031**	-0.0060***	-0.0059***	0.0472***	0.0381***	0.0433***	0.0055	0.0168**	0.0139**
	(0.0013)	(0.0013)	(0.0013)	(0.0117)	(0.0089)	(0.0102)	(0.0060)	(0.0069)	(0.0066)
ΔSize$_{i,t-1}$*Real Estate Boom$_t$	-0.0248***	-0.0149**	-0.0124**	0.0208**	0.0235***	0.0135*	0.0318***	0.0177**	0.0108*
	(0.0063)	(0.0053)	(0.0056)	(0.0081)	(0.0067)	(0.0074)	(0.0072)	(0.0062)	(0.0063)
ΔSize$_{i,t-1}$*Real Estate Bust$_t$	-0.0149	0.0279*	0.0058	0.0406**	-0.0224	0.0088	0.0107	-0.0328*	-0.005
	(0.0143)	(0.0163)	(0.0148)	(0.0171)	(0.0185)	(0.0173)	(0.0174)	(0.0188)	(0.0176)
ΔSize$_{i,t-1}$*Equity Boom$_t$	0.2060***	0.1157***	0.1155***	-0.1663***	-0.1184***	-0.1319***	-0.2533***	-0.1204***	-0.1016**
	(0.0370)	(0.0295)	(0.0284)	(0.0392)	(0.0325)	(0.0326)	(0.0410)	(0.0342)	(0.0326)
ΔSize$_{i,t-1}$*Equity Bust$_t$	0.0168	0.0268	0.0333*	-0.1070***	-0.0884**	-0.0860**	0.1853***	0.1164**	0.1196**
	(0.0225)	(0.0188)	(0.0202)	(0.0324)	(0.0279)	(0.0294)	(0.0477)	(0.0436)	(0.0437)
ΔGDP$_{t-1}$	-0.0006***								
	(0.0000)								
ΔCPI$_{t-1}$	-0.1413***								
	(0.0071)								
10-year Government Bond$_{t-1}$	-0.0029***								
	(0.0001)								
Investment-to-GDP$_{t-1}$	-0.0002								
	(0.0002)								
Money Market MCI$_{t-1}$	0.0016***								
	(0.0001)								
Constant	0.0345***	0.0330***	0.0326***						
	(0.0025)	(0.0019)	(0.0019)						
Fixed Effects	YES	YES	YES						
Catogories Dummy (Prime and Government)	YES	YES	YES						
Bubbles Dummy	YES	YES	YES						
Dummy MMFs US*Bubbles	YES	YES	YES						
Dummy MMFs US$	YES	YES	YES						
Time Dummy	NO	NO	YES						
Macro Controls	YES	NO	NO						
ΔCoVaR state variables	NO	YES	NO						
N. Obs.	106,108	106,108	106,108						
Adjusted R^2 *within*	0.28	0.37	0.38						
F-Test	60.67***	60.52***	70.42***						

The table reports the results between the measure of systemic risk for MMFs and asset price bubbles. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ of only US-domiciled MMFs on the bubble indicators, fund fixed effects, macroeconomic controls (column [i]), $\Delta CoVaR$ state variables (column [ii]) and monthly dummies (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

coefficients in specifications [i], [ii] and [iii]] implies a 17 basis points increase in the $\Delta CoVaR$ or (equivalently) an increase in systemic risk at the 1-month horizon. This corresponds to 9.7% of the unconditional monthly standard deviation of $\Delta CoVaR$ ([0.17/1.75 (std. dev. $\Delta CoVaR$)]*100 in Table 2).

4.2.2 The interconnectedness of the domestic and offshore market

The last aspect we tackle in our analysis is to incorporate the contribution of offshore MMFs. The question we aim to answer is: does the fact that funds denominated in US dollars but domiciled in Europe invest in the US market increase or decrease the importance of MMFs for systemic risk? On the one hand, these funds serve investors based in other jurisdictions who may be exposed to other shocks, be in different part of the economic cycle and overall behave in ways that contrast with that of US funds, thereby absorbing stress and reduce systemic risk. On the other hand, these funds may simply have similar reaction functions to US-based ones as they respond to what happens in the US dollar market, thereby exacerbating risks[9]. Which one of these prevails overall is essentially an empirical question.

To answer it, we repeat the analysis (see Equation (7)) including offshore MMFs in our sample. As there are no offshore *tax free* MMFs, the interpretation of the coefficients does not change compared to the previous analysis. The results are reported in Table 9. The goodness of fit of the estimated models is reduced somewhat, but the results show that the inclusion of offshore MMFs does not significantly change the picture compared to the analysis performed only with US-domiciled funds. The signs of most of the coefficients do not change while some of the marginal effects associated with *government* and *prime* funds

[9] Previous studies have documented the connectedness of the US and European markets, showing that EU issuers rely on US MMFs for funding (Aquilina et al., 2023).

Table 9: MMFs US$ and US$ Off Shore by categories during 2004:1-2022:12 time period.

Dependent variable: ΔCoVaR$_{i,t}$	**[i]**	**[ii]**	**[iii]**	**Marginal Effects for MMFs Prime**			**Marginal Effects for MMFs Government**		
				[i]	**[ii]**	**[iii]**	**[i]**	**[ii]**	**[iii]**
Size$_{i,t-1}$	-0.0007*	-0.0009**	-0.0008*	0.0006	0.0005	0.0006	0.0004	0.0002	-0.0001
	(0.0005)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Size$_{i,t-1}$*Real Estate Boom$_t$	-0.0000***	-0.0000***	0.0002***	-0.0005***	-0.0002**	-0.0003**	0.0000	0.0001	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Size$_{i,t-1}$*Real Estate Bust$_t$	-0.0002	-0.0003	-0.0002	-0.0002	0.0000	0.0000	0.0003	0.0005**	0.0005**
	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
Size$_{i,t-1}$*Equity Boom$_t$	0.0002	0.0001	0.0003	0.0004	0.0001	0.0001	0.0003	0.0002	0.0003
	(0.0003)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Size$_{i,t-1}$*Equity Bust$_t$	0.0001	0.0001	0.0001	0.0004	0.0001	0.0002	-0.0001	-0.0002	-0.0001
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Wam$_{i,t-1}$	-0.0032*	-0.0031*	-0.0027*	0.0043**	0.0049**	0.0042**	0.0017	0.0027*	0.0024
	(0.0017)	(0.0016)	(0.0016)	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0016)	(0.0016)
Wam$_{i,t-1}$*Real Estate Boom$_t$	-0.0055***	-0.0055***	-0.0055***	0.0070***	0.0053***	0.0060***	0.0071***	0.0054***	0.0058***
	(0.0016)	(0.0014)	(0.0014)	(0.0017)	(0.0015)	(0.0015)	(0.0016)	(0.0014)	(0.0015)
Wam$_{i,t-1}$*Real Estate Bust$_t$	-0.0049***	-0.0058***	-0.0059***	0.0087***	0.0086***	0.0087***	0.0071***	0.0067***	0.0071***
	(0.0011)	(0.0011)	(0.0011)	(0.0012)	(0.0012)	(0.0012)	(0.0011)	(0.0011)	(0.0011)
Wam$_{i,t-1}$*Equity Boom$_t$	0.0099***	0.0099***	0.0084***	-0.0095***	-0.0100***	-0.0087***	-0.0110***	-0.0111***	-0.0100***
	(0.0020)	(0.0020)	(0.0019)	(0.0021)	(0.0020)	(0.0020)	(0.0020)	(0.0020)	(0.0020)
Wam$_{i,t-1}$*Equity Bust$_t$	0.0069***	0.0077***	0.0070***	-0.0084***	-0.0078***	-0.0072***	-0.0077***	-0.0078***	-0.0077***
	(0.0021)	(0.0021)	(0.0021)	(0.0022)	(0.0022)	(0.0022)	(0.0021)	(0.0021)	(0.0021)
Wal$_{i,t-1}$	0.0023	0.0023	0.0021	-0.0034*	-0.0036**	-0.0032*	-0.0025	-0.0025	-0.0025
	(0.0017)	(0.0017)	(0.0016)	(0.0018)	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0017)
Wal$_{i,t-1}$*Real Estate Boom$_t$	0.0042**	0.0044**	0.0047***	-0.0050**	-0.0044**	-0.0050***	-0.0045**	-0.0048***	-0.0051***
	(0.0016)	(0.0014)	(0.0014)	(0.0016)	(0.0014)	(0.0015)	(0.0016)	(0.0014)	(0.0015)
Wal$_{i,t-1}$*Real Estate Bust$_t$	0.0038***	0.0046***	0.0047***	-0.0067***	-0.0068***	-0.0070***	-0.0052***	-0.0058***	-0.0059***
	(0.0008)	(0.0008)	(0.0008)	(0.0010)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Wal$_{i,t-1}$*Equity Boom$_t$	-0.0076***	-0.0079***	-0.0069***	0.0079***	0.0087***	0.0077***	0.0098***	0.0101***	0.0092***
	(0.0019)	(0.0019)	(0.0019)	(0.0021)	(0.0020)	(0.0020)	(0.0020)	(0.0020)	(0.0019)
Wal$_{i,t-1}$*Equity Bust$_t$	-0.0044**	-0.0048**	-0.0044**	0.0055**	0.0057**	0.0051**	0.0056**	0.0060**	0.0057**
	(0.0020)	(0.0020)	(0.0020)	(0.0021)	(0.0021)	(0.0021)	(0.0020)	(0.0020)	(0.0020)
ΔSize$_{i,t-1}$	-0.0024*	-0.0049***	-0.0042***	0.0436***	0.0352***	0.0400***	0.0003	0.0098*	0.0045
	(0.0012)	(0.0012)	(0.0012)	(0.0122)	(0.0094)	(0.0102)	(0.0056)	(0.0055)	(0.0056)
ΔSize$_{i,t-1}$*Real Estate Boom$_t$	-0.0192**	-0.0146**	-0.0113**	0.0149*	0.0227***	0.0142**	0.0202**	0.0113*	0.0043
	(0.0059)	(0.0052)	(0.0054)	(0.0076)	(0.0067)	(0.0072)	(0.0066)	(0.0061)	(0.0061)
ΔSize$_{i,t-1}$*Real Estate Bust$_t$	(0.0102)	0.0216	0.0058	0.0283*	-0.0154	0.0054	-0.0057	-0.0324*	-0.0165
	(0.0145)	(0.0160)	(0.0150)	(0.0170)	(0.0181)	(0.0172)	(0.0175)	(0.0184)	(0.0177)
ΔSize$_{i,t-1}$*Equity Boom$_t$	0.1435***	0.0904***	0.0807**	-0.1322***	-0.1002**	-0.1031**	-0.1782***	-0.0832**	-0.0557*
	(0.0321)	(0.0270)	(0.0261)	(0.0383)	(0.0329)	(0.0323)	(0.0359)	(0.0303)	(0.0292)
ΔSize$_{i,t-1}$*Equity Bust$_t$	0.0080	0.0212	0.0271	-0.0820**	-0.0724**	-0.0767**	0.1209**	0.0776*	0.0728*
	(0.0218)	(0.0191)	(0.0200)	(0.0311)	(0.0274)	(0.0283)	(0.0469)	(0.0431)	(0.0429)
ΔGDP$_{t-1}$	-0.0004***								
	(0.0000)								
ΔCPI$_{t-1}$	-0.1118***								
	(0.0061)								
10-year Government Bond$_{t-1}$	-0.0023***								
	(0.0001)								
Investment-to-GDP$_{t-1}$	-0.0011***								
	(0.0002)								
Money Market MCI$_{t-1}$	0.0013***								
	(0.0001)								
Constant	0.0342***	0.0248***	0.0220***						
	(0.0040)	(0.0035)	(0.0035)						
Fixed Effects	YES	YES	YES						
Catogories Dummy (Prime and Government)	YES	YES	YES						
Bubbles Dummy	YES	YES	YES						
Dummy MMFs US*Bubbles	YES	YES	YES						
Dummy MMFs US$	YES	YES	YES						
Time Dummy	NO	NO	YES						
Macro Controls	YES	NO	NO						
ΔCoVaR state variables	NO	YES	NO						
N. Obs.	134,083	134,083	134,083						
Adjusted R^2 *within*	0.23	0.30	0.31						
F-Test	37.23***	38.56***	42.50***						

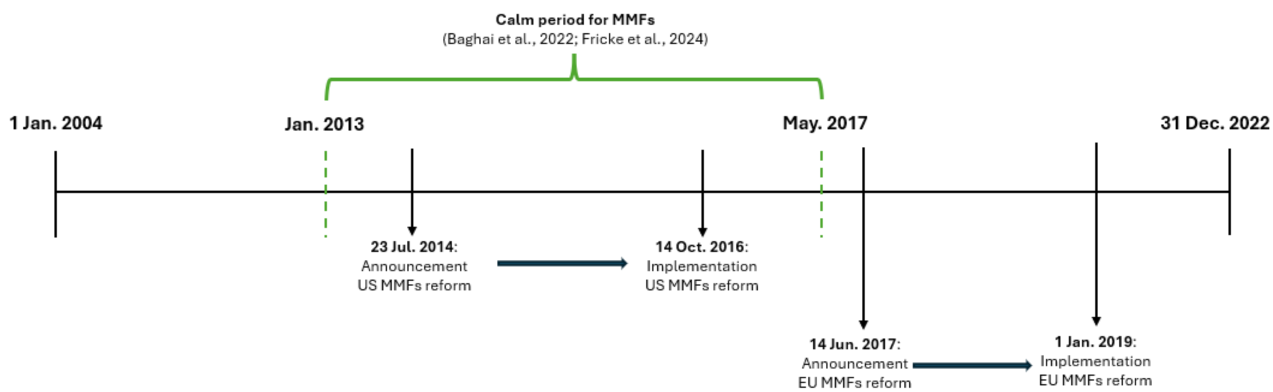
The table reports the results between the measure of systemic risk for MMFs and asset price bubbles. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ of only US-Off shore MMFs on the bubble indicators, fund fixed effects, macroeconomic controls (column [i]), $\Delta CoVaR$ state variables (column [ii]) and monthly dummies (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

during bubble periods are of a slightly smaller magnitude suggesting that the inclusion of offshore funds may dilute the overall effects of MMFs on systemic risk. However, we do not find evidence that the existence of offshore funds acts as either an amplifier or as a significant buffer for the systemic risk caused by money market funds.

