# Assessing Credit Risk in Money Market Fund Portfolios

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27 May 2014

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May 27, 2014

**Abstract**

This paper measures credit risk in prime money market funds (MMFs), studies how such credit risk evolved in 2011-2012, and tests the efficacy of the Securities and Exchange Commission's (SEC) January 2010 reforms. To accomplish this, we estimate the credit default swap premium (CDS) needed to insure each fund's portfolio against credit losses. We also calculate by Monte Carlo the cost of insuring a fund against losses amounting to over 50 basis points. We find that credit risk of prime MMFs rose from June to December 2011 before receding in 2012. Contrary to common perceptions, this did not primarily reflect funds' credit exposure to eurozone banks. Instead, credit risk in prime MMFs rose because of the deteriorating credit outlook of banks in the Asia/Pacific region. Finally, we find evidence that the SEC's 2010 liquidity and weighted average life (WAL) requirements reduced the credit risk of prime MMFs.

JEL: G01, G18, G23, G28

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## 1 Introduction

Money market funds (MMFs) are mutual funds that invest in short-term high quality money market instruments. Unlike banks, money market funds do not hold capital against credit losses, nor are they insured by the federal government. Instead, risks in money market funds are mitigated by SEC Rule 2a-7, which is promulgated under the Investment Company Act. Among other things, Rule 2a-7 sets strict maturity limits on a fund's portfolio, requires funds to hold short-term securities of high credit quality, imposes diversification limits, and requires MMFs to hold a significant portion of their portfolios in very liquid assets. Money market funds have no leverage and must hold only U.S. dollar-denominated assets. These limits are in many ways much more stringent than the rules under which banks operate.

Money market funds, like banks and other financial institutions, faced extraordinary stresses in September 2008 in light of the U.S. federal government's decision to let Lehman Brothers fail.[1] In January 2010, in an effort to improve the resiliency of money market funds to withstand severe market stresses, the Securities and Exchange Commission (SEC, 2010) adopted a number of wide-ranging revisions to Rule 2a-7.

Since 2010, many regulators have called for further reforms to money market funds. One rationale offered for such reforms is the suggestion that money market funds take significant credit risk (Rosengren, 2012). However, to date, there has been little formal research assessing the credit risk in money market funds. This paper seeks to fill that gap. This paper develops a methodology for assessing MMF credit risk and applies it to the period 2011-2012 to study the influence of the European debt crisis on the credit quality of money market fund portfolios and on the influence of the SEC's 2010 reforms on funds' credit risk.

At first glance, the most obvious way to estimate the credit risk on an MMF is by the difference between the yield on a prime money market fund and the yield on a comparable government-only money market fund. Prime MMFs are money market funds that invest in a range of money market securities, including commercial paper, bank CDs, medium-term and floating-rate notes, repurchase agreements (repos) and Treasury and agency securities. Government money market funds typically invest only in Treasury or agency securities or

[1] See FCIC (2011), chapter 18, for an account and links to first-hand documents describing the federal government's decision on September 14, 2008 to provide no funding in support of a Lehman Brothers bailout or takeover.

repos backed by Treasuries and agencies and therefore should be default-risk-free. Figure 1 plots month-end values of the difference between the average gross yield on prime MMFs and government MMFs. For comparison, the figure also plots month-end values of the Bloomberg index of 5-year credit default swap (CDS) premiums for U.S. banks, as well as of the iTraxx 5-year CDS premium index for senior European financial debt (which primarily reflects 5-year CDS premiums for eurozone banks). As seen, in comparison with the 5-year CDS premiums for banks, the prime-to-government yield spread is small. Over the period 2011 to 2012, this spread averaged 18 basis points and the maximum spread was 23 basis points. This suggests that the credit risk of prime money market funds is small.

An issue arises, however, because money market funds price their portfolio holdings at amortized cost. A longstanding GAAP provision allows firms, both financial and nonfinancial, to value their holdings of money market securities at amortized cost. A provision of SEC Rule 2a-7 allows a money market fund to price all of its securities at amortized cost (but the fund must abide by the risk-limiting requirements of Rule 2a-7). The use of amortized cost may weaken the value of a prime-to-government yield spread as an indicator of a money market fund's credit risk. A fund calculates its yield as income accrued (on an amortized cost basis) over a given period (e.g., one month) divided by the fund's amortized cost value (generally $1.00 per share) at the beginning of the period. If a fund holds a security and that security's credit quality declines, the security's market price should also decline, boosting the security's market yield. But because funds use amortized cost accounting, the rise in the security's yield would not be immediately reflected in the fund's yield. Generally speaking, only if that security matures and the fund rolls over its holding of that security, would the fund's yield then rise to reflect the increased credit risk.

There are other potential issues with using a prime-to-government fund yield spread to assess the credit risk of prime money market funds. One issue is that the interest on Treasury securities is exempt from state and local taxes. Also, there is a unique demand for Treasury securities, such as by banks to meet capital standards. In part because of this unique demand, the Treasury market is generally the most liquid bond market, imparting a liquidity premium to Treasuries. These effects reduce the yield of Treasuries relative to taxable money market instruments, perhaps leading a prime-to-government fund yield spread to overstate the credit exposure of prime money market funds.

Consequently, it seems appropriate to consider alternative ways to assess the credit risk of prime MMFs. CDS premiums provide one alternative. In theory, the spread between the yield on a credit-risky security and a comparable risk-free security equals the CDS premium for insuring against default on the credit-risky security (Hull and White, 2000). Thus, CDS premiums can be used to estimate the credit risk in a pool of securities. Numerous recent studies have sought either to assess the credit risk or capital adequacy of banks using CDS premiums. For example, Segoviano and Goodhart (2009) treat the entire banking system as a portfolio, the riskiness of which is based on the CDS premiums of individual banks. Other studies have used 5-year CDS premiums to assess systemic risk in bank portfolios at a fixed horizon, such as over the next quarter or the coming year (Avesani, Pascual, and Li, 2006; Huang, Zhou, and Zhu, 2009).