4.2.3 A calm period for MMFs and the regulatory reforms in the US and Europe

Following the financial crisis in 2008, authorities in both the United States and Europe introduced various reforms in the MMF sector to mitigate the risks it posed. In this section, we examine the effects of these reforms, which aimed to enhance liquidity and increase transparency (Figure 6). From the authorities' perspective, these changes were intended to stabilize MMFs, reducing their likelihood of causing financial disruptions during market stress.

Figure 6: Timeline of US and EU MMF reforms.



The Figure reports the dates of different reforms of the MMF industry in the US and the EU financial systems.

The response of systemic risk of MMFs, their characteristics and the role played by the reforms is investigated using the following regression model:

$$\Delta CoVaR_{i,t} = \alpha_i + \beta_1 * I_t^{MMFs\ Reforms} + \beta_2 * MMFs\ Char._{i,t-1} +$$
$$\beta_3 * I_t^{MMFs\ Reforms} * MMFs\ Char._{i,t-1} +$$
$$\beta_4 * I_t^{MMFs\ Reforms} * MMFs\ Cat._i * MMFs\ Char._{i,t-1} +$$
$$\lambda_1 * Macro_{t-1}\ [or\ \ \lambda_2 * \Delta CoVaR\ Macro_{t-1}\ or\ Time\ Dummies_t] + \varepsilon_{i,t} \quad (8)$$

where $I_t^{MMFs\ Reforms}$ captures the US and the EU MMF reforms over the period 2013:1-2017:5. We follow Baghai et al. (2022) and Fricke et al. (2024), that highlight how the period 2013:1-2017:5 is one of calm for MMFs and also overlaps with many of the reforms in the US and Europe. Tables 10 shows the results. We find that this period is associated with changes in the characteristics of MMFs and in their contribution to systemic risk. In particular, over this period, the systemic risk for larger government MMFs decreased, highlighting their role as a potential safe haven, which was evident in March 2020, when they experienced substantial inflows at the outset of the COVID-19 pandemic. Indeed, for prime MMFs (both denominated in US$ and offshore), systemic risk is unaffected by their size after MMFs reforms.

We also find that over the period of reforms, both the *Wam* and *Wal* of MMF assets changed. Starting with the former, as regulations added liquidity requirements and limited certain investments *prime* MMFs tried to keep their yields by investing in longer-maturity assets. For *prime* MMFs, a one standard deviation increase in *Wam* (0.51 in Table 2) and 0.01 [the average of the coefficients specification [i], [ii] and [iii]], implies a 0.52 basis points increase in the $\Delta CoVaR$ or (equivalently) an increase in systemic risk at the 1-month horizon. For *government* MMFs, the economic magnitude is quite similar. In particular, a one standard deviation increase in Wam (0.67 in Table 2) and 0.007 [the average of the coefficients in specification [i], [ii], and [iii]], implies to a 0.5 basis points increase in the $\Delta CoVaR$ or (equivalently) an increase in systemic risk at the 1-month horizon. Longer maturities usually offer higher yields, but they also raise risks related to interest rates and liquidity. This can worsen systemic risk if investors want to redeem their investments during market stress.

Additionally, we observe that the MMFs' *Wal* decrease systemic risk following the period of reform in MMFs. Our results suggest that, for *prime* MMFs, an increase in *Wal* of one standard deviation (0.57 in Table 2) and 0.009 [the average of the coefficients in specifications [i], [ii] and [iii], implies a 0.5 basis points decrease in the $\Delta CoVaR$ or (equivalently) a decrease in systemic risk at the 1-month horizon. For *government* MMFs, we find that a one standard deviation increase (0.5 in Table 2) and 0.01 [the average of the coefficients in specifications [i], [ii] and [iii]], implies a 0.51 basis points decrease in the $\Delta CoVaR$ or (equivalently) a decrease in systemic risk at the 1-month horizon. A possible explanation is that by shortening the *Wal* of MMFs, regulators have ensured that these funds may respond more quickly to redemption requests without incurring substantial losses. This change has also enhanced their resilience and improved their capability to manage redemption pressures effectively.

5 Robustness checks

To ensure the robustness of our analysis, we performed a number of checks and in this

Table 10: MMFs US$ and US$ Off Shore by categories during 2004:1-2022:12 time period and MMFs Reforms.

Dependent variable: ΔCoVaR$_{i,t}$	**[i]**	**[ii]**	**[iii]**	**Marginal Effects for MMFs Prime**			**Marginal Effects for MMFs Government**		
				[i]	**[ii]**	**[iii]**	**[i]**	**[ii]**	**[iii]**
MMFs Reforms$_t$	-0.0105***	-0.0125***	-0.0092***	0.0056	0.0038	0.0056	0.0232***	0.0222***	0.0236***
	(0.0026)	(0.0027)	(0.0026)	(0.0036)	(0.0037)	(0.0036)	(0.0031)	(0.0032)	(0.0031)
Size$_{i,t-1}$	-0.0014***	-0.0018***	-0.0016***	0.0012**	0.0017***	0.0013**	0.0008*	0.0017***	0.0012**
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Size$_{i,t-1}$*MMFs Reforms$_t$	0.0005	0.0005	0.0005	-0.0004	-0.0005	-0.0004	-0.0005	-0.0006*	-0.0006*
	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Wam$_{i,t-1}$	0.0021**	0.0020*	0.0030**	-0.0020*	-0.0027**	-0.0021*	-0.0035**	-0.0041***	-0.0037***
	(0.0010)	(0.0011)	(0.0011)	(0.0011)	(0.0012)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Wam$_{i,t-1}$*MMFs Reforms$_t$	-0.0063**	-0.0078**	-0.0080**	0.0098**	0.0109***	0.0098**	0.0069**	0.0080**	0.0074**
	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)
Wal$_{i,t-1}$	-0.0021*	-0.0023**	-0.0028**	0.0018	0.002	0.0020*	0.0036**	0.0046***	0.0045***
	(0.0011)	(0.0012)	(0.0011)	(0.0011)	(0.0012)	(0.0012)	(0.0011)	(0.0012)	(0.0012)
Wal$_{i,t-1}$*MMFs Reforms$_t$	0.0064**	0.0074**	0.0076**	-0.0086**	-0.0090**	-0.0088**	-0.0097**	-0.0104**	-0.0103**
	(0.0032)	(0.0033)	(0.0032)	(0.0033)	(0.0033)	(0.0033)	(0.0033)	(0.0033)	(0.0033)
ΔSize$_{i,t-1}$	-0.002	-0.0035**	-0.0064***	0.0256**	0.0305**	0.0227**	0.0178**	0.0152**	0.0204***
	(0.0014)	(0.0015)	(0.0014)	(0.0098)	(0.0098)	(0.0095)	(0.0056)	(0.0051)	(0.0055)
ΔSize$_{i,t-1}$*MMFs Reforms$_t$	-0.0135***	-0.0140***	-0.0067**	0.0117**	0.0128**	0.0127**	0.0111***	0.0153***	0.0077**
	(0.0029)	(0.0031)	(0.0029)	(0.0045)	(0.0047)	(0.0045)	(0.0032)	(0.0033)	(0.0031)
ΔGDP$_{t-1}$		-0.0003***							
		(0.0000)							
ΔCPI$_{t-1}$		-0.1177***							
		(0.0102)							
10-year Government Bond$_{t-1}$		-0.0013***							
		(0.0001)							
Investment-to-GDP$_{t-1}$		0.0034***							
		(0.0002)							
Money Market MCI$_{t-1}$		0.0007***							
		(0.0000)							
Constant	0.0280***	0.0145***	0.0324***						
	(0.0033)	(0.0041)	(0.0033)						
Fixed Effects	YES	YES	YES						
Time Dummy	YES	NO	NO						
Macro Controls	NO	YES	NO						
ΔCoVaR state variables	NO	NO	YES						
Categories Dummy (Prime and Government)	YES	YES	YES						
N. Obs.	134,083	134,083	134,083						
Adjusted R^2 *within*	0.32	0.26	0.32						
F-Test	54.99***	45.89***	58.68***						

The table reports the results between the measure of systemic risk for MMFs and asset price bubbles. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ of only US-Off shore MMFs on the bubble indicators, fund fixed effects, macroeconomic controls (column [i]), $\Delta CoVaR$ state variables (column [ii]) and monthly dummies (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

section, we report their results. We devote most of the discussion to replacing the X^{system} variable with the spread of commercial paper yields over the federal fund rate, and the systemic risk measure in our analysis with the marginal expected shortfall MES, and we only briefly describe the additional checks we performed. In particular we validate our results considering an alternative estimation strategy for $\Delta CoVaR$ and we replicate our analyses after excluding the observations during the COVID-19 time period.

5.1 Alternative system variable for $\Delta CoVar$ in MMFs

This paper emphasizes the importance of studying the systemic risk of MMFs. One intended contribution is to understand the important role of MMFs in short-term funding markets. To this end, we conduct an additional robustness check using an alternative proxy for the X^{system} variable that is more directly linked to short-term funding markets, where MMFs play a central role. We measure short-term funding stress as the spread between the 90-day AA financial commercial paper rate and the 3-month Treasury bill rate, using FRED data. An increase in this spread indicates that short-term private funding becomes more expensive relative to Treasury bills, consistent with greater stress in short-term funding markets.

Table 11 reports the results. By comparing the baseline estimates presented in Table 6, we find that most of the results are qualitatively unchanged. In particular, the negative relation between $\Delta CoVaR$ and *Size* remains robust across specifications, while the negative association with *Wam* is also confirmed, though with the statistical significance of its coefficients lower (specification [iii]). Likewise, *Wal* shows the same sign and significance across specifications. The main difference concerns $\Delta Size$, which loses statistical significance in specification [i] and becomes negative and statistically significant in specification [ii]. These results suggest that our main findings are broadly robust to the use of a system variable closer to MMFs, related to short-term funding transmission channel.

Table 11: MMFs US$ and US$ Off Shore without periods of bubbles using Commercial Paper as X^{system}.

Dependent variable: ΔCoVaR$_{i,t}$	**[i]**	**[ii]**	**[iii]**
Size$_{i,t-1}$	-0.0342*	-0.0698***	-0.0717***
	(0.0164)	(0.0153)	(0.0153)
Wam$_{i,t-1}$	-0.2917***	-0.0047	-0.0355*
	(0.0203)	(0.0156)	(0.0164)
Wal$_{i,t-1}$	0.1232***	-0.0365	-0.0191
	(0.0207)	(0.0194)	(0.0197)
ΔSize$_{i,t-1}$	0.1417	-0.3264**	-0.1894
	(0.1216)	(0.1034)	(0.1049)
ΔGDP$_{t-1}$	-0.0303***		
	(0.0025)		
ΔCPI$_{t-1}$	12.3092***		
	(0.9933)		
10-year Government Bond$_{t-1}$	-0.1833***		
	(0.0078)		
Investment-to-GDP$_{t-1}$	0.3242***		
	(0.0256)		
Money Market MCI$_{t-1}$	0.1126***		
	(0.0052)		
Constant	1.5140***	3.8709***	3.4435***
	(0.2078)	(0.1470)	(0.1811)
Fixed Effects	YES	YES	YES
Time Dummy	NO	NO	YES
Macro Controls	YES	NO	NO
ΔCoVaR state variables	NO	YES	NO
N. Obs.	134,083	134,083	134,083
Adjusted R^2	0.09	0.25	0.27
F-Test	78.53***	171.70***	90.71***

The table reports the results between systemic risk and MMFs characteristics. The dependent variable is ΔCoVaR computed using X^{System} as the spread of commercial paper yields over the federal fund rate. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ of both US-domiciled and US-Off shore MMFs on the bubble indicators, fund fixed effects, macroeconomic controls (column [i]), $\Delta CoVaR$ state variables (column [ii]) and monthly dummies (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

5.2 Marginal Expected Shortfall

The MES of a financial institution measures the degree to which that institution is exposed to tail shocks and systemic risk. It is a useful complement to $\Delta CoVaR$ which measures the institution contribution to overall systemic risk. As neither of the measures are grounded in solid economic theory researchers typically use multiple measures and look for common trends. In our case, we are more interested in the contribution of each MMFs to overall systemic risk rather to its exposure, and so we focused on $\Delta CoVaR$ in the main analysis. We compute the *MES* as a complementary robustness check. Since *MES* is computed using the same MMF gross yields employed in the $\Delta CoVaR$ setting, it should not be interpreted as an independent validation of the gross yields input, but rather as an additional check on the robustness of the systemic risk analysis. We calculate the *MES* as the average return of each MMF during the 5% of days when the financial system experienced the most severe losses. Specifically, we analyze the 5% worst system returns over the past 12 months on a monthly basis. Following Acharya et al. (2017), we use the overall market return, proxied by the S&P 500 index.

We then repeat the analysis we carried out in Section 4 using *MES* as our dependent variable. Table 12 reports the results. Most of the results carry over using this alternative systemic risk measure. The signs and magnitudes of the control variables are stable and most of the effect of the MMFs characteristics are confirmed. Specifically, larger MMFs have lower *MES* and bubble periods are indeed associated with higher systemic risk. Some differences emerge with respect to the effect of *Wam* and *Wal* when they are interacted with boom and busts dummies. In the robustness regressions, these variables are mostly associated with increases in systemic risk during bubble periods. A potential explanation is the fact that while a higher *MES* indicates that an MMF has greater systemic risk *exposure*, a higher $\Delta CoVaR$ indicates that a MMF has a larger systemic risk *contribution.* So MMFs with higher maturity mismatches or that are more exposed to credit risk could suffer more during bubble periods, more than contributing to increases in systemic risk.

In particular, when we analyze MMFs in the US, we find that both $\Delta CoVaR$ and *MES* decrease with higher values of *Wam*, while both measures increase with higher *Wal* values. Similar to $\Delta CoVaR$, *MES* also decreases with greater growth of *Government* MMFs during equity market bubble periods. Both $\Delta CoVaR$ and *MES* increase with greater growth of *Government* MMFs during bust periods of the S&P 500. There are only two differences between $\Delta CoVaR$ and *MES*: the first corresponds to the growth of *Government* MMFs during real estate boom periods, and the second corresponds to the growth of *Prime* MMFs during equity market bust periods.

When we consider both MMFs in the US off shore, we find that both $\Delta CoVaR$ and *MES* decrease with increasing *Wam*, while both increase with higher *Wal*. Additionally, similar to $\Delta CoVaR$, *MES* decreases with greater growth of *Government* MMFs during equity market bubble periods. Both $\Delta CoVaR$ and *MES* increase with greater growth of *Government* MMFs during bust periods of the S&P 500. However, there are three differences between $\Delta CoVaR$ and *MES*: first, in correspondence with the *Size* of *Prime* MMFs; second, in correspondence with the *Wal* of *Prime* MMFs during real estate boom periods; and third, in correspondence with the growth of *Prime* MMFs during equity market bust periods.

Table 12: MMFs US$ and US$ Off Shore using MES.

Dependent variable: $MES_{i,t}$	MMFs US and MMFs Off Shore	MMFs US$	Prime	Government	MMFs US and MMFs Off Shore	Prime	Government
	[i]	[i]	[ii]	[iii]	[i]	[ii]	[iii]
$Size_{i,t-1}$	-0.0001	0.0042	-0.0063	0.0024	0.0005	-0.0095**	0.0120**
	(0.0019)	(0.0034)	(0.0041)	(0.0037)	(0.0036)	(0.0047)	(0.0042)
$Size_{i,t-1}$*Real Estate Boom	-0.0043***	-0.0076**	-0.0047	0.0072**	-0.0031	0.0038	0.0093**
	(0.0001)	(0.0027)	(0.0040)	(0.0031)	(0.0029)	(0.0051)	(0.0034)
$Size_{i,t-1}$*Real Estate $Bust_t$	0.0073***	-0.0018	0.002	0.0061**	-0.0018	0.0085**	0.0111***
	(0.0010)	(0.0015)	(0.0025)	(0.0019)	(0.0019)	(0.0037)	(0.0023)
$Size_{i,t-1}$*Equity $Boom_t$	-0.0013	0.0036*	0.0152***	-0.0036	0.0059**	-0.0011	-0.0128***
	(0.0013)	(0.0022)	(0.0041)	(0.0026)	(0.0022)	(0.0044)	(0.0029)
$Size_{i,t-1}$*Equity $Bust_t$	-0.0036**	0.0053**	0.0034	-0.0071**	0.0089***	-0.0091**	-0.0170***
	(0.0013)	(0.0022)	(0.0031)	(0.0024)	(0.0024)	(0.0031)	(0.0028)
$Wam_{i,t-1}$	0.0059*	0.0035	0.0043	-0.012	0.0290*	0.0233	-0.0369**
	(0.0031)	(0.0183)	(0.0190)	(0.0187)	(0.0152)	(0.0170)	(0.0156)
$Wam_{i,t-1}$*Real Estate $Boom_t$	0.0892***	-0.0158	0.0145	0.0928***	-0.1524***	0.1719***	0.2697***
	(0.0046)	(0.0184)	(0.0216)	(0.0191)	(0.0198)	(0.0236)	(0.0207)
$Wam_{i,t-1}$*Real Estate $Bust_t$	0.0343***	0.0367**	-0.0887***	-0.0165	-0.0547**	0.0797**	0.0956***
	(0.0038)	(0.0131)	(0.0157)	(0.0138)	(0.0226)	(0.0254)	(0.0231)
$Wam_{i,t-1}$*Equity $Boom_t$	-0.0669***	0.0271	-0.0002	-0.1003***	0.0752***	-0.1023***	-0.1647***
	(0.0044)	(0.0220)	(0.0255)	(0.0226)	(0.0138)	(0.0190)	(0.0150)
$Wam_{i,t-1}$*Equity $Bust_t$	-0.0331***	-0.0342	0.0570**	0.0199	0.0074	-0.0573**	-0.0380**
	(0.0039)	(0.0229)	(0.0243)	(0.0234)	(0.0154)	(0.0189)	(0.0164)
$Wal_{i,t-1}$	-0.0034	-0.0039	0.007	-0.0085	-0.0364**	0.0014	0.0254
	(0.0031)	(0.0188)	(0.0193)	(0.0190)	(0.0154)	(0.0169)	(0.0158)
$Wal_{i,t-1}$*Real Estate $Boom_t$	-0.0744***	0.0077	-0.0376*	-0.0540**	0.1589***	-0.2245***	-0.2756***
	(0.0037)	(0.0193)	(0.0225)	(0.0208)	(0.0200)	(0.0264)	(0.0224)
$Wal_{i,t-1}$*Real Estate $Bust_t$	-0.0560***	-0.0473***	0.0685***	-0.0033	0.0482**	-0.0976***	-0.1458***
	(0.0037)	(0.0141)	(0.0158)	(0.0160)	(0.0230)	(0.0255)	(0.0246)
$Wal_{i,t-1}$*Equity $Boom_t$	0.0690***	-0.0029	0.0123	0.0635**	-0.0484***	0.1364***	0.1436***
	(0.0041)	(0.0226)	(0.0269)	(0.0239)	(0.0136)	(0.0225)	(0.0171)
$Wal_{i,t-1}$*Equity $Bust_t$	0.0574***	0.0486**	-0.0418	-0.0019	0.0146	0.0711***	0.0600***
	(0.0037)	(0.0244)	(0.0256)	(0.0244)	(0.0158)	(0.0188)	(0.0171)
$\Delta Size_{i,t-1}$	0.0139	0.0172	0.4435***	-0.2287**	0.0104	0.6192**	-0.4193***
	(0.0137)	(0.0153)	(0.0922)	(0.0885)	(0.0177)	(0.1904)	(0.1169)
$\Delta Size_{i,t-1}$*Real Estate $Boom_t$	-0.1416**	-0.3319***	-0.2275	0.5604***	-0.3653***	-0.0757	0.5875***
	(0.0445)	(0.0962)	(0.1555)	(0.1045)	(0.0895)	(0.1763)	(0.0968)
$\Delta Size_{i,t-1}$*Real Estate $Bust_t$	-0.2396***	-0.5080***	0.6318***	0.5780***	-0.4622***	0.3800**	0.4559***
	(0.0647)	(0.0550)	(0.1013)	(0.0998)	(0.0533)	(0.1179)	(0.1086)
$\Delta Size_{i,t-1}$*Equity $Boom_t$	1.4103***	2.0237***	1.2656*	-4.4805***	2.1972***	-0.1595	-4.3878***
	(0.3757)	(0.3341)	(0.7172)	(0.4360)	(0.2920)	(0.7244)	(0.4155)
$\Delta Size_{i,t-1}$*Equity $Bust_t$	2.5389***	1.4380***	0.6694	0.295	1.4742***	1.2178**	0.0629
	(0.2616)	(0.1228)	(0.5695)	(0.5446)	(0.1253)	(0.5788)	(0.5304)
ΔGDP	-0.0148***	-0.0190***			-0.0142***		
	(0.0004)	(0.0002)			(0.0004)		
ΔCPI_{t-1}	-2.9109***	-3.9401***			-3.3014***		
	(0.1079)	(0.1098)			(0.1052)		
10-year Government Bond	0.0108***	0.0056***			0.0109***		
	(0.0009)	(0.0009)			(0.0009)		
Investment-to-GDP_{t-1}	0.1069***	0.1474***			0.0959***		
	(0.0048)	(0.0028)			(0.0040)		
Money Market MCI_{t-1}	0.0450***	0.0525***			0.0439***		
	(0.0007)	(0.0005)			(0.0007)		
Constant	-0.7308***	-0.9679***			-0.6498***		
	(0.0365)	(0.0238)			(0.0446)		
Fixed Effects	YES	YES			YES		
Catogories Dummy (Prime and Government)	NO	YES			YES		
Bubbles Dummy	YES	YES			YES		
Dummy MMFs US*Bubbles	YES	YES			YES		
Dummy MMFs US$	YES	YES			NO		
Dummy MMFs US Offshore	NO	NO			YES		
Macro Controls	YES	YES			YES		
N. Obs.	126,703	106,108			126,703		
Adjusted R^2 *within*	0.51	0.63			0.53		
F-Test	367.91***	459.75***			193.19***		

The table reports the results between MES, as alternative systemic risk measure for MMFs, and asset price bubbles. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

5.3 Economic mechanisms and additional evidence for key findings

In this section, we present additional evidence and we provide a discussion supporting the "*safe haven*" interpretation of *government* MMFs, with particular emphasis on the role of weighted average maturity in the MMFs context.

We begin by examining the role of MMFs' size and how its effect differs between *government* and other MMFs. To this end, we include a dummy variable equal to 1 for government MMFs, and 0 elsewhere, together with its interaction with the *Size* of MMFs. Table 13 shows that the interaction term $MMFs\ Government_i*Size_{i,t-1}$ is negative and statistically significant when $\Delta CoVaR$ is used as dependent variable (specifications [i], [ii], and [iii]), whereas the coefficient on $Size_{i,t-1}$ alone is small and statistically insignificant.

This suggests that the risk-reducing effect is associated with size is concentrated among *government* MMFs. Consistent results emerge when systemic risk is measured using *MES*. In this case, the interaction term $MMFs\ Government_i*Size_{i,t-1}$ remains negative and statistically significant in specifications [ii] and [iii], indicating that larger *government* MMFs are associated with lower contributions to systemic risk. Overall, these findings support the interpretation of large *government* MMFs as safe-haven vehicles during periods of financial stress. A plausible explanation is that, during periods of market turbulence and "*flight to quality*", investors reallocate liquidity toward larger government MMFs, which hold safer and more liquid assets and therefore transmit less risk to the financial system.

We also test the role played by the weighted average maturity in the MMFs context. In particular, we conduct three empirical tests to evaluate the portfolio quality and rollover mechanisms. First, we test the effect of *Wam* on systemic risk in relation to the portfolio

Table 13: Testing the "*safe-haven*" interpretation for *government* MMFs.

Dependent variable:	**ΔCoVaR**			**MES**		
	[i]	**[ii]**	**[iii]**	**[i]**	**[ii]**	**[iii]**
MMFs $Government_i$	0.0012	0.0010	0.0000	-0.0193*	0.0381**	0.0187
	(0.0018)	(0.0018)	(0.0018)	(0.0088)	(0.0137)	(0.0106)
MMFs $Government_i$*$\text{Size}_{i,t-1}$	-0.0009***	-0.0008**	-0.0007**	0.0026	-0.0056**	-0.0043**
	(0.0003)	(0.0002)	(0.0002)	(0.0014)	(0.0020)	(0.0016)
$\text{Size}_{i,t-1}$	-0.0002	0.0002	-0.0003	-0.0033**	0.0076***	-0.0013
	(0.0002)	(0.0002)	(0.0002)	(0.0011)	(0.0016)	(0.0012)
$\Delta\text{Size}_{i,t-1}$	-0.0008	0.0019	-0.0015	0.0393***	0.0438**	0.0444**
	(0.0010)	(0.0011)	(0.0010)	(0.0095)	(0.0138)	(0.0171)
$\text{Wam}_{i,t-1}$	0.0000	-0.0007***	0.0003	-0.0300***	-0.0175***	-0.0120***
	(0.0002)	(0.0002)	(0.0002)	(0.0017)	(0.0023)	(0.0018)
$\text{Wal}_{i,t-1}$	-0.0004*	-0.0001	-0.0005*	0.0241***	0.0252***	0.0263***
	(0.0002)	(0.0002)	(0.0002)	(0.0021)	(0.0031)	(0.0025)
Constant	0.0286***	0.0272***	0.0301***	0.0465***	-1.1190***	0.4285***
	(0.0015)	(0.0017)	(0.0015)	(0.0086)	(0.0218)	(0.0112)
Fixed Effects	YES	YES	YES	YES	YES	YES
Time Dummy	YES	NO	NO	YES	NO	NO
Macro Controls	NO	YES	NO	NO	YES	NO
ΔCoVaR state variables	NO	NO	YES	NO	NO	YES
Bubble periods	YES	YES	YES	YES	YES	YES
N. Obs.	106,108	106,108	106,108	106,108	106,108	106,108
R^2 *Adjusted*	0.36	0.25	0.36	0.83	0.59	0.73
F-Test	196.04***	203.48***	199.91***	3602.76***	1859.02***	2206.45***

The table reports the results between systemic risk measures, $\Delta CoVaR$ and *MES*, for MMFs and MMFs characteristics. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF; *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days). As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ and *MES* of US MMFs on the bubble indicators, fund fixed effects, monthly dummies (column [i]), macroeconomic controls (column [ii]) and $\Delta CoVaR$ state variables (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

quality. We expect a negative relationship between the systemic risk measure and the interaction term between *Wam* and a composite rating measure. We construct a proxy for credit quality by combining information (available from our dataset) from major rating agencies such as Standard & Poor's, Moody's, and Fitch. For each of them, we convert the MMF's rating into a three-level ordinal variable, taking values 1, 2, and 3, where 3 denotes the highest quality (i.e., "top tier"), 2 is an intermediate tier, and 1 is all remaining non-missing categories (i.e., "lower tier"). In particular, for S&P we assign 3 to "AAAf/S1+", 2 to "AAAm" and “AAAmG”, and 1 to any other non-empty S&P rating. For Moody’s, we assign 3 to the top category “AAA/Aaa” and equivalent “Aaa-mf”, “Aaa/MR1+”, 2 to “Aa-mf”, and 1 to any other non-empty Moody’s rating. For Fitch, we assign 3 to “AAA/V-1+” or “AAA/V1+”, 2 to “AAAmf” and “AAmmf”, and 1 to any other non-empty Fitch rating. We then construct the composite measure as the row-wise mean of the available agency-specific scores. Second, we investigate whether higher values of *Wam* are associated with the level of MMFs’ gross yields. We find that higher *Wam* is associated with lower gross yields. The result is consistent with a shift in the portfolio composition toward safer (higher-quality) instruments within Rule 2a-7 constraints, rather than search for yield. Finally, we also investigate whether higher values of *Wam* are associated with more stable gross yields, measured by the rolling 12-month volatility of gross yields. We find that longer *Wam* is associated with significantly lower yield volatility, consistent with reduced rollover exposure and a “locking-in” of more stable yield dynamics.