Rosengren (2012) uses CDS premiums in an attempt to assess the credit risk of prime money market funds. He matches CDS premiums issuer-by-issuer with the portfolio holdings of prime MMFs. His results suggest that prime MMFs take on significant credit risk: he indicates that 37 percent of the assets of prime money market funds have an associated CDS premium of nearly 300 basis points (287 basis points on an asset-weighted basis).[2] If correct, that premium is large. A shortcoming of Rosengren's approach, however, is that he measures credit risk using 5-year CDS premiums. This is a concern because the term structure of CDS premiums is generally upward sloping for high quality issuers (Agrawal and Bohn, 2006; Han and Zhou, 2011).[3] Thus, it should generally be less costly in terms of CDS premiums to insure against default on a portfolio composed of short-dated, high quality securities. Money market fund portfolios fit these characteristics. Under Rule 2a-7, MMFs must hold securities that mature or can be redeemed with 397 days. In addition, MMFs' weighted average life (WAL) must be 120 days or less. In practice, many of prime funds maintain even lower WALs. For example, the WAL of prime funds averaged 72 days in July 2012. Also, MMFs may only hold

[2]In Congressional testimony on potential reform of money market funds, Scharfstein (2012) cites Rosengren's 2012 estimate as indicating that "a meaningful fraction of the securities in prime MMFs were issued by firms with CDS spreads well in excess of those of the safest investment grade companies."

[3]For example, on July 27, 2012, the 5-year CDS premium for insuring against the default on Boeing was 65.50, whereas the premium for a 1-year CDS was 13.47 (both are annual costs). Thus, an investor could obtain $10,000,000 of default insurance for 1 year on Boeing at a cost of $13,470, using a 1-year CDS, or pay $65,500 for one year's insurance with a 5-year CDS. The 1-year CDS would expire after one year, however, leaving the purchaser of the 1-year CDS with roll-over risk.

high quality securities. Under Rule 2a-7, virtually all (97 percent) of a money market fund's portfolio must be in securities having the highest short-term credit rating (i.e., A1/P1/F1) or, if a credit rating is unavailable, in securities judged to be of minimal credit risk. Thus, Rosengren's use of 5-year CDS premiums likely overstates the credit risk of prime MMFs, but the level of the overstatement is an empirical question.

Collins, Gallagher, Heinrichs, and Plantier (2013) seek to improve on Rosengren's approach by matching money market funds' holdings with maturity-appropriate CDS premiums. For example, if a fund holds a Ford Motor medium term note that has a remaining maturity of 6 months, that note is matched with a 6-month CDS quote for Ford Motor. Aggregating (on an asset-weighted basis) across all of a fund's holdings provides an estimate of the CDS premium needed to insure the fund's portfolio against any and all credit losses under the assumption that the fund holds each security until it matures (or defaults). We call this credit risk measure "expected loss-to-maturity" ($ELM$). Collins et al. (2013) find that the expected-loss-to maturity on all prime money market funds averaged 27 basis points in 2011, again suggesting that the credit risk of prime money market funds is small.

Expected loss-to-maturity has elements in common with Bank for International Settlement (BIS) guidelines for assessing Incremental Risk Charge (IRC). Under Basel II, a bank may face a capital surcharge (the IRC) on its "trading book," those securities a bank intends to actively trade and hold for less than one year. Under BIS guidelines, to determine the capital surcharge, the bank models the credit risk in its trading book under three assumptions: (a) the horizon for measuring credit risk ("credit horizon") is one year; (b) the capital surcharge takes into account a security's "liquidity horizon," which is the point at which the bank can dispose of trading book securities (generally, the shorter the liquidity horizon, the lower is the IRC); (c) the bank maintains a "constant-risk" trading book, periodically rebalancing its trading book to maintain a constant level of credit quality (for example, if the credit rating of a trading book security declines from AAA to AA, the bank is assumed to replace that security with a AAA-rated security). Studies by regulators (Dunn, Gibson, Ikosi, Jones, Monet, and Sullivan, 2006) indicate that the incremental risk charge is 30 percent lower for a hypothetical bank with a liquidity horizon of 1-month compared to a bank with a liquidity horizon of 1 year. Given that we are measuring the annual cost of insuring a fund's portfolio against losses, $ELM$ implicitly sets a fund's "credit horizon" to one year. In addition, *ELM* implicitly sets a fund's "liquidity horizon" to the remaining maturity of its securities holding.[4] Finally, *ELM* implicitly assumes that a fund maintains a "constant risk portfolio" throughout the year. In effect, this means that as a fund's securities mature, it is assumed that the fund rolls the assets into identical securities.

As noted, money market funds hold the bulk of their assets in very short-term securities, typically those maturing in 3 months or less. But CDS premiums are generally not quoted at maturities of less than 6 months. To deal with this, Collins et al. (2013) assume that the CDS premium on a security with one month to maturity is one-fourth the 6-month CDS premium for the same issuer. Collins et al. (2013) present some evidence from short-term credit spreads that this one-fourth assumption is not implausible. Quotes for intervening maturities (say 2 months) are then interpolated from the 6-month quote and 1-month estimate. However, this method does not acknowledge that the CDS market may be thinly traded for some issuers, especially at the 6-month horizon.

This paper seeks to improve further on the credit risk measure of Collins et al. (2013) by synthetically creating CDS premiums for short-dated securities using default probabilities collected from the Risk Management Institute (RMI) of the National University of Singapore. RMI generates forward-looking probabilities for about 50,000 worldwide issuers on a daily basis for maturities of 1, 3, 6, 9, 12, 18, and 24 months ahead.[5] RMI produces these default probabilities using a reduced form model of issuer credit risk, which among other things, incorporates the Merton (1974) distance-to-default concept, as well as firm-specific and macroeconomic variables. Research (Chen, 2013) indicates that RMI's default probabilities have a good track record, especially for issuers in developed countries, at maturities of 6 months or less, which is the horizon we are most concerned with in this paper. Given the RMI default probabilities,

[4]Our *ELM* concept is in some sense more conservative than the BIS guidelines under which banks compute IRC. BIS guidelines allow banks to treat a security's liquidity horizon as the date by which the bank can reasonably expect to dispose of the security in the market with little price pressure. Thus, if a bank holds a 10-year corporate bond and believes it could dispose of it in, say, 6 months with little or no price pressure, Basel II standards allow the bank to treat the bond's liquidity horizon as 6 months. Suppose, in contrast, that a money market fund holds a medium term note with a remaining maturity of 6 months. Even if the money market fund could sell the note with no price pressure within, say, 7 days, our *ELM* concept implicitly sets the note's liquidity horizon to the remaining maturity of 6 months.