Table 14: Testing the "*portfolio quality and rollover*" mechanism for MMFs.

Dependent variable:	**ΔCoVaR**		**Gross Yield**		**12-month rolling window Gross Yield**	
	[i]	**[ii]**	**[i]**	**[ii]**	**[i]**	**[ii]**
$\text{Size}_{i,t-1}$	-0.0006***	-0.0002	0.0159***	0.0392***	0.0101***	0.0470***
	(0.0001)	(0.0002)	(0.0056)	(0.0066)	(0.0015)	(0.0043)
$\Delta\text{Size}_{i,t-1}$	-0.0008	0.0018	0.4134***	0.5264***	0.2267***	0.3336***
	(0.0011)	(0.0012)	(0.0885)	(0.1019)	(0.0343)	(0.0441)
$\text{Wam}_{i,t-1}$	0.0001	0.0005**	0.1874***	0.1538***	0.0305***	0.0178***
	(0.0002)	(0.0002)	(0.0192)	(0.0177)	(0.0056)	(0.0056)
$\text{Wal}_{i,t-1}$	0.0025***	0.0022***	-0.5688***	-0.4377***	-0.1352***	-0.0765***
	(0.0007)	(0.0007)	(0.0723)	(0.0650)	(0.0225)	(0.0268)
Rating $\text{Score}_{i,t}$	0.0041***	0.0047***	0.2693	0.1101	0.2433***	0.1554*
	(0.0014)	(0.0014)	(0.2170)	(0.1753)	(0.0779)	(0.0837)
Rating $\text{Score}_{i,t}$*$\text{Wam}_{i,t-1}$	-0.0016***	-0.0016***	0.0368	-0.0066	0.0012	-0.0112
	(0.0003)	(0.0003)	(0.0321)	(0.0288)	(0.0101)	(0.0118)
Constant	0.0169***	0.0087**	0.4049	0.5459	-0.0118	-0.3925**
	(0.0035)	(0.0035)	(0.4842)	(0.3863)	(0.1748)	(0.1880)
Fixed Effects	YES	YES	YES	YES	YES	YES
Time Dummy	YES	NO	YES	NO	YES	NO
Bubble periods	NO	YES	NO	YES	NO	YES
N. Obs.	91,575	91,575	91,167	91,167	91,555	91,555
R^2 *Adjusted*	0.27	0.11	0.68	0.65	0.58	0.33
F-Test	54.92***	87.46***	3120.75***	4775.82***	7135.37***	1989.89***

The table reports the results between systemic risk measure, $\Delta CoVaR$, *Gross Yield*, and *12-month rolling window Gross Yield*, for MMFs and MMFs characteristics. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF; *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days). As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ and *MES* of US MMFs on fund fixed effects, monthly dummies (column [i]), and on fund fixed effects and bubble indicators (column [ii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

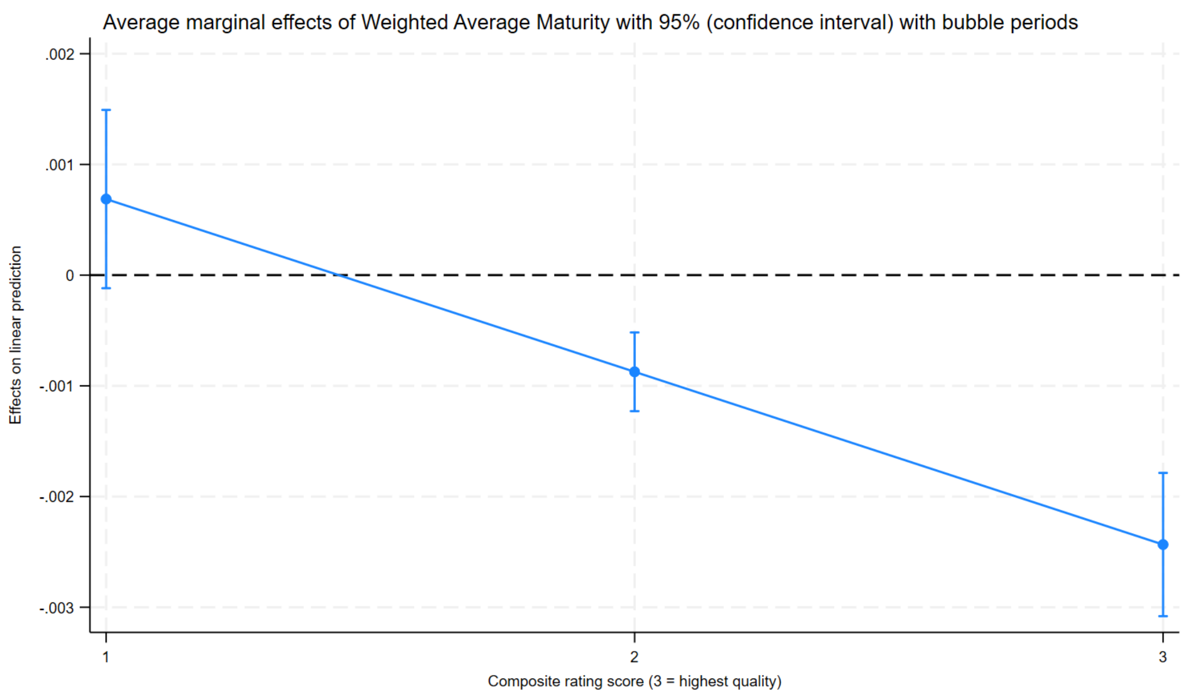
Table 14 reports the results[10]. When the dependent variable is $\Delta CoVaR$, we find that the interaction between *rating score* and *Wam* is negative and statistically significant. We have also computed the marginal effects, and we find an interesting pattern: in particular, for specification [i], when the dependent variable is the $\Delta CoVaR$ the marginal effect of *Wam* on systemic risk is positive for low-quality portfolios: for funds with rating 1, the coefficient is 0.0009**, but turns negative and grows in magnitude for higher-quality portfolios. When the

[10]As a sample-comparability check, we re-estimate the baseline specifications on the restricted sample used in the mechanism tests. The results are broadly similar to those in the full sample and are available upon request.

rating is 2, the coefficient is -0.0007***, while when the rating is 3, the coefficient becomes -0.0022***.

We also provide a margin plot that shows the clear pattern. The dependent variable is the $\Delta CoVaR$, and we compute the marginal effects on the interaction term $Rating\ Score_{i,t} * Wam_{i,t-1}$, during bubble periods (Figure 7) and with time fixed effects (Figure 8).

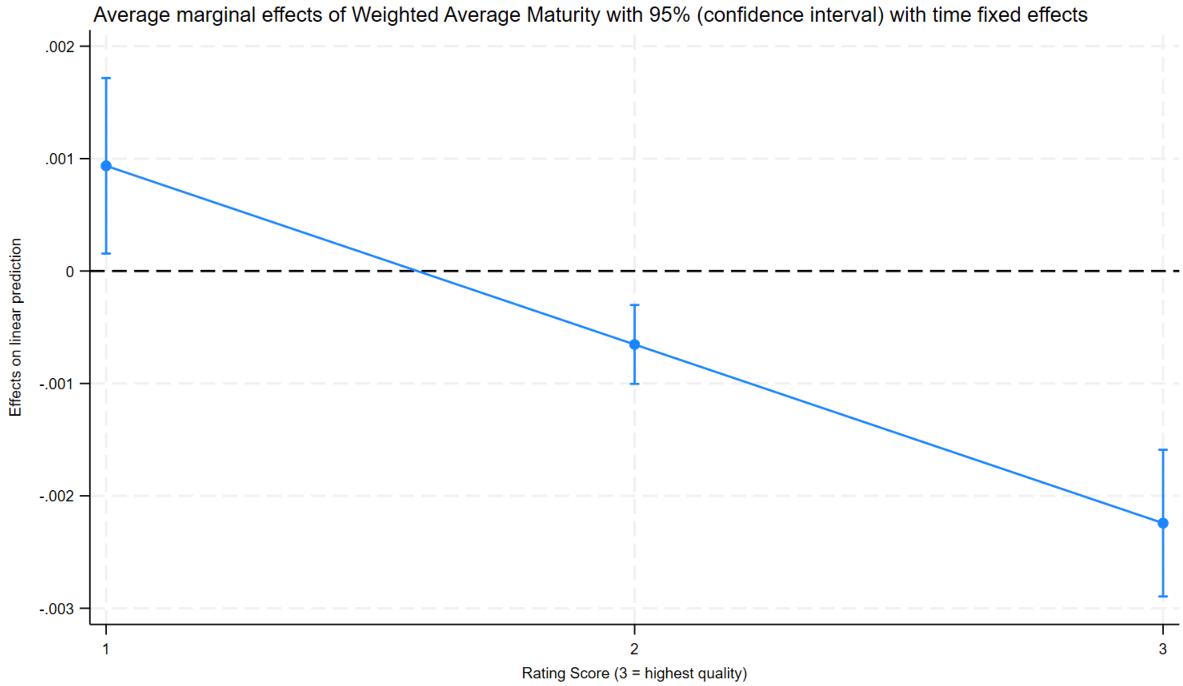
Figure 7: Marginal effects of *Wam* and rating score during bubble periods.



Source: Authors elaboration.

Finally, we test for non-linear (threshold) effects by allowing the marginal effect of *Wal* to differ for MMFs in the upper tail. *High Wal* is a dummy variable equal to 1 when it exceeds the 75^{th} percentile and zero otherwise. Table 15 reports the results. We find that the interaction term $High\ Wal_i * Wal_{i,t-1}$ is positive and statistically significant in several specifications, and that the marginal effects show that the association between *Wal* and

Figure 8: Marginal effects of *Wam* and rating score with time fixed effects.



Source: Authors elaboration.

systemic risk measures ($\Delta CoVaR$ and MES) is concentrated among MMFs with higher Wal values. The findings are consistent with a rollover/liquidity-mismatch channel through which MMFs' vulnerabilities may translate into higher systemic risk. However, the Wal threshold test is a partial proxy for the MMF liquidity dynamics. While it captures the asset-side maturity, it does not fully reflect the liability side liquidity mismatch, including redemption pressure, fire-sale dynamics, and contagion effects.

5.4 Further sensitivity analyses

Finally, we conducted two further sensitivity analyses to our main results. First, we compute MMFs' VaR from their past equity returns using 1-year rolling windows; second,

Table 15: Testing the "*threshold effects*" for *Wal*.

Dependent variable:	**ΔCoVaR**			**MES**		
	[i]	**[ii]**	**[iii]**	**[i]**	**[ii]**	**[iii]**
$\text{Size}_{i,t-1}$	-0.0006***	-0.0004**	-0.0006***	-0.0029**	0.0016	-0.0047***
	(0.0001)	(0.0001)	(0.0001)	(0.0013)	(0.0015)	(0.0014)
$\Delta\text{Size}_{i,t-1}$	-0.0009	0.0011	-0.0016*	0.0338***	0.0478***	0.0515***
	(0.0009)	(0.0010)	(0.0010)	(0.0116)	(0.0135)	(0.0160)
$\text{Wam}_{i,t-1}$	-0.0002	-0.0006***	0.0001	-0.0311***	-0.0143***	-0.0145***
	(0.0002)	(0.0002)	(0.0002)	(0.0021)	(0.0025)	(0.0023)
$\text{Wal}_{i,t-1}$	-0.0004**	-0.0003	-0.0005**	0.0299***	0.0232***	0.0283***
	(0.0002)	(0.0002)	(0.0002)	(0.0028)	(0.0035)	(0.0032)
High Wal_i (>p75^{th})	0.0002	-0.0048*	-0.0063***	-0.0459	-0.4644***	-0.2367***
	(0.0026)	(0.0025)	(0.0024)	(0.0313)	(0.0402)	(0.0346)
High Wal_i*$\text{Wal}_{i,t-1}$	0.0001	0.0012**	0.0015***	0.0097	0.1017***	0.0513***
	(0.0006)	(0.0006)	(0.0005)	(0.0069)	(0.0090)	(0.0077)
Constant	0.0261***	0.0356***	0.0262***	0.0437***	-0.6490***	0.3513***
	(0.0013)	(0.0018)	(0.0012)	(0.0114)	(0.0357)	(0.0131)
Fixed Effects	YES	YES	YES	YES	YES	YES
Time Dummy	YES	NO	NO	YES	NO	NO
Macro Controls	NO	YES	NO	NO	YES	NO
ΔCoVaR state variables	NO	NO	YES	NO	NO	YES
Bubble periods	YES	YES	YES	YES	YES	YES
Marginal effects: High Wal_i*$\text{Wal}_{i,t-1}$	-0.0003	0.0009	0.0010*	0.0396***	0.1249***	0.0797***
	(0.0006)	(0.0006)	(0.0006)	(0.0069)	(0.0087)	(0.0073)
N. Obs.	134,953	134,953	134,953	127,454	127,454	127,454
R^2 *Adjusted*	0.27	0.19	0.26	0.69	0.48	0.60
F-Test	86.79***	100.31***	99.92***	616.05***	552.6***	461.60***

The table reports the results between systemic risk measures, $\Delta CoVaR$ and *MES*, for MMFs and MMFs characteristics. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF; *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days). As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. We regress the $\Delta CoVaR$ and *MES* of US MMFs on the bubble indicators, fund fixed effects, monthly dummies (column [i]), macroeconomic controls (column [ii]) and $\Delta CoVaR$ state variables (column [iii]). Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

we replicate our analyses after excluding the COVID-19 period, specifically from June 2019 to June 2020 to make sure that they are not driven simply by an exogenous stress episode. The results are reported in Table C1 and in Table C2, respectively, of the Internet Appendix. In both cases, the paper's main findings are confirmed. Finally, most of the identified bubble episodes in the sample occurred after 2020, raising the possibility that the results are heavily influenced by the COVID-19 period. We conduct a robust check by excluding the entire 2020–2022 period from their sample. This further robustness check confirms in full our main findings. We do not report the results but they are available upon request.