[5]RMI uses the forward intensity model of Duan, Sun, and Wang (2012) to estimate firms' default probabilities for several periods into the future. Covariates include macroeconomic factors (e.g., trailing 1-year returns on the S&P 500), a firm's "distance-to-default" based on Merton (1974), as well as firm-specific capital structure, liquidity, and volatility metrics.

the estimated (synthetic) CDS premium for a given issuer and given remaining maturity is the relevant default probability times the expected loss given default. We use standard CDS market assumptions about expected loss given default. By interpolating, we are able to obtain estimated CDS premiums for the vast majority of assets that money market funds hold. This, in turn, allows us to calculate *ELM* for individual prime money market funds and for prime money market funds as a group.

Investors, fund managers, and policymakers may, however, also be interested in the cost of insuring against the likelihood that a money market fund might "break the dollar." Under Rule 2a-7, a money market fund may offer a per-share price of \$1.00 only if its mark-to-market value remains within 1/2 cent (50 basis points) of \$1.00. If its mark-to-market value drops below \$.995, the fund must lower its per-share price to \$.99. This is colloquially known as "breaking the dollar." Policymakers and other experts have expressed concerns that this could lead to a run on money market funds.[6] We assess the cost of insuring against such an event, which we call $BDI(l,u)$, for Break the Dollar Insurance. We allow for a insurance deductible $l$ and a maximum loss of $u$ ($u$ could be the entire value of the fund), where $l$ and $u$ are measured in basis points of a fund's assets.

As we discuss, $BDI(l,u)$ is more difficult to calculate than *ELM* because defaults may be correlated across issuers. For example, money market funds hold (U.S. dollar-denominated) commercial paper and other short-term debt issued by large global banks. The failure of a large global bank could threaten the solvency of other large banks if, for instance, surviving banks hold debt issued by the failing bank. To correctly assess the probability that a fund might break the dollar, default correlations need to be taken into account. We do this using a copula (Li, 2000) implemented by Monte Carlo simulation. Our approach has much in common with measures of systemic risk and stress indicators for banks (Tarashev and Zhu, 2008; Huang et al., 2009; Segoviano and Goodhart, 2009).

To undertake the analysis, we create a new dataset comprising the entire record of the portfolio holdings of each prime money market fund over the period January 2011 to December 2012. We obtain funds' portfolio holdings from SEC form N-MFP. This form, which all money market funds have been required to report since November 2010, collects monthly data on a

[6] See, for example, FSOC (2012) and Squam Lake (2011, 2013).

fund's entire list of portfolio securities. By hand, we match the month-end portfolio holdings of prime money market funds issuer-by-issuer and maturity-by-maturity with default probabilities obtained from RMI (Section 3 provides details). We are able to match roughly 90 percent of the assets of prime money market funds with estimated (synthetic) CDS premiums.

Our results indicate that there is generally limited credit risk-to-maturity in prime money market funds. Over the 24 months between January 2011 and December 2012, prime money market funds had an (asset-weighted) average $ELM$ of 15 basis points. The credit risk exposure of prime funds did evolve over this period. Credit exposure was lower (11 basis points) in early 2011. It rose somewhat in the fall of 2011 to a maximum (on an asset-weighted average basis) of 22 basis points in November and December 2011.[7] Thereafter, average credit risk receded to just 9 basis points at the end of 2012.

Regulators, press reports and some academic studies (Chernenko and Sunderam, 2014) have included claims that the credit risk of prime MMFs increased in March-August of 2011 because these funds held, or even increased their holdings of, securities issued by eurozone banks in order to boost fund yields. Our results present a rather different picture. We find that MMF holdings of eurozone or other European banks did not contribute importantly to the modest increase in the average credit risk (as measured by $ELM$) of prime MMFs in the second half of 2011. Instead, the rise was primarily due to an increased contribution from prime fund holdings of banks domiciled in the Asia-Pacific region. As credit conditions deteriorated for eurozone banks in the fall of 2011, MMFs drastically reduced their holdings of eurozone bank debt and shortened the maturities of their remaining eurozone holdings. This offset to a great extent an increase in the credit risk of holding eurozone banks. At the same time, prime funds increased their holdings of bank debt in Canada, Norway, Australia/New Zealand, and Japan. In the fall of 2011, however, as the eurozone situation continued to worsen, CDS spreads rose across the world, in particular in the Asia/Pacific region. Some of this likely reflected concerns that the failure of a large eurozone bank would reverberate across the world financial system. More generally, slowing global economic growth might also have lowered the credit quality of banks in the Asia/Pacific region and other export-driven economies. The timing of the rise in CDS spreads also suggests that S&P's August 5th downgrade of the U.S. credit rating in-

[7]The maximum credit risk in any individual prime MMF was 47 basis points in December 2011.

fluenced perceptions. Finally, the credit quality of Japanese banks might have suffered from the lingering impact of the March 2011 tsunami and the ongoing nuclear crisis. This growth in global credit risk, combined with the increased holdings of money market funds in these presumably safer regions of the world, largely explains why prime MMFs experienced a modest rise in measured credit risk in the second half of 2011. Given that eurozone developments only *indirectly* affected banks in the Asia/Pacific region, we conclude that the mild increase in the credit risk of prime money market funds in the second half of 2011 reflected contagion in the worldwide banking system, not actions taken by money market funds.

The cost of break-the-dollar insurance $BDI(l,u)$ should be less than $ELM$ for two reasons. First, break-the-dollar insurance would kick in only if a fund actually breaks the dollar, in other words if its mark-to-market value drops below $.995 per share. Second, like conventional insurance policies, break-the-dollar insurance can be structured to have a deductible $l$ and a maximum coverage amount $u$. The deductible and maximum coverage limit the insurance provider's exposure and thus the cost of purchasing the insurance. As we show, $BDI(l,u)$ is indeed less than $ELM$. We estimate that for plausible values of $l$ and $u$, the cost of break-the-dollar insurance over the period January 2011 to December 2012 averaged 7 basis to 9 basis points (weighted by assets), roughly half the 15 basis point average cost (as measured by $ELM$) of insuring a fund against all expected losses over the 24-month period. Interestingly, this break-the-dollar insurance estimate is similar to the range of fees the U.S. Treasury assessed under its 2008-2009 temporary guarantee program.

Finally, using fund-by-fund values of $ELM$, we examine whether the SEC's 2010 reforms reduced the credit risk of money market funds. Using a panel data regression, we find that $ELM$ declines as a fund's liquidity rises and its $WAL$ declines. This suggests that the SEC's decision to impose a minimum liquidity standard and a maximum $WAL$ on MMFs in January 2010 reduced the credit risk of prime funds. It is difficult to gauge how sizable the effect was because funds did not report their monthly portfolio holdings, $WAL$s, or weekly liquidity (according to the SEC definition of weekly liquidity) before November 2010. However, using plausible assumptions about the levels of weekly liquidity and fund $WAL$s before 2010, we show that these two new provisions had the potential to substantially lower a fund's credit risk.

## 2 Methodology

This section describes our approach to estimating the credit risk of prime money market funds. For exposition, we introduce the following notation:

| | | |
|---|---|---|
| $I$ | = | total number of issuers in a fund's portfolio |
| $J$ | = | total number of securities in a fund's portfolio |
| $T_j$ | = | remaining days to maturity on security $j$ |
| $D_i$ | = | remaining days to a default by issuer $i$ |
| $w_{ij}$ | = | proportion of a fund's assets invested in security $j$ issued by issuer $i$ |
| $R_i$ | = | recovery rate on an issuer $i$'s securities in the event of a default |
| $CDS_i(T_j)$ | = | expected loss (annual rate) on security $j$ issued by $i$ with remaining life $T_j$ |
| $p_i(T_j)$ | = | cumulative probability up to time $T_j$ that issuer $i$ defaults; i.e., $P(D_i < T_j)$ |
| $\widetilde{p}_i(T_j)$ | = | $1 - \left[1 - p_i(T_j)\right]^{360/T_j}$, the annualized counterpart of $p_i(T_j)$ |
| $Y_i^{T_j}$ | = | equal to 1 if $D_i < T_j$ and zero otherwise |

Define expected loss-to-maturity $(ELM)$ for a given fund at a given moment in time to be:

$$ELM = \sum_{i=1}^{I} \sum_{j=1}^{J} w_{ij} CDS_i(T_j) \tag{1}$$

As noted, CDS premiums are not generally quoted for maturities of fewer than 6 months. To make Equation (1) operational, we use default probabilities provided by RMI. As the next section discusses, RMI creates forward-looking default probabilities for about 50,000 issuers worldwide for maturities of 1, 3, 6, 9, 12, 18, and 24 months. We interpolate these to obtain $p_i(T_j)$ for any intervening maturity.

Given the RMI default probabilities (or interpolated values), we approximate the annualized CDS premium for insuring against credit losses on issuer $i$ as:

$$C\hat{D}S_i(T_j) = (1 - R_i)\widetilde{p}_i(T_j) = (1 - R_i)\left\{1 - \left[1 - p_i(T_j))\right]^{360/T_j}\right\} \tag{2}$$

Substituting Equation (2) into Equation (1) gives:

$$ELM = \sum_{i=1}^{I} \sum_{j=1}^{J} w_{ij}(1 - R_i)\widetilde{p}_i(T_j) \tag{3}$$

$ELM$ approximates the expected loss on a fund's portfolio. In theory, the expected loss, or $CDS_i(T_j)$, on a given issuer should equal the difference between the yield on that issuer's debt, $r_i(T_j)$, and the yield on a risk-free security of comparable maturity, $r_g(T_j)$, (Hull and White, 2000). Thus, it should be that:

$$ELM = \sum_{i=1}^{I} \sum_{j=1}^{J} w_{ij} \left[ r_i(T_j) - r_g(T_j) \right] = \left( \bar{r} - \bar{r}_g \right) \tag{4}$$

where $\bar{r}$ is the fund's gross yield and $\bar{r}_g$ is the gross yield of a portfolio of risk-free securities with maturities that are identical to the corresponding risky securities in the fund's portfolio. If Equation (4) holds, it indicates that the gross yield advantage of a prime fund over a comparable government money market fund measures a prime fund's credit risk. As is discussed in the introduction, however, a fund's reported yield is based on the amortized cost of its securities, rather than mark-to-market values. Consequently, $ELM$ is likely to be more variable than $(\bar{r} - \bar{r}_g)$ and the two measures could diverge from month-to-month. Later, we evaluate the divergence between $ELM$ and $(\bar{r} - \bar{r}_g)$ and find that it is, on average, small across prime funds.

$ELM$ measures the annual cost of insuring a fund's portfolio against any credit losses, however large or small, assuming defaults are independent events. It also may be useful to measure the cost of insuring against a fund "breaking the dollar." As noted earlier, a fund is said to break the dollar if its mark-to-market value falls below \$.995. Under the assumption that the fund maintains a "constant risk" portfolio, the cost of insuring against this event depends on expected losses as well as any first-loss (deductible) provision and the maximum amount of the coverage. For example, one could envision designing a "break-the-dollar" insurance policy with a 50-basis-point deductible and a cap on total losses incurred by the insurer of 300 basis points.[8] Define any first-loss provision as $l$ and the insurer's cap as $u$. Then, break-the-dollar ($BDI$) insurance is:

$$BDI(l, u) = E \left\{ min \left[ max \left( Loss - l, 0 \right), u \right] \right\} \tag{5}$$

[8]For example, given defaults amounting to 300 basis points, the fund would be responsible for 50 basis points and the insurer would be responsible for 250 basis points. For defaults amounting to more than 350 basis points, the fund receives 300 basis points from the insurer but incurs the 50 basis point deductible plus any losses greater than 350 basis points.

where $Loss = \left[\sum_{i=1}^{I}\sum_{j=1}^{J} w_{ij}(1-R_i)Y_i^{T_j}\right]$, $P\left(Y_i^{T_j}=1\right) = \widetilde{p}_i(T_j)$, $(1-R_i)$ is the loss rate if issuer $i$ defaults, $l = 50$ basis points, $u$ =300 basis points, and E$\{\bullet\}$ is the expectations operator. This is the annualized cost of providing "break the dollar" insurance ($BDI$) against a "constant risk" money market fund portfolio.

Calculating $ELM$ is straightforward, requiring only multiplication and addition. If defaults were independent events, calculating $BDI(l,u)$ would also be straightforward. Things are more challenging when we assume defaults are correlated across issuers. In that case, calculating $BDI(l,u)$ requires computation of an $I$-dimensional integral (where $I \leq J$) representing the joint probability that there are $I$ defaults in the fund's portfolio over a given period. This is a well-known problem in the banking literature on calculating value-at-risk (VaR) and required regulatory capital such as IRC. That literature generally assumes that defaults of banks and other financial institutions are correlated. Many of the securities that money market funds hold are issued by banks or other financial intermediaries. Thus, we assume defaults are correlated across issuers.