6 Conclusions

In this paper, we used $\Delta CoVaR$ to investigate the systemic risk contribution of 3,586 Money Market Funds during asset price bubbles in the US from January 2004 to December 2022. Leveraging state-of-the-art statistical techniques for bubble detection and granular fund-level data on MMF characteristics, we showed that these characteristics are key determinants of systemic risk.

We found that large MMFs and *government* MMFs investing exclusively in US Treasury securities are associated with lower systemic risk, whereas *prime* MMFs - which invest primarily in commercial paper and certificates of deposit - contribute more significantly to systemic risk. More specifically, we found that systemic risk during bubble periods is driven more by a fund's rapid growth than by its size *per se.* During equity bubbles, systemic risk increases significantly with higher MMF growth, possibly due to investors *reaching for yield* amid an equity boom. Additionally, $\Delta CoVaR$ is sensitive to the weighted average maturity (*Wam*) of *prime* MMFs during real estate bubbles, particularly in boom phases. In contrast, systemic risk for *government* MMFs remained unaffected by *Wam.* We also found that $\Delta CoVaR$ responds to a fund's weighted average life (*Wal*) during an equity boom, suggesting that MMFs with a higher *Wal* may face greater losses, impacting financial system stability. Finally, we showed that US dollar-denominated MMFs domiciled offshore behave similarly to their US-domiciled counterparts.

Our results remained robust when using *MES* instead of $\Delta CoVaR$ as the measure of systemic risk, incorporating $\Delta CoVaR$ state variables in the estimations, applying an alternative estimation strategy for $\Delta CoVaR$, and excluding the COVID-19 period from the analysis.

The findings of this paper carry several policy implications. First, our result that rapid asset growth in MMFs increases systemic risk suggests that supervisors should closely monitor funds experiencing significant asset inflows, particularly during periods of market exuberance. Second, our findings underscore the importance of examining the microeconomic drivers of systemic risk rather than focusing solely on macroeconomic variables correlated with asset price bubbles. In particular, we highlight the crucial role of non-bank intermediaries-whose contribution has been relatively underexplored in the literature-in amplifying systemic risk. Further research should explore the linkages between banks and non-bank financial intermediaries and how their interactions shape systemic risk in response to evolving economic, financial, and regulatory environments. Understanding these dynamics is essential for designing a resilient financial system. We leave these important questions to future research.

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INTERNET APPENDIX

Asset Price Bubbles and Systemic Risk in Money Market Funds

May 31, 2026

Appendix A Measuring Bubble Episodes

Exuberance behavior in asset prices is a primary indicator of market exuberance during the phase of a bubble. These episodes may be subject to econometric testing using recursive testing procedures, like the right-sided unit root tests in Phillips et al. (2011). Recursive right-sided unit root tests seem to be particularly effective as real-time detection mechanisms for slightly explosive behavior and market exuberance.

As first step, we start with the following Augmented Dickey Fuller (ADF) regression equation:

$$\Delta y_t = \alpha_{r_1,r_2} + \beta_{r_1,r_2} y_{t-1} + \sum_{i=1}^{k} \delta^i_{r_1,r_2} \Delta y_{t-i} + \varepsilon_t \tag{A1}$$

where Δ is the first-difference operator; y_t denotes the time series of interest at time t; k is a scalar that denotes the number of lags of the dependent variable that are included to accommodate serial correlation; r_1 and r_2 denote the fraction of the total number of time periods in the sample that specify the starting and the ending points, respectively; α_{r_1,r_2}, β_{r_1,r_2} and $\delta^i_{r_1,r_2}$ are regression coefficients; ε_t is the error term. We test the null hypothesis of a unit root in y_t, $H_0 : \beta_{r_1,r_2} = 0$, against the alternative of exuberance behavior, $H_1 : \beta_{r_1,r_2} > 0$.

The ADF test statistic corresponding to the null hypothesis is given by: $ADF_{r_1}^{r_2} = \frac{\hat{\beta}_{r_1,r_2}}{s.e.(\hat{\beta}_{r_1,r_2})}$.

Phillips et al. (2011) propose a methodology that is consistent with a single boom-bust episode. The methodology involves estimating Equation (A1) using a forward expanding sample. In this setting, the beginning of the sub sample is held constant at $r_1 = 0$, while the end of the sub sample, r_2, increases from r_0 (the minimum window size) to 1 (the entire sample period). Recursive estimation of Equation (A1) yields a sequence of $ADF_0^{r_2}$ statistics. The supremum of this sequence is called the SADF and is defined as follows:

$$SADF_{r_0} = \sup_{r_2 \in [r_0,1]} ADF_0^{r_2} \tag{A2}$$

similar to the standard ADF test, when the SADF statistic exceeds the right-tailed critical value, the unit root hypothesis is rejected in favor of exuberance behavior. However, in contrast to the standard ADF test, the alternative hypothesis of the SADF test is that of exuberance dynamics in some parts of the sample. One potential limitation of the recursive approach suggested by Phillips et al. (2011) is that it provides consistent estimates of the origination and ending dates of the first bubble but not subsequent ones.

Phillips et al. (2015a,b) propose an extension of the SADF, the Generalized SADF (GSADF), which has the same alternative hypothesis as the SADF but which covers a larger number of sub samples. The GSADF test involves an extensive set of regressions, in which the first observation varies from 0 to $r_2 - r_0$, while the last observation varies from r_0 to 1. In comparison to the SADF, the GSADF test shows a more flexibility on the estimation window and it is consistent with multiple exuberance periods, while the SADF test is consistent only with a single episode. The GSADF statistic is defined as:

$$GSADF_{r_0} = \sup_{r_2 \in [r_0,1], r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2} \tag{A3}$$

The rejection of the unit root hypothesis in favor of exuberance behavior requires that the test statistic exceeds the right-tailed critical value from its limit distribution. If the null of a unit root in y_t is rejected, then the SADF and the GSADF methodologies can provide a sequence of episodes of exuberance. The inference for the ADF, SADF and GSADF statistics requires critical values computed using Monte Carlo simulations.

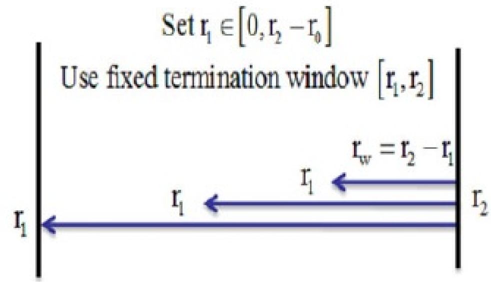
Consequently, Phillips et al. (2015a,b) introduce the Backward Supremum Augmented Dickey Fuller (BSADF) statistic defined as follows:

$$BSADF_{r2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \left\{ SADF_{r_1}^{r_2} \right\} \tag{A4}$$

where r_1 and r_2 denote the starting and the ending fraction of the sample, respectively, implying that $r_1 < r_2$; r_0 is the fractional threshold and it is chosen on a lower bound of 1% of the full sample with the following functional form: $r_0 = \left(0.01 + 1.8/\sqrt{T}\right)$, where T refers to the number of observations in the sample. We denote r_w, the window size of the regression, as $r_1 - r_2$. Appendix A describes the estimation approach.

Phillips et al. (2015a) suggest to implement the BSADF test on a sample sequence where the end point is fixed at r_2, and expands backwards to the starting point, r_1, which varies between 0 and $(r_2 - r_0)$. Let r_e the fraction of the sample at which the bubble starts, r_f the fraction of the sample at which it ends, and $\hat{r}_e$ and $\hat{r}_f$ the estimators of both. The origination

Figure A1: Recursive nature of the BSADF test.



Source: Phillips et al. (2015a, p. 1052).

and termination points of a bubble, i.e. r_e and r_f, are calculated according to the Equations (A5) and (A6):

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left[r_2 : BSADF_{r_2}(r_0) > scv^{\beta}_{r_2} \right] \tag{A5}$$

$$and \quad \hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta log(T), 1]} \left[r_2 : BSADF_{r_2}(r_0) < scv^{\beta}_{r_2} \right] \tag{A6}$$

where T is the number of observations, $scv^{\beta}_{r_2}$ is the critical value of the BSADF statistic based on $\lfloor Tr_2 \rfloor$ observations and confidence level β. $\lfloor Tr_2 \rfloor$ refers to the largest integer smaller than or equal to Tr_2. Phillips et al. (2015a) impose a condition that for a bubble to exist its duration must exceed a slowly varying (at infinity) quantity such as $L_T = log(T)$. This condition helps to exclude short lived blips in the fitted autoregressive coefficient and can be adjusted to consider the data frequency. Thus, $\delta log(T)$ is a minimal bubble length, and δ is a frequency-dependent parameter chosen freely.

Tables A1 and A2 report the BSADF and the BSADF 95% critical values computed on the Case-Shiller index and on the S&P500, respectively.

Table A1: Case-Shiller Index - Periods of Explosiveness, Boom and Bust.