The challenge of calculating expected losses like Equation (5) when defaults are correlated is often solved by Monte Carlo. We calculate Equation (5) using a copula approach (Li, 2000) implemented by Monte Carlo. Appendix 1 provides details. Briefly, the approach involves simulating random default times for each issuer $i$ a large number of times (*m=1 to M* trials) for each month in the sample. Default probabilities, and hence the random default times, are correlated across issuers with correlations calibrated to historical movements in default probabilities from January 2011 to December 2012. If a given simulation indicates that issuer $i$ defaults before time $T_j$, a fund experiences a loss equal to the sum of $w_{ij}(1-R_i)$ . Losses across all of a fund's securities are accumulated during a particular simulation $m$. If a fund's losses in simulation $m$ accumulate to more than 50 basis points of the fund's assets, the fund is counted as having broken the dollar (i.e., $Loss > l$).

Brute force Monte Carlo calculates Equation (5) by sampling Bernoulli random variates $Y_i^{T_j}$ with a probability of success ("success" meaning default) of $\widetilde{p}_i(T_j)$, where $\widetilde{p}_i(T_j)$ are correlated across issuers. This, however, may require very large numbers of simulated random draws because credit defaults are "rare events" (Glasserman and Li, 2005). Consequently, researchers often use variance reduction techniques such as importance sampling (Rubenstein and Kroese, 2007) to improve simulation accuracy. We reduce variance by "reusing" simulated random variates. For example, instead of sampling $24 \times 50,000 \times number\ of\ funds$ Bernoulli random variates $Y_i^{T_j}$, we draw one sample of 50,000 Bernoulli variates and use these in trial $m$ to calculate $BDI(l, u)$ for each of the 24 different months and for each fund in our sample. This appears to be sufficient to reduce variance because the standard errors of $BDI(l, u)$ are small, generally in the range of 1 basis point or less.

# 3 Data

To undertake the analysis, we create a new dataset comprising a complete record of the individual holdings of prime money market funds over the period January 2011 to December 2012. The analysis seeks to match those individual holdings on an issuer-by-issuer basis with estimated credit default swap premiums (via Equation 2) for the same issuer.

We obtain the complete record of the portfolio holdings of all prime money market funds from the SEC's form N-MFP. We categorize these holdings by the parent of the issuer. For example, Honda Auto Receivables Owner Trust, which issues commercial paper in the U.S. to help finance auto loans to U.S. residents, is affiliated with Honda Motor Company Ltd. which we take to be its "parent."

Parent companies are often global firms that may for any number of reasons need dollar funding from money market funds and other financial market participants. For instance, prime money market funds lend dollars on a short-term basis to large global banks (including those with headquarters in Europe, Japan, Australia and elsewhere) to make loans to subsidiaries of foreign companies that do business in the United States, to make consumer or car loans to U.S. residents, or to invest in U.S. Treasury and agency securities. Eurozone banks may also borrow dollars to make dollar loans to subsidiaries of U.S. companies that do business in Europe. Unlike U.S. banks, large foreign banks do not have significant retail U.S. dollar deposits to fund their global dollar-based operations and thus may seek to borrow dollars elsewhere, such as from money market funds or other institutional investors. Some global banks, including some domiciled in Europe, Asia, Canada, and the U.K. are "primary dealers," which are banks that are approved as trading counterparties of the New York Federal Reserve Bank; these banks engage in repurchase agreements, including with money market funds. We assign each parent firm to a particular region of the world based on the parent firm's headquarters. For example, BNP Paribas SA is headquartered in France and thus assigned a region of "Europe." Similarly, JPMorgan Chase & Co, although having worldwide operations, is assigned a region of "U.S."

In measuring a fund's credit risk, we use the final legal maturity date (e.g., 271 days) as reported to the SEC in form N-MFP.[9] The final legal maturity includes any "demand feature" a security may have, which allows a fund to demand its return of capital within a prespecified number of days.

Figure 2 provides summary statistics on the holdings of prime money market funds. As can be seen, prime money market funds invest in a range of money market instruments including commercial paper, bank CDs, Eurodollar deposits, medium term- and floating-rate notes, Treasury and agency securities, and repurchase agreements. In January 2011, commercial paper constituted 30.8 percent of prime fund assets (30.8 percent), bank CDs 25.5 percent, Treasury and agency securities 13.4 percent, repurchase agreements 16.1 percent, and other securities 4.1 percent.

Figure 3 tabulates these holdings by the issuer's region of the world, either Americas, Europe, Asia/Pacific, or Other. In January 2011, one-third (35.7 percent) of prime funds' assets were invested in issuers headquartered in the Americas, mostly in the United States; about 8 percent of funds' assets were invested in Canadian issuers (primarily banks). A bit more than 50 percent of prime funds assets were attributable to issuers domiciled in Europe, the bulk of which was invested in issuers domiciled in three countries (France, 14.9 percent; U.K., 11 percent, and Germany, 8.3 percent). Another 12.2 percent of prime fund assets were invested in issuers domiciled in the Asia/Pacific region, split about evenly between Japan and Australia/New Zealand.

From RMI, we obtain month-end cumulative default probabilities for maturities of 1, 3, 6, 9, 12, 18, and 24 months for as many issuers as possible in our sample. To calculate $ELM$ and $BDI(l,u)$ we need default probabilities that match the remaining maturity of each security a fund holds. Without some assumptions, we would be unable to match most of the securities

[9]This is in contrast to the security's maturity date, which a fund may use to determine its weighted average maturity ($WAM$). Consider, for example, a floating rate note that matures in 271 days but whose yield resets weekly. Consistent with the security's weekly interest rate reset, the fund may use a maturity of 7 days in calculating its $WAM$. But the fund must use the legal maturity date of 271 days in calculating the fund's weighted average life ($WAL$).

that prime funds hold with RMI-supplied default probabilities (e.g., for a security with a remaining maturity of 67 days). We deal with this by linearly interpolating default probabilities for every day between the maturities that RMI provides. Because some of the securities that prime funds hold mature within 1 to 7 days (e.g., overnight repurchase agreements), we also need estimates of default probabilities for maturities of less than 1 month. We solve this problem by imposing the condition that for any random variable $x$ whose support is in the range $[0, \infty)$, if $x$ has a continuous cumulative probability distribution, then $P[x \leq 0] = 0$. This condition implies that $\widetilde{p}_i(T_j = 0) = 0$, allowing us to linearly interpolate between that value and $\widetilde{p}_i(T_j) = 30/360)$.