Case-Shiller U.S. National Price Index Normalized for the personal consumption expenditure deflator																	
Date (monthly)	BSADF statistics	Critical Value 95	Expl.	Boom phase	Bust phase	Date (monthly)	BSADF statistics	Critical Value 95	Expl.	Boom phase	Bust phase	Date (monthly)	BSADF statistics	Critical Value 95	Expl.	Boom phase	Bust phase
01/01/2004	4.20	1.37	1	0	1	01/05/2010	-0.95	1.42	0	0	0	01/09/2016	-0.16	1.48	0	0	0
01/02/2004	3.96	1.37	1	0	1	01/06/2010	-0.90	1.42	0	0	0	01/10/2016	-0.20	1.48	0	0	0
01/03/2004	3.58	1.37	1	0	1	01/07/2010	-0.79	1.42	0	0	0	01/11/2016	-0.02	1.48	0	0	0
01/04/2004	3.56	1.37	1	0	1	01/08/2010	-0.55	1.42	0	0	0	01/12/2016	-0.10	1.48	0	0	0
01/05/2004	3.54	1.37	1	1	0	01/09/2010	-0.57	1.42	0	0	0	01/01/2017	-0.25	1.48	0	0	0
01/06/2004	3.54	1.37	1	1	0	01/10/2010	-0.56	1.42	0	0	0	01/02/2017	-0.29	1.48	0	0	0
01/07/2004	3.55	1.37	1	1	0	01/11/2010	-0.65	1.42	0	0	0	01/03/2017	-0.09	1.48	0	0	0
01/08/2004	3.51	1.38	1	1	0	01/12/2010	-0.73	1.42	0	0	0	01/04/2017	-0.24	1.48	0	0	0
01/09/2004	3.53	1.38	1	1	0	01/01/2011	-0.61	1.42	0	0	0	01/05/2017	0.03	1.48	0	0	0
01/10/2004	3.43	1.38	1	1	0	01/02/2011	-0.44	1.44	0	0	0	01/06/2017	0.00	1.48	0	0	0
01/11/2004	3.48	1.38	1	1	0	01/03/2011	-0.59	1.44	0	0	0	01/07/2017	0.05	1.48	0	0	0
01/12/2004	3.73	1.38	1	1	0	01/04/2011	-0.64	1.44	0	0	0	01/08/2017	0.04	1.48	0	0	0
01/01/2005	3.90	1.38	1	1	0	01/05/2011	-0.68	1.44	0	0	0	01/09/2017	-0.11	1.48	0	0	0
01/02/2005	3.97	1.38	1	1	0	01/06/2011	-0.86	1.44	0	0	0	01/10/2017	0.39	1.48	0	0	0
01/03/2005	4.05	1.38	1	1	0	01/07/2011	-0.81	1.44	0	0	0	01/11/2017	0.69	1.48	0	0	0
01/04/2005	4.00	1.38	1	1	0	01/08/2011	-0.74	1.44	0	0	0	01/12/2017	0.88	1.48	0	0	0
01/05/2005	4.05	1.38	1	1	0	01/09/2011	-0.72	1.44	0	0	0	01/01/2018	0.70	1.48	0	0	0
01/06/2005	4.09	1.38	1	1	0	01/10/2011	-0.72	1.44	0	0	0	01/02/2018	0.90	1.48	0	0	0
01/07/2005	3.86	1.38	1	0	1	01/11/2011	-0.59	1.44	0	0	0	01/03/2018	1.00	1.48	0	0	0
01/08/2005	3.49	1.38	1	0	1	01/12/2011	-0.73	1.44	0	0	0	01/04/2018	0.73	1.48	0	0	0
01/09/2005	2.47	1.38	1	0	1	01/01/2012	-0.74	1.44	0	0	0	01/05/2018	0.64	1.48	0	0	0
01/10/2005	3.06	1.38	1	1	0	01/02/2012	-0.80	1.44	0	0	0	01/06/2018	0.77	1.48	0	0	0
01/11/2005	4.31	1.38	1	1	0	01/03/2012	-1.17	1.44	0	0	0	01/07/2018	0.58	1.48	0	0	0
01/12/2005	3.86	1.38	1	0	1	01/04/2012	-1.22	1.44	0	0	0	01/08/2018	0.53	1.48	0	0	0
01/01/2006	3.06	1.38	1	0	1	01/05/2012	-1.35	1.44	0	0	0	01/09/2018	0.17	1.48	0	0	0
01/02/2006	2.89	1.38	1	0	1	01/06/2012	-1.36	1.44	0	0	0	01/10/2018	0.15	1.48	0	0	0
01/03/2006	2.36	1.38	1	0	1	01/07/2012	-1.29	1.45	0	0	0	01/11/2018	0.16	1.48	0	0	0
01/04/2006	0.41	1.38	0	0	0	01/08/2012	-1.16	1.45	0	0	0	01/12/2018	0.00	1.48	0	0	0
01/05/2006	0.06	1.39	0	0	0	01/09/2012	-1.17	1.45	0	0	0	01/01/2019	-0.07	1.48	0	0	0
01/06/2006	-0.90	1.39	0	0	0	01/10/2012	-1.18	1.45	0	0	0	01/02/2019	-0.19	1.48	0	0	0
01/07/2006	-1.15	1.39	0	0	0	01/11/2012	-1.38	1.45	0	0	0	01/03/2019	-0.31	1.48	0	0	0
01/08/2006	-1.26	1.39	0	0	0	01/12/2012	-1.39	1.45	0	0	0	01/04/2019	-0.37	1.48	0	0	0
01/09/2006	0.94	1.39	0	0	0	01/01/2013	-1.45	1.45	0	0	0	01/05/2019	-0.14	1.48	0	0	0
01/10/2006	1.57	1.39	1	1	0	01/02/2013	-1.38	1.45	0	0	0	01/06/2019	-0.15	1.48	0	0	0
01/11/2006	1.44	1.39	1	0	1	01/03/2013	-0.97	1.45	0	0	0	01/07/2019	-0.19	1.49	0	0	0
01/12/2006	1.07	1.39	0	0	0	01/04/2013	-1.01	1.45	0	0	0	01/08/2019	-0.02	1.49	0	0	0
01/01/2007	0.84	1.39	0	0	0	01/05/2013	-1.10	1.45	0	0	0	01/09/2019	-0.02	1.49	0	0	0
01/02/2007	0.52	1.39	0	0	0	01/06/2013	-1.03	1.45	0	0	0	01/10/2019	-0.06	1.49	0	0	0
01/03/2007	-0.09	1.39	0	0	0	01/07/2013	-1.00	1.45	0	0	0	01/11/2019	0.13	1.49	0	0	0
01/04/2007	-0.66	1.39	0	0	0	01/08/2013	-1.01	1.45	0	0	0	01/12/2019	0.05	1.50	0	0	0
01/05/2007	-1.18	1.39	0	0	0	01/09/2013	-0.96	1.45	0	0	0	01/01/2020	0.10	1.50	0	0	0
01/06/2007	-1.24	1.39	0	0	0	01/10/2013	-1.02	1.46	0	0	0	01/02/2020	0.12	1.50	0	0	0
01/07/2007	-1.10	1.39	0	0	0	01/11/2013	-1.08	1.46	0	0	0	01/03/2020	0.27	1.50	0	0	0
01/08/2007	-0.87	1.39	0	0	0	01/12/2013	-1.06	1.46	0	0	0	01/04/2020	0.53	1.51	0	0	0
01/09/2007	-0.95	1.39	0	0	0	01/01/2014	-1.08	1.46	0	0	0	01/05/2020	0.01	1.51	0	0	0
01/10/2007	-1.14	1.39	0	0	0	01/02/2014	-1.09	1.47	0	0	0	01/06/2020	-0.04	1.51	0	0	0
01/11/2007	-1.50	1.39	0	0	0	01/03/2014	-1.15	1.47	0	0	0	01/07/2020	0.21	1.51	0	0	0
01/12/2007	-1.29	1.39	0	0	0	01/04/2014	-1.24	1.47	0	0	0	01/08/2020	0.88	1.51	0	0	0
01/01/2008	-1.54	1.39	0	0	0	01/05/2014	-1.27	1.47	0	0	0	01/09/2020	1.46	1.51	0	0	0
01/02/2008	-1.58	1.39	0	0	0	01/06/2014	-1.22	1.47	0	0	0	01/10/2020	1.81	1.51	1	1	0
01/03/2008	-1.51	1.40	0	0	0	01/07/2014	-1.20	1.47	0	0	0	01/11/2020	1.83	1.51	1	1	0
01/04/2008	-1.18	1.40	0	0	0	01/08/2014	-1.00	1.47	0	0	0	01/12/2020	1.63	1.51	1	1	0
01/05/2008	-0.99	1.40	0	0	0	01/09/2014	-0.89	1.47	0	0	0	01/01/2021	1.95	1.51	1	1	0
01/06/2008	-0.77	1.40	0	0	0	01/10/2014	-0.73	1.47	0	0	0	01/02/2021	1.98	1.51	1	1	0
01/07/2008	-0.99	1.40	0	0	0	01/11/2014	-0.58	1.47	0	0	0	01/03/2021	2.05	1.51	1	1	0
01/08/2008	-1.22	1.40	0	0	0	01/12/2014	-0.46	1.47	0	0	0	01/04/2021	2.27	1.51	1	1	0
01/09/2008	-1.10	1.41	0	0	0	01/01/2015	-0.21	1.47	0	0	0	01/05/2021	2.59	1.51	1	1	0
01/10/2008	-1.38	1.41	0	0	0	01/02/2015	-0.59	1.47	0	0	0	01/06/2021	2.85	1.52	1	1	0
01/11/2008	-1.36	1.41	0	0	0	01/03/2015	-0.48	1.47	0	0	0	01/07/2021	2.73	1.52	1	1	0
01/12/2008	-0.93	1.41	0	0	0	01/04/2015	-0.48	1.47	0	0	0	01/08/2021	2.75	1.52	1	1	0
01/01/2009	-0.38	1.41	0	0	0	01/05/2015	-0.57	1.47	0	0	0	01/09/2021	2.78	1.52	1	1	0
01/02/2009	-0.23	1.41	0	0	0	01/06/2015	-0.54	1.48	0	0	0	01/10/2021	2.43	1.52	1	1	0
01/03/2009	-0.41	1.41	0	0	0	01/07/2015	-0.42	1.48	0	0	0	01/11/2021	2.68	1.52	1	1	0
01/04/2009	-0.34	1.41	0	0	0	01/08/2015	-0.27	1.48	0	0	0	01/12/2021	2.79	1.52	1	1	0
01/05/2009	-0.61	1.41	0	0	0	01/09/2015	-0.03	1.48	0	0	0	01/01/2022	3.14	1.52	1	1	0
01/06/2009	-0.44	1.41	0	0	0	01/10/2015	-0.04	1.48	0	0	0	01/02/2022	3.18	1.52	1	1	0
01/07/2009	-0.84	1.41	0	0	0	01/11/2015	-0.08	1.48	0	0	0	01/03/2022	3.01	1.52	1	1	0
01/08/2009	-0.46	1.41	0	0	0	01/12/2015	0.00	1.48	0	0	0	01/04/2022	3.22	1.52	1	1	0
01/09/2009	-0.58	1.41	0	0	0	01/01/2016	-0.09	1.48	0	0	0	01/05/2022	2.50	1.52	1	0	1
01/10/2009	-0.43	1.42	0	0	0	01/02/2016	-0.18	1.48	0	0	0	01/06/2022	1.08	1.52	0	0	0
01/11/2009	-0.73	1.42	0	0	0	01/03/2016	-0.37	1.48	0	0	0	01/07/2022	1.67	1.52	1	0	1
01/12/2009	-0.67	1.42	0	0	0	01/04/2016	-0.46	1.48	0	0	0	01/08/2022	0.33	1.52	0	0	0
01/01/2010	-0.50	1.42	0	0	0	01/05/2016	-0.33	1.48	0	0	0	01/09/2022	0.37	1.52	0	0	0
01/02/2010	-0.14	1.42	0	0	0	01/06/2016	-0.35	1.48	0	0	0	01/10/2022	0.91	1.52	0	0	0
01/03/2010	-0.83	1.42	0	0	0	01/07/2016	-0.16	1.48	0	0	0	01/11/2022	1.05	1.52	0	0	0
01/04/2010	-0.96	1.42	0	0	0	01/08/2016	-0.12	1.48	0	0	0	01/12/2022	0.19	1.52	0	0	0

The Table reports *BSADF* and the *BSADF* 95% critical values (cv) computed on the Case-Shiller index. The *BSADF* 95% critical values are based on a window size given by $r_0 = \left(0.01 + 1.8/\sqrt{T}\right)$, where T refers to the number of observations in the sample. Explosive behavior is an indicator variable equal to 1 when *BSADF* is above its 95% critical value and 0 otherwise.

Table A2: S&P 500 Index - Periods of Explosiveness, Boom and Bust.

S&P 500 Index																	
Date (monthly)	**BSADF statistics**	**Critical Value 95**	**Expl.**	**Boom phase**	**Bust phase**	**Date (monthly)**	**BSADF statistics**	**Critical Value 95**	**Expl.**	**Boom phase**	**Bust phase**	**Date (monthly)**	**BSADF statistics**	**Critical Value 95**	**Expl.**	**Boom phase**	**Bust phase**
1/1/2004	-0.95	0.45	0	0	0	5/1/2010	-0.93	0.46	0	0	0	9/1/2016	0.10	0.63	0	0	0
2/1/2004	-0.92	0.47	0	0	0	6/1/2010	-0.87	0.44	0	0	0	10/1/2016	0.06	0.62	0	0	0
3/1/2004	-0.90	0.45	0	0	0	7/1/2010	-0.82	0.45	0	0	0	11/1/2016	-0.09	0.62	0	0	0
4/1/2004	-0.95	0.46	0	0	0	8/1/2010	-0.98	0.43	0	0	0	12/1/2016	0.10	0.57	0	0	0
5/1/2004	-0.98	0.47	0	0	0	9/1/2010	-0.95	0.48	0	0	0	1/1/2017	0.22	0.62	0	0	0
6/1/2004	-0.98	0.49	0	0	0	10/1/2010	-1.03	0.52	0	0	0	2/1/2017	0.32	0.57	0	0	0
7/1/2004	-0.98	0.43	0	0	0	11/1/2010	-1.07	0.50	0	0	0	3/1/2017	0.65	0.57	1	1	0
8/1/2004	-1.02	0.48	0	0	0	12/1/2010	-1.08	0.48	0	0	0	4/1/2017	0.49	0.53	0	0	0
9/1/2004	-1.03	0.43	0	0	0	1/1/2011	-1.09	0.48	0	0	0	5/1/2017	0.56	0.55	1	1	0
10/1/2004	-1.00	0.41	0	0	0	2/1/2011	-1.07	0.48	0	0	0	6/1/2017	0.67	0.60	1	1	0
11/1/2004	-1.01	0.46	0	0	0	3/1/2011	-1.08	0.54	0	0	0	7/1/2017	0.63	0.60	1	1	0
12/1/2004	-0.60	0.47	0	0	0	4/1/2011	-1.07	0.57	0	0	0	8/1/2017	0.75	0.59	1	1	0
1/1/2005	-0.54	0.49	0	0	0	5/1/2011	-1.04	0.52	0	0	0	9/1/2017	0.72	0.56	1	1	0
2/1/2005	-0.64	0.42	0	0	0	6/1/2011	-1.11	0.54	0	0	0	10/1/2017	0.86	0.50	1	1	0
3/1/2005	-0.53	0.40	0	0	0	7/1/2011	-1.09	0.54	0	0	0	11/1/2017	0.99	0.55	1	1	0
4/1/2005	-0.77	0.43	0	0	0	8/1/2011	-1.15	0.57	0	0	0	12/1/2017	1.16	0.52	1	1	0
5/1/2005	-0.82	0.49	0	0	0	9/1/2011	-1.20	0.50	0	0	0	1/1/2018	1.22	0.52	1	1	0
6/1/2005	-0.66	0.45	0	0	0	10/1/2011	-1.16	0.64	0	0	0	2/1/2018	1.67	0.49	1	1	0
7/1/2005	-0.55	0.44	0	0	0	11/1/2011	-1.28	0.64	0	0	0	3/1/2018	1.05	0.48	1	0	1
8/1/2005	-0.27	0.45	0	0	0	12/1/2011	-1.27	0.63	0	0	0	4/1/2018	0.70	0.48	1	0	1
9/1/2005	-0.39	0.45	0	0	0	1/1/2012	-1.20	0.58	0	0	0	5/1/2018	0.88	0.51	1	0	1
10/1/2005	-0.38	0.51	0	0	0	2/1/2012	-1.05	0.60	0	0	0	6/1/2018	1.08	0.59	1	0	1
11/1/2005	-0.54	0.48	0	0	0	3/1/2012	-0.91	0.62	0	0	0	7/1/2018	1.02	0.54	1	0	1
12/1/2005	-0.25	0.49	0	0	0	4/1/2012	-0.77	0.60	0	0	0	8/1/2018	1.24	0.59	1	0	1
1/1/2006	-0.39	0.52	0	0	0	5/1/2012	-0.85	0.66	0	0	0	9/1/2018	1.48	0.59	1	0	1
2/1/2006	-0.21	0.53	0	0	0	6/1/2012	-1.25	0.64	0	0	0	10/1/2018	1.50	0.57	1	0	1
3/1/2006	-0.18	0.54	0	0	0	7/1/2012	-1.09	0.66	0	0	0	11/1/2018	0.82	0.65	1	0	1
4/1/2006	-0.17	0.49	0	0	0	8/1/2012	-1.07	0.65	0	0	0	12/1/2018	0.93	0.62	1	0	1
5/1/2006	-0.16	0.52	0	0	0	9/1/2012	-0.99	0.61	0	0	0	1/1/2019	0.11	0.56	0	0	0
6/1/2006	-0.31	0.52	0	0	0	10/1/2012	-0.88	0.60	0	0	0	2/1/2019	0.49	0.60	0	0	0
7/1/2006	-0.36	0.57	0	0	0	11/1/2012	-0.94	0.60	0	0	0	3/1/2019	0.70	0.60	1	1	0
8/1/2006	-0.43	0.51	0	0	0	12/1/2012	-1.00	0.53	0	0	0	4/1/2019	0.83	0.56	1	1	0
9/1/2006	-0.24	0.54	0	0	0	1/1/2013	-0.96	0.58	0	0	0	5/1/2019	0.95	0.55	1	1	0
10/1/2006	-0.14	0.53	0	0	0	2/1/2013	-0.72	0.61	0	0	0	6/1/2019	0.44	0.57	0	0	0
11/1/2006	0.06	0.48	0	0	0	3/1/2013	-0.71	0.59	0	0	0	7/1/2019	0.89	0.59	1	1	0
12/1/2006	0.22	0.46	0	0	0	4/1/2013	-0.57	0.61	0	0	0	8/1/2019	0.84	0.59	1	1	0
1/1/2007	0.34	0.50	0	0	0	5/1/2013	-0.51	0.60	0	0	0	9/1/2019	0.74	0.60	1	1	0
2/1/2007	0.49	0.50	0	0	0	6/1/2013	-0.31	0.60	0	0	0	10/1/2019	0.75	0.61	1	1	0
3/1/2007	0.08	0.54	0	0	0	7/1/2013	-0.44	0.60	0	0	0	11/1/2019	1.03	0.58	1	1	0
4/1/2007	0.19	0.48	0	0	0	8/1/2013	-0.10	0.62	0	0	0	12/1/2019	1.11	0.54	1	1	0
5/1/2007	0.73	0.55	1	1	0	9/1/2013	-0.46	0.61	0	0	0	1/1/2020	1.38	0.61	1	1	0
6/1/2007	1.24	0.59	1	1	0	10/1/2013	-0.27	0.59	0	0	0	2/1/2020	1.39	0.60	1	1	0
7/1/2007	0.73	0.47	1	0	1	11/1/2013	-0.05	0.61	0	0	0	3/1/2020	0.91	0.60	1	1	0
8/1/2007	0.16	0.53	0	0	0	12/1/2013	0.09	0.64	0	0	0	4/1/2020	-0.48	0.60	0	0	0
9/1/2007	0.18	0.51	0	0	0	1/1/2014	0.28	0.64	0	0	0	5/1/2020	-0.07	0.63	0	0	0
10/1/2007	0.58	0.50	1	1	0	2/1/2014	-0.28	0.65	0	0	0	6/1/2020	0.27	0.67	0	0	0
11/1/2007	0.24	0.49	0	0	0	3/1/2014	0.04	0.65	0	0	0	7/1/2020	0.37	0.72	0	0	0
12/1/2007	-0.01	0.47	0	0	0	4/1/2014	0.15	0.64	0	0	0	8/1/2020	0.68	0.72	0	0	0
1/1/2008	-0.06	0.51	0	0	0	5/1/2014	0.09	0.64	0	0	0	9/1/2020	1.11	0.67	1	1	0
2/1/2008	-0.43	0.51	0	0	0	6/1/2014	0.21	0.59	0	0	0	10/1/2020	0.74	0.73	1	1	0
3/1/2008	-0.65	0.60	0	0	0	7/1/2014	0.35	0.60	0	0	0	11/1/2020	0.57	0.70	0	0	0
4/1/2008	-0.56	0.53	0	0	0	8/1/2014	0.12	0.63	0	0	0	12/1/2020	1.20	0.69	1	1	0
5/1/2008	-0.45	0.58	0	0	0	9/1/2014	0.35	0.72	0	0	0	1/1/2021	1.37	0.66	1	1	0
6/1/2008	-0.55	0.55	0	0	0	10/1/2014	0.09	0.70	0	0	0	2/1/2021	1.37	0.67	1	1	0
7/1/2008	-0.82	0.51	0	0	0	11/1/2014	0.30	0.70	0	0	0	3/1/2021	1.62	0.64	1	1	0
8/1/2008	-0.86	0.58	0	0	0	12/1/2014	0.38	0.64	0	0	0	4/1/2021	1.84	0.65	1	1	0
9/1/2008	-0.84	0.57	0	0	0	1/1/2015	0.36	0.70	0	0	0	5/1/2021	2.20	0.66	1	1	0
10/1/2008	-0.89	0.59	0	0	0	2/1/2015	0.18	0.65	0	0	0	6/1/2021	2.16	0.63	1	1	0
11/1/2008	0.41	0.60	0	0	0	3/1/2015	0.52	0.66	0	0	0	7/1/2021	2.39	0.63	1	1	0
12/1/2008	1.70	0.60	1	1	0	4/1/2015	0.25	0.68	0	0	0	8/1/2021	2.49	0.63	1	1	0
1/1/2009	0.35	0.58	0	0	0	5/1/2015	0.40	0.72	0	0	0	9/1/2021	2.76	0.66	1	1	0
2/1/2009	0.95	0.53	1	0	1	6/1/2015	0.39	0.67	0	0	0	10/1/2021	2.23	0.68	1	1	0
3/1/2009	1.67	0.47	1	0	1	7/1/2015	0.24	0.66	0	0	0	11/1/2021	2.75	0.67	1	1	0
4/1/2009	0.47	0.52	0	0	0	8/1/2015	0.29	0.68	0	0	0	12/1/2021	2.42	0.68	1	1	0
5/1/2009	0.02	0.56	0	0	0	9/1/2015	-0.35	0.64	0	0	0	1/1/2022	2.98	0.64	1	1	0
6/1/2009	-0.30	0.48	0	0	0	10/1/2015	-0.34	0.64	0	0	0	2/1/2022	2.24	0.61	1	0	1
7/1/2009	-0.27	0.50	0	0	0	11/1/2015	0.11	0.69	0	0	0	3/1/2022	1.62	0.68	1	0	1
8/1/2009	-0.54	0.47	0	0	0	12/1/2015	0.09	0.66	0	0	0	4/1/2022	2.04	0.65	1	0	1
9/1/2009	-0.54	0.44	0	0	0	1/1/2016	-0.11	0.58	0	0	0	5/1/2022	1.13	0.60	1	0	1
10/1/2009	-0.62	0.51	0	0	0	2/1/2016	-0.41	0.61	0	0	0	6/1/2022	1.01	0.64	1	0	1
11/1/2009	-0.66	0.54	0	0	0	3/1/2016	-0.33	0.63	0	0	0	7/1/2022	0.51	0.58	0	0	0
12/1/2009	-0.79	0.51	0	0	0	4/1/2016	-0.10	0.62	0	0	0	8/1/2022	0.91	0.64	1	0	1
1/1/2010	-0.81	0.47	0	0	0	5/1/2016	-0.09	0.59	0	0	0	9/1/2022	0.64	0.61	1	0	1
2/1/2010	-0.79	0.49	0	0	0	6/1/2016	-0.05	0.59	0	0	0	10/1/2022	0.18	0.56	0	0	0
3/1/2010	-0.84	0.45	0	0	0	7/1/2016	-0.05	0.63	0	0	0	11/1/2022	0.40	0.61	0	0	0
4/1/2010	-0.91	0.52	0	0	0	8/1/2016	0.12	0.62	0	0	0	12/1/2022	0.69	0.62	1	0	1