Next, we match cumulative default probabilities (either actual or interpolated values) by hand with the list of parent firms collected from the holdings of money market funds as reported in the N-MFP reports. We are able to match default probabilities with parent firms for over 90 percent of the assets of prime money market funds. To calculate $ELM$ and $BDI(l, u)$ we also need recovery rates $R_i$ for each issuer. Consistent with market practice, we use a recovery rate of .40 for all private sector issuers except Japanese banks. For Japanese banks, we follow market convention and use a recovery rate of .35.[10] Our analysis could be extended by randomizing recovery rates. However, evidence in Tarashev and Zhu (2008) suggests that the added complexity may not add much additional insight in terms of results; they indicate, based on data collected from Markit for 136 entities, that the recovery rate market participants expect varies in a narrow range around 40 percent for daily data from late 2003 to early 2005. Consequently, we simply fix our recovery rates at either .35 or .4 depending on the parent company.

Our analysis could overstate $ELM$ and $BDI(l, u)$ because we use a number of simplifying assumptions. The fixed income securities prime funds hold sometimes have credit enhancements, such as a guarantee, letter of credit, or other provision that guarantees return of principal and interest. Although such enhancements reduce the risk of holding a security, we do not take them into account except in cases where the guarantee is provided by the U.S. government or other sovereign nation. Second, money market funds sometimes hold asset-backed

[10]For example, on its CDSW page, Bloomberg uses a recovery rate of .4 to estimate implied default probabilities for private sector issuers from CDS premiums. The only exception appears to be that Bloomberg uses a recovery rate of .35 for Japanese banks.

securities. All else equal, asset-backed securities have less credit risk than securities that are not asset-backed. For example, recovery rates on asset-backed securities that defaulted during the 2007-2008 crisis are generally reported to have been much higher (in the range of 80 percent or more) compared with a recovery rate of about 40 percent on unsecured Lehman Brothers debt. We ignore this fact and simply treat asset-backed securities as senior unsecured debt. Third, repurchase agreements are more than fully collateralized by securities that a fund's repo counterparty (the borrower) must place with a third-party custodian. The fund may seize this collateral if the repo counterparty fails to unwind the repo (i.e., fails to return the fund's cash) when the repo expires. All else equal, this makes repurchase agreements less risky than other senior unsecured debt. Nevertheless, we ignore this, treating repurchase agreements as uncollateralized (i.e., the credit risk is the full credit risk of the repo counterparty) unless the repos are fully collateralized by Treasury and agency securities, in which case we treat repos as having the default risk of the U.S. government.[11] Fourth, some of the roughly 10 percent of assets that we cannot match with default probabilities are securities issued by non-financial companies. Generally speaking, when available, CDS premiums on non-financial corporations have tended to be lower than those on financial companies.[12]

On the other hand, our analysis could understate $ELM$ and $BDI(l,u)$ because of how we treat sovereign debt. RMI does not publish default probabilities for sovereigns. Consequently, we simply assume that the default probabilities for U.S. Treasury and agency securities are zero at all maturities. We doubt many readers would object to this treatment for Treasury securities. With respect to agency securities, we note that over our sample short-term agency securities have yielded only a few basis points more than Treasury securities, indicating that market participants view short-term agency debt as about as risky as Treasury debt, consistent with the federal government's takeover of Fannie Mae and Freddie Mac in September 2008. Nevertheless, market participants do not necessarily view Treasury and agency securities as risk free.

[11]For a money market fund, there may be *liquidity* risk (which is not the subject of this paper) in a repurchase agreement backed by Treasury and agency collateral but there is arguably no *credit* risk (which is the subject of this paper). If a fund's repo counterparty fails to return the fund's cash when the repo matures, the fund would seize the Treasury and agency collateral pledged by the repo counterparty. A fund might need to liquidate some of the Treasury and agency collateral to meet shareholder redemptions, but that is case of liquidity risk, not credit risk. Put differently, we assume that if the fund were to hold the Treasury and agency collateral to maturity, it would all mature at par.

[12]For example, on January 31, 2011, then 1-year CDS premium on Pepsi Co, Inc. was quoted at 11 basis points, compared to 50 basis points for BNP Paribas SA, a large European bank.

For example, CDS premiums on Treasury securities are low but not zero (The Economist, 2011). It is unclear whether this arises because the CDS market for Treasury securities is thin (Austin and Miller, 2011) or because market participants now view Treasury securities as having some, albeit still very small, default risk. If it is the latter, our analysis might understate $ELM$ and $BDI(l,u)$ by some, presumably small, margin.[13]

## 4 Industry Average Results

Figure 4 plots the asset-weighted average across all prime funds of expected loss-to-maturity ($ELM$) for the period January 2011 to December 2012. For comparison, the figure also plots the prime-to-government fund yield spread shown in Figure 1.

$ELM$ is more volatile than the prime-to-government yield spread, consistent with the fact that funds report yields that are based on amortized cost rather than mark-to-market values. In some months, the two measures diverge by as much as 7 basis points, primarily because of month-to-month variation in $ELM$. Nevertheless, $ELM$ and the prime-to-government yield spread track each reasonably well, rising and falling more or less in tandem. On average, the two measures differ little (1 basis point) from each other over the 24-month period. Given that the credit risk measures track each other, for purposes of assessing fund credit risk, regulators and investors might prefer the prime-to-government yield spread as simpler, more readily available alternative to measures such as $ELM$ or credit risk measures constructed from CDS quotes (e.g., Rosengren, 2012). The paper examines that possibility in more detail later.

Figure 4 suggests that the aggregate credit risk of prime funds is low. $ELM$ averaged just 15 basis points on an asset-weighted basis from January 2011 to December 2012. This low level is consistent with these facts: (a) money market funds hold very short-term securities; (b) these securities are investment grade and virtually all are of the highest short-term credit rating; (c) the term structure of credit default swap spreads is upward sloping. Together, these

[13]The SEC's N-MFP data indicate that money market funds hold very little, if any, sovereign debt of other countries. This reflects the fact that money market funds may only hold U.S. dollar denominated securities in combination with an apparent lack of issuance by non-U.S. sovereigns of money market instruments denominated in U.S. dollars. In our N-MFP data, a very small number of securities are linked to a sovereigns other than the U.S. federal government. These limited cases arise: (a) because a sovereign has guaranteed the money market instrument of a private or quasi-private sector issuer; (b) a sovereign has taken over the liabilities of a private sector company. Virtually all of these cases arise from Germany, France, Belgium, Norway, or Japan. We assume that the default probabilities of these securities are zero.

characteristics limit the credit risk of prime money market funds. These estimates also suggest that Collins et al. (2013) overstated the credit risk of prime money market funds. Collins et al. (2013) estimated that $ELM$ averaged (on an asset-weighted basis) 27 basis points over 2011. Here, using a better approach to estimate default probabilities at maturities of less than 6 months, we find that $ELM$ averaged (on an asset-weighted basis) about half that, just 15 basis points over 2011.

$ELM$, though remaining low over the 24-month period, does vary. It changed little in the first half of 2011, ranging only between 10 and 12 basis points. It varied more in the second half of 2011, rising from 11 basis points in June 2011 to a maximum of 21 basis points in November. That rise is consistent with the market's intensifying concerns about eurozone banks, a deteriorating outlook for the U.S. economy, and the looming U.S. federal government debt ceiling crisis (see Collins et al., 2013). Still, the rise was small compared to the increases in 5-year CDS premiums on European financial institutions and large U.S. banks over the same period (Figure 1). By February 2012, $ELM$ had receded to 13 basis points, little different from its level in July 2011. $ELM$ fell, on average, over the remainder of 2012, likely reflecting the challenges of eurozone policy makers to find an all-encompassing economic and political solution to the eurozone's problems and the risks that the lack of a solution posed for global financial markets.

Prime fund managers acted vigorously in the second half of 2011 to reduce their exposure to the eurozone crisis. Prime funds also sharply reduced their holdings of issuers whose parents were domiciled in Europe (Figure 5). From May to December 2011, prime MMFs reduced holdings of French-domiciled issuers by 75 percent (from 15.1 percent to 3.3 percent of portfolio holdings), with the bulk of the decline occurring from June to September. As prime funds pulled back from the eurozone, they reallocated their investments to regions presumably more insulated from the eurozone crisis, including the U.S., Canada, certain Northern European countries, and, most notably, the Asia/Pacific region. Prime funds' assets attributable to Asia/Pacific-domiciled issuers rose from 11.6 percent in June 2011 to 17.5 percent by December 2011, an increase of $71 billion. This increase went primarily to banks headquartered in Japan and Australia/New Zealand.

In addition, prime funds mitigated credit risks from European issuers by lowering the $WAL$ of their remaining holdings in European-domiciled issuers. As Figure 6 shows, the $WAL$

for prime funds' European holdings fell from 63 days in May 2011 to 30 days in December 2011. Prime funds achieved this, in part, by raising the proportion of their remaining eurozone holdings devoted to overnight or 7-day repurchase agreements, most of which were collateralized by U.S. Treasury and agency securities.

These steps were effective in helping to insulate prime funds from the eurozone crisis. As evidence, Figure 7 shows results of a counterfactual comparing *ELM* to the *ELM* that would have occurred had prime funds continued throughout the remainder of 2011 to hold the portfolios they held in May 2011 (in other words, had they not taken steps to insulate their portfolios from the eurozone crisis). As seen in the upper-left panel, *ELM* would have been modestly higher (a peak difference of 4 basis points by November 2011) had prime funds continued to hold their May-level portfolio allocations throughout the rest of 2011.

The actions prime funds took to insulate themselves from the eurozone crisis would have been more effective had concerns about eurozone banks not spilled over into the global banking system. The remaining panels in Figure 7 show the contribution by region (either North America, Europe, or Asia/Pacific) to the *ELM* measure in the upper-left panel. Throughout 2011, the contribution from North America remained low and stable, in part reflecting the fact that much of prime funds' exposure to North America includes holdings of Treasury and agency securities. The lower-left panel shows the contribution of Europe to *ELM*. The solid black line shows that the actual contribution from Europe rose only slightly (3 basis points) from May to December 2011, consistent with prime funds' actions to limit exposure to eurozone issuers. Moreover, the counterfactual *ELM*—the red dashed line in the that panel—indicates that the contribution from Europe would have risen substantially (11 basis points rather than 3) had funds not acted to limit their exposure to the eurozone. Thus, most of the rise in *ELM* from June to December 2011 reflected contributions from countries outside Europe, notably those in the Asia/Pacific region. As the lower-right panel indicates, the Asia/Pacific region contributed *more* to the credit exposure of prime funds in the second half of 2011.

Thus, the steps prime funds took to insulate themselves from the eurozone crisis were offset to an extent by the exposure of prime funds to issuers domiciled in the Asia/Pacific region.[14] This, in turn, appears to reflect that prime funds were, to some extent, passive recip-

[14]This result is even more pronounced when we examine only those funds with *ELM* in the top quartile as of May 31, 2011. For this group of funds carrying higher credit risk in May, asset-weighted average *ELM* peaked in

ients of contagion from eurozone banks to the global banking system. Figure 8 plots the index of 5-year CDS premiums for large European financial institutions (i.e., the Markit iTraxx senior financial index). The figure also plots the averages of 5-year CDS premiums for selected large Japanese and Australian banks. The CDS premiums on Japanese and Australian banks are almost always lower than the European CDS index. Thus, all else equal, by shifting their portfolios toward banks in Japan and Australia, prime money market funds expected to reduce risk. But, as shown here, the three series are correlated. Notably, the 5-year CDS premiums for the Japanese and Australian banks rose from low levels (100 basis points or less) in January 2011 to over 250 basis points on October 4, the same day the 5-year CDS index for European financials hit its highest level (296 basis points) to that point in 2011. CDS premiums on Japanese banks, and to a lesser extent on Australian banks, spiked again in late November when the CDS index on European financials hit its highest point ever (355 basis points). This correlation is not perfect, however. For example, in mid-September, CDS premiums on Japanese and Australian banks fell somewhat while those on European banks continued to climb, indicating that non-eurozone factors also influenced the perceived credit quality of Japanese and Australian banks. Notably, the August 5th downgrade of the S&P's U.S. credit rating likely reverberated internationally. Furthermore, export-driven Japanese and Australian economies are particularly vulnerable to slowing global economic growth. Finally, the lingering effects of the tsunami and the resulting nuclear disaster may also stoked anxieties about the health of Japanese banks. The spike in CDS premiums among banks headquartered in Japan and Australia thus boosted the credit risk of prime funds in the fall of 2011.