The Table reports *BSADF* and the *BSADF* 95% critical values (cv) computed on the S&P500 index. The *BSADF* 95% critical values are based on a window size given by $r_0 = \left(0.01 + 1.8/\sqrt{T}\right)$, where T refers to the number of observations in the sample. Explosive behavior is an indicator variable equal to 1 when *BSADF* is above its 95% critical value and 0 otherwise.

Appendix B Additional evidence on $\Delta \boldsymbol{CoVaR}$ and $\boldsymbol{MES}$

In this section, we report the correlation matrix among US state variables and the $\Delta CoVaR$, time-series properties for MMFs' returns in relation to these US state variables (*Section B.1*), and the Marginal Expected Shortfall (MES) used in our analysis (*Section B.2*).

B.1 $\Delta CoVaR$

Table B1 reports the correlations between $\Delta CoVaR$ and the proxies for US macro-financial conditions such as *Liquidity Spread*, *Credit Spread*, *T-Bill change*, *S&P 500 returns*, and the *VIX*.

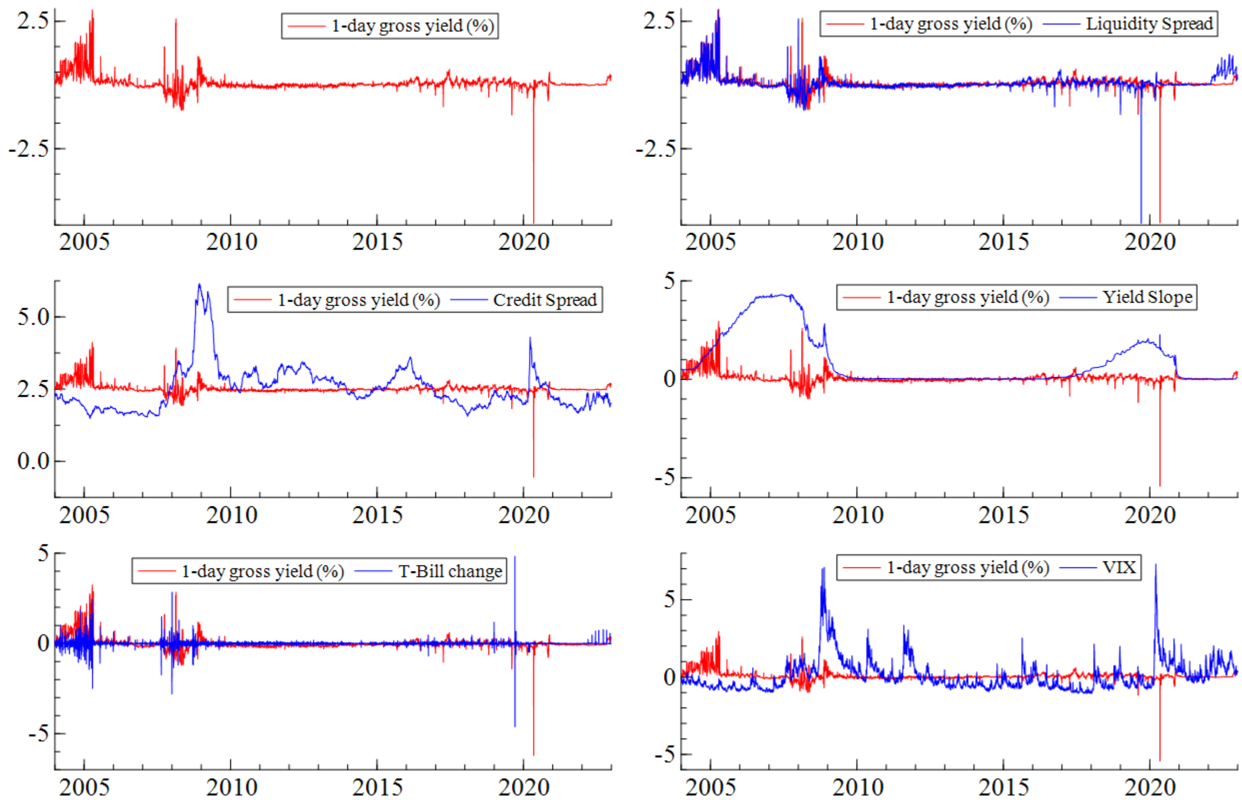
Table B1: Correlation matrix among US state variables. Dependent variable $\Delta CoVaR$.

	$\Delta CoVaR_t$	Liquidity Spread$_{t-1}$	Credit Spread$_{t-1}$	Yield slope$_{t-1}$	T-Bill change$_{t-1}$	S&P 500 Returns$_{t-1}$	VIX$_{t-1}$
$\Delta CoVaR_t$	1						
Liquidity Spread$_{t-1}$	0.0657*	1					
Credit Spread$_{t-1}$	0.3440*	-0.0658*	1				
Yield slope$_{t-1}$	0.0616*	-0.4519*	0.4090*	1			
T-Bill change$_{t-1}$	-0.1219*	-0.0170*	-0.1372*	0.0919*	1		
S&P 500 Returns$_{t-1}$	-0.0437*	-0.0459*	-0.0280*	0.0115*	0.1349*	1	
VIX$_{t-1}$	0.4179*	0.0430*	0.7010*	0.2042*	-0.1360*	0.0397*	1

The table reports the correlations among state variables on daily data from January 2004 to December 2022. *Liquidity Spread*, the difference between the 3-month US repo rate and the 3- month US T-bill yield; *Credit Spread*, the difference between the 10-year Moody's seasoned Baa corporate bond and the 10-year US Treasury bond; *Yield slope*, the first difference curve (yield spread between the US Treasury benchmark 10-year bonds and the US 3-month T-bill); *T-Bill change*, the first difference of the US Treasury bill secondary market 3-month rate; *S&P 500 Returns*, the returns of S&P500 composite; *VIX*, the volatility index of the Chicago Board Options Exchange (CBOE). All these variables are sampled daily.

Figure B1 shows the time-series properties for MMFs' returns (1-day gross yield) in relation to the US state variables such as Liquidity Spread, Credit Spread, Yield slope, T-Bill change, and the VIX index. The Figures report that the gross yield shows interesting time-series variation and reacts to major episodes of financial stress, such as the 2008 global financial crisis and the 2020 COVID-19 pandemic. In addition, there are some co-movements between the gross yield and US state variables: the increase in liquidity and credit risk, yield curve shifts, and spikes in volatility tend to coincide with pronounced movements in MMF yields.

Figure B1: Time-series properties for MMFs' retuns and US state variables.



Source: Authors elaboration.

B.2 Marginal Expected Shortfall

The Marginal Expected Shortfall (*MES*) of a financial institution is defined as the contribution of that institution to the Expected Shortfall (ES) of the system (Acharya et al., 2017). The *ES* of the system is defined as the expected value of the market return conditional to the event that the market return is lower than a certain threshold C with the market return defined as the weighted average of all financial institutions' returns:

$$ES_{m,t}(C) = \mathbb{E}_{t-1}(r_{m,t}|r_{m,t} < C) = \sum_{i=1}^{N} \omega_{i,t}\mathbb{E}_{t-1}(r_{i,t}|r_{m,t} < C) \tag{B1}$$

where $r_{m,t} = \sum_{i=1}^{N} \omega_{i,t} r_{i,t}$, and $\omega_{i,t}$ is the market share or capitalization of financial institution i. We set the threshold C at 5% level to ensure comparability with the other measures of systemic risk. The contribution of institution i to the System Expected Shortfall (the *MES* of institution i) is, therefore, defined as the partial derivative of the *ES* with respect to the weight of institution i, hence the term "marginal":

$$MES_{i,t} = \frac{\partial ES_{m,t}(C)}{\partial \omega_{i,t}} = \mathbb{E}_{t-1}(r_{i,t}|r_{m,t} < C) \tag{B2}$$

We calculate the *MES* as the average return of the MMF during the 5% of days when the financial system experienced the most severe losses. Specifically, we analyze the 5% worst system returns over the past 12 months on a monthly basis. Following Acharya et al. (2017), we use the overall market return, proxied by the S&P 500 index.

Appendix C Sensitivity Analyses

We compute MMFs' VaR from their past equity returns using 1-year rolling windows. The results are reported in Table C1, which confirm our main findings.

Table C1: MMFs US$ and US$ Off Shore using $\Delta CoVaR$ rolling window.

Dependent variable: ΔCoVaR$_{i,t}$	MMFs US and MMFs Off Shore	MMFs US$	Prime	Government	MMFs US and MMFs Off Shore	Prime	Government
	[i]	[i]	[ii]	[iii]	[i]	[ii]	[iii]
Size$_{i,t-1}$	-0.0004**	-0.0006	0.0007	0.0001	-0.0007	0.0004	0.0003
	(0.0002)	(0.0005)	(0.0005)	(0.0005)	(0.0004)	(0.0005)	(0.0005)
Size$_{i,t-1}$*Real Estate Boom$_t$	-0.0002***	-0.0003	-0.0002	0.0002	-0.0004*	-0.0001	0.0003*
	(0.0000)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Size$_{i,t-1}$*Real Estate Bust$_t$	0.0001	-0.0004*	-0.0001	0.0003	-0.0002	-0.0002	0.0003
	(0.0001)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0003)	(0.0002)
Size$_{i,t-1}$*Equity Boom$_t$	0.0000	-0.0004	0.0006*	0.0006**	-0.0002	0.0005*	0.0003
	(0.0001)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Size$_{i,t-1}$*Equity Bust$_t$	0.0000	0.0001	0.0002	0.0000	0.0001	0.0005*	-0.0001
	(0.0001)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0003)
Wam$_{i,t-1}$	-0.0006**	-0.0016	0.0025	0.0004	-0.0032**	0.0051**	0.0021
	(0.0002)	(0.0022)	(0.0023)	(0.0023)	(0.0016)	(0.0017)	(0.0016)
Wam$_{i,t-1}$*Real Estate Boom$_t$	0.0002	-0.0054**	0.0057**	0.0069***	-0.0031**	0.0030*	0.0042**
	(0.0002)	(0.0019)	(0.0020)	(0.0019)	(0.0015)	(0.0016)	(0.0016)
Wam$_{i,t-1}$*Real Estate Bust$_t$	0.0019***	-0.0012	0.003	0.0035*	-0.0040***	0.0077***	0.0062***
	(0.0002)	(0.0020)	(0.0021)	(0.0020)	(0.0010)	(0.0011)	(0.0011)
Wam$_{i,t-1}$*Equity Boom$_t$	-0.0002	0.0089**	-0.0075**	-0.0097***	0.0094***	-0.0093***	-0.0107***
	(0.0003)	(0.0027)	(0.0028)	(0.0027)	(0.0020)	(0.0021)	(0.0020)
Wam$_{i,t-1}$*Equity Bust$_t$	-0.0006*	0.0046*	-0.0070**	-0.0053**	0.0051**	-0.0076***	-0.0061**
	(0.0003)	(0.0025)	(0.0027)	(0.0026)	(0.0019)	(0.0020)	(0.0019)
Wal$_{i,t-1}$	0.0004	0.001	-0.0016	-0.0016	0.0023	-0.0038**	-0.0027
	(0.0002)	(0.0023)	(0.0024)	(0.0023)	(0.0016)	(0.0017)	(0.0017)
Wal$_{i,t-1}$*Real Estate Boom$_t$	-0.0006**	0.0043**	-0.0046**	-0.0043**	0.0017	-0.0014	-0.0013
	(0.0002)	(0.0019)	(0.0020)	(0.0020)	(0.0015)	(0.0016)	(0.0016)
Wal$_{i,t-1}$*Real Estate Bust$_t$	-0.0009***	0.0005	-0.0013	-0.0015	0.0038***	-0.0060***	-0.0050***
	(0.0002)	(0.0021)	(0.0022)	(0.0022)	(0.0009)	(0.0010)	(0.0010)
Wal$_{i,t-1}$*Equity Boom$_t$	-0.0004	-0.0067**	0.0054*	0.0083**	-0.0070***	0.0072***	0.0092***
	(0.0003)	(0.0027)	(0.0029)	(0.0028)	(0.0019)	(0.0021)	(0.0020)
Wal$_{i,t-1}$*Equity Bust$_t$	-0.0010**	-0.0033	0.0048*	0.0038	-0.0037**	0.0047**	0.0045**
	(0.0003)	(0.0025)	(0.0026)	(0.0025)	(0.0018)	(0.0019)	(0.0019)
ΔSize$_{i,t-1}$	-0.0025**	-0.0049***	0.0324***	0.0101	-0.0041***	0.0299**	0.0058
	(0.0010)	(0.0011)	(0.0085)	(0.0063)	(0.0011)	(0.0094)	(0.0057)
ΔSize$_{i,t-1}$*Real Estate Boom$_t$	-0.0103***	-0.0288***	0.0209**	0.0335***	-0.0234***	0.0165**	0.0249***
	(0.0030)	(0.0064)	(0.0080)	(0.0071)	(0.0059)	(0.0077)	(0.0066)
ΔSize$_{i,t-1}$*Real Estate Bust$_t$	-0.0083*	-0.0093	0.0215*	-0.0007	-0.0059	0.0186	-0.0149
	(0.0048)	(0.0109)	(0.0128)	(0.0134)	(0.0111)	(0.0135)	(0.0138)
ΔSize$_{i,t-1}$*Equity Boom$_t$	0.0523***	0.2263***	-0.1645***	-0.2722***	0.1578***	-0.1264**	-0.1940***
	(0.0138)	(0.0394)	(0.0421)	(0.0439)	(0.0347)	(0.0405)	(0.0388)
ΔSize$_{i,t-1}$*Equity Bust$_t$	0.0103	0.0381*	-0.0617**	0.0311	0.0289	-0.0650**	0.0106
	(0.0121)	(0.0209)	(0.0272)	(0.0397)	(0.0203)	(0.0264)	(0.0388)
ΔGDP$_{t-1}$	-0.0005***	-0.0007***			-0.0006***		
	(0.0000)	(0.0000)			(0.0000)		
ΔCPI$_{t-1}$	-0.0532***	-0.0617***			-0.0512***		
	(0.0040)	(0.0047)			(0.0045)		
10-year Government Bond$_{t-1}$	-0.0026***	-0.0033***			-0.0026***		
	(0.0001)	(0.0001)			(0.0001)		
Investment-to-GDP$_{t-1}$	-0.0008***	0.0006***			-0.0006**		
	(0.0002)	(0.0002)			(0.0002)		
Money Market MCI$_{t-1}$	0.0013***	0.0017***			0.0014***		
	(0.0001)	(0.0001)			(0.0001)		
Constant	0.0300***	0.0293***			0.0306***		
	(0.0020)	(0.0024)			(0.0040)		
Fixed Effects	YES	YES			YES		
Catogories Dummy (Prime and Government)	NO	YES			YES		
Bubbles Dummy	YES	YES			YES		
Dummy MMFs US*Bubbles	YES	YES			YES		
Dummy MMFs US$	YES	YES			NO		
Dummy MMFs US Offshore	NO	NO			YES		
Macro Controls	YES	YES			YES		
N. Obs.	134,083	106,108			134,083		
Adjusted R^2 *within*	0.22	0.33			0.26		
F-Test	64.62***	54.54***			34.95***		

The table reports the results between the measure of systemic risk for MMFs and asset price bubbles. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. The dependent variable is $\Delta CoVaR$ rolling window. Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.

We also replicate our analyses after excluding the COVID-19 period, specifically from June 2019 to June 2020. The results, presented in Table C2, confirm our main findings.

Table C2: MMFs US$ and US$ Off Shore after excluding COVID-19 time period.

Dependent variable: ΔCoVaR$_{i,t}$	**MMFs US and MMFs Off Shore**	**MMFs US$**	**Prime**	**Government**	**MMFs US and MMFs Off Shore**	**Prime**	**Government**
	[i]	**[i]**	**[ii]**	**[iii]**	**[i]**	**[ii]**	**[iii]**
Size$_{i,t-1}$	-0.0005**	-0.0005	0.0005	-0.0005	-0.0005	0.0003	-0.0003
	(0.0002)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Size*Real Estate Boom$_t$	-0.0001	-0.0003	-0.0001	0.0003	-0.0003*	0	0.0004**
	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Size$_{i,t-1}$*Real Estate Bust$_t$	0.0002**	-0.0005*	0.0001	0.0005*	-0.0003	0.0001	0.0006**
	(0.0001)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0003)
Size$_{i,t-1}$*Equity Boom$_t$	-0.0001	-0.0003	0.0001	0.0005*	-0.0002	0.0001	0.0003
	(0.0001)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0003)
Size$_{i,t-1}$*Equity Bust$_t$	-0.0001	0.0001	-0.0001	0.0000	0.0001	0.0001	-0.0001
	(0.0001)	(0.0003)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Wam$_{i,t-1}$	-0.0003	-0.0016	0.0025	0.0013	-0.0019	0.0031*	0.0017
	(0.0003)	(0.0023)	(0.0023)	(0.0023)	(0.0017)	(0.0018)	(0.0017)
Wam$_{i,t-1}$*Real Estate Boom$_t$	-0.0001	-0.0056**	0.0065**	0.0057**	-0.0053***	0.0060***	0.0055***
	(0.0002)	(0.0019)	(0.0020)	(0.0019)	(0.0015)	(0.0015)	(0.0015)
Wam$_{i,t-1}$*Real Estate Bust$_t$	0.0009***	0.0007	-0.0007	0.0006	-0.0052***	0.0081***	0.0063***
	(0.0002)	(0.0021)	(0.0022)	(0.0021)	(0.0012)	(0.0013)	(0.0012)
Wam$_{i,t-1}$*Equity Boom$_t$	-0.0006*	0.0067**	-0.0071**	-0.0074**	0.0071***	-0.0076***	-0.0088***
	(0.0003)	(0.0027)	(0.0028)	(0.0027)	(0.0020)	(0.0021)	(0.0021)
Wam$_{i,t-1}$*Equity Bust$_t$	0.0004	0.0042	-0.004	-0.0046	0.0054**	-0.0057**	-0.0063**
	(0.0004)	(0.0028)	(0.0030)	(0.0029)	(0.0023)	(0.0024)	(0.0023)
Wal$_{i,t-1}$	0.0004	0.0015	-0.0022	-0.002	0.0014	-0.0024	-0.0018
	(0.0002)	(0.0024)	(0.0024)	(0.0024)	(0.0018)	(0.0018)	(0.0018)
Wal$_{i,t-1}$*Real Estate Boom$_t$	-0.0006**	0.0050**	-0.0052**	-0.0051**	0.0048***	-0.0053***	-0.0048***
	(0.0002)	(0.0019)	(0.0020)	(0.0019)	(0.0014)	(0.0015)	(0.0015)
Wal$_{i,t-1}$*Real Estate Bust$_t$	-0.0009***	-0.0022	0.0021	0.0016	0.0042***	-0.0064***	-0.0051***
	(0.0002)	(0.0022)	(0.0023)	(0.0023)	(0.0009)	(0.0010)	(0.0010)
Wal$_{i,t-1}$*Equity Boom$_t$	-0.0002	-0.0057**	0.0057**	0.0068**	-0.0058**	0.0067**	0.0081***
	(0.0003)	(0.0027)	(0.0028)	(0.0027)	(0.0020)	(0.0021)	(0.0021)
Wal$_{i,t-1}$*Equity Bust$_t$	-0.0012**	-0.0021	0.0025	0.0028	-0.0031	0.0036	0.0043*
	(0.0004)	(0.0028)	(0.0029)	(0.0029)	(0.0022)	(0.0023)	(0.0022)
ΔSize$_{i,t-1}$	-0.0023**	-0.0054***	0.0415***	0.0113*	-0.0043***	0.0393***	0.004
	(0.0011)	(0.0012)	(0.0102)	(0.0060)	(0.0011)	(0.0104)	(0.0053)
ΔSize$_{i,t-1}$*Real Estate Boom$_t$	-0.0071**	-0.0131**	0.0126*	0.0138**	-0.0116**	0.0131*	0.0066
	(0.0027)	(0.0055)	(0.0072)	(0.0062)	(0.0054)	(0.0074)	(0.0061)
ΔSize$_{i,t-1}$*Real Estate Bust$_t$	-0.0018	0.0056	0.0071	-0.004	0.0059	0.0033	-0.0145
	(0.0061)	(0.0150)	(0.0175)	(0.0177)	(0.0152)	(0.0174)	(0.0178)
ΔSize$_{i,t-1}$*Equity Boom$_t$	0.0311**	0.1204***	-0.1295***	-0.1146***	0.0900***	-0.1110***	-0.0728**
	(0.0121)	(0.0282)	(0.0316)	(0.0319)	(0.0270)	(0.0330)	(0.0298)
ΔSize$_{i,t-1}$*Equity Bust$_t$	0.0324**	0.0393*	-0.0786**	0.1220**	0.0384*	-0.0735**	0.0595
	(0.0155)	(0.0215)	(0.0299)	(0.0467)	(0.0219)	(0.0297)	(0.0458)
Constant	0.0221***	0.0323***			0.0178***		
	(0.0018)	(0.0019)			(0.0033)		
Fixed Effects	YES	YES			YES		
Catogories Dummy (Prime and Government)	YES	YES			YES		
Bubbles Dummy	YES	YES			YES		
Dummy MMFs US*Bubbles	YES	YES			YES		
Dummy MMFs US$	YES	YES			YES		
Dummy MMFs US Offshore	NO	NO			YES		
Time Dummy	YES	YES			YES		
N. Obs.	126,431	100,273			126,431		
Adjusted R^2 *within*	0.27	0.37			0.30		
F-Test	57.11***	58.43***			38.39***		

The table reports the results between the measure of systemic risk for MMFs and asset price bubbles. *Size* is the MMF fund size defined as the natural logarithm of the fund portfolio's outstanding assets ($millions); *Weighted average maturity* (Wam) is the asset-weighted time (in days) until the securities in the portfolio mature for MMF; *Weighted average life* (Wal) is the weighted average life (in days); $\Delta Size$ is the Δln(Size) based on a twelve-month rolling window of portfolio assets for MMF. As macroeconomic controls, we consider: ΔGDP as the monthly growth rate of real GDP; ΔCPI is the monthly percentage change in the US Consumer Price Index; *10-year Government Bond* refers to the monthly rate of 10-year Government Bond; *Investment-to-GDP* as the monthly ratio between investment and real GDP; *Money Market MCI* is the market indicator for US money market. The dependent variable is $\Delta CoVaR$. Standard errors are clustered at the MMF levels and reported in parentheses. *, **, *** denote the 10%, 5% and 1% significance level, respectively.