These factors, not eurozone developments, appear to be the primary reasons the credit risks of prime money market funds rose somewhat in the second half of 2011. We conclude that the increase in the credit risk of prime money market funds in the second half of 2011 reflected worsening global economic conditions and contagion in the worldwide banking system, rather than actions taken by money market funds.

December at 29 basis points. These funds' European holdings contributed 7 basis points to their asset-weighted average *ELM* in May. This contribution rose to 11 basis points in December 2011 – well below the counterfactual contribution of their European holdings, which would have amounted to 21 basis points in December had funds not reacted. Similarly, the contribution from the Asia/Pacific region was 15 basis points in December, compared to 9 basis points had these funds continued to hold their May-level portfolio allocations throughout the rest of 2011.

### 4.1 Breaking the Dollar: Insurance Cost

This section presents estimates of $BDI(l,u)$. As noted earlier, this is the cost of insuring a fund against defaults when losses total more than 50 basis points of a fund's assets. We estimate $BDI(l,u)$ using a t-density copula, which we simulate by Monte Carlo using 50,000 random draws per month (see Appendix 1), with 5 degrees of freedom ($df = 5$).[15]

We present two different sets of $BDI(l,u)$. We set $l = 0$ or $l = 50$ basis points of fund assets. Setting $l = 0$ implies that the insurance has no deductible. Setting $l = 50$ implies that there is a 50-basis-point deductible, which could be assumed either by the fund's adviser or by fund shareholders. In both cases, we set $u = 300$ basis points. Under this assumption, the maximum insurable loss, after the 50-basis-point deductible is incurred, would be 300 basis points of fund assets. If a fund's losses from defaults totaled more than 350 basis points, the insurance would pay out, and the fund would close. Any losses greater than 350 basis points would accrue to fund investors.

We selected these choices for $l$ and $u$, in part, because they are roughly in line with the parameters of the U.S. Treasury's 2008-2009 guarantee program for money market funds. Under that program, the Treasury temporarily provided break-the-dollar insurance for money market funds. The insurance kicked in if a fund's market-to-market price per share fell below $.995, in other words, if the fund broke the dollar. If a fund broke the dollar and used the Treasury's insurance, the fund was required to close and liquidate. Consequently, Treasury's losses would have been limited to the difference between a fund's $1.00 NAV and the market value of the fund's assets. The Treasury's program was backed by, and limited to, balances in the Treasury's Exchange Stabilization Fund (ESF). When the Treasury introduced the money market fund guarantee program in September 2008, the balance in the ESF was about $50 billion, which implies that the Treasury's potential exposure was limited to about 3 percent of the total assets of prime money market funds.[16] In addition, some regulators and academics argue for

[15] Rather than try to estimate the relevant degrees of freedom $df$ in the t-copula, following Hull and White (2004), we simply set $df = 5$. Experiments with $df = 1$ and $df = 10$ indicate marginal differences from those based on $df = 5$.

[16] It has occasionally been suggested that the Treasury Department guaranteed trillions of dollars in money market fund assets (e.g., Bair, 2013). The Treasury's exposure, however, was limited to the roughly $50 billion available to it through the ESF. Also, the Treasury guarantee only applied to, at most, the assets in funds as of September 19, 2008. On that date, prime money market funds had assets of $1,728 billion, according to iMoneyNet.com. Thus, the total exposure of the Treasury Department was limited to 289 basis points of prime fund assets, based on the calculation 10,000 $\times$$50 billion/$1,728 billion.

requiring money market fund advisers to commit capital to support losses their money market funds might experience. Regulators in Europe argue for a capital buffer of 300 basis points of fund assets. Some academics (Squam Lake, 2013; Hanson, Scharfstein, and Sunderam, 2013) have suggested that U.S. fund advisers be required to hold a capital buffer in the range of 3 to 4 percent of risk-weighted assets. On the basis of these considerations, we set $u = 300$ basis points.

The Treasury's guarantee program did not impose an explicit deductible, which, on one hand, suggests setting $l = 0$. On the other hand, the guarantee program required a fund using the Treasury insurance to demand payment on any capital support agreement provided by the fund's adviser. For various reasons, fund advisers sometimes voluntarily entered into capital support agreements with their money market funds. In such an arrangement, the adviser would typically agree to buy, guarantee to buy, or provide insurance on the value of, one or more fund securities at par value. In effect, this would provide a deductible to the Treasury on its insurance. It is unclear how much this deductible would have been worth to the Treasury Department because no money market fund ever drew on the Treasury's insurance program. Consequently, we rather arbitrarily set $l = 0$ or $l = 50$ basis points. As will be seen, results are similar under either assumption.

Figure 9 presents estimates of $BDI(0, 300)$ and $BDI(50, 300)$. As would be expected, these are lower than $ELM$. For example, in November 2011, $ELM$ hit a peak of 21 basis points compared to peak levels of 12 and 11 basis points for $BDI(0, 300)$ and $BDI(50, 300)$. Over the 24 months, $BDI(0, 300)$ and $BDI(50, 300)$ averaged 9 and 7 basis points, compared to 15 basis points for $ELM$.

Interestingly, the estimates for $BDI(0, 300)$ and $BDI(50, 300)$ are about in the range of fees the U.S. Treasury assessed under its 2008-2009 temporary guarantee program. The Treasury Department initially set the cost to funds for this insurance at 4 basis points at an annual rate for funds with a mark-to-market value of \$.9975 or above and 6 basis points for funds with a mark-to-market value of less than \$.9975 but greater than \$.9950 (insurance was not available to money market funds with a mark-to-market value of less than \$0.9950).[17] The Treasury raised the cost to 6 to 8.8 basis points at an annual rate (again depending on whether a fund's

[17]See U.S. Treasury Department, "Treasury Announces Temporary Guarantee Program for Money Market Funds," September 29, 2008.

mark-to-market was above or below \$.9975) when it first renewed the insurance program, about in line with our estimates of 9 and 7 basis points for $BDI(0,300)$ and $BDI(50,300)$ over the period 2011-2012.

# 5 Individual Fund Results

Until now, we have focused primarily on asset-weighted averages of $ELM$ and $BDI(l,u)$. As Figure 10 indicates, though, averages can could mask interesting details, notably that there is considerable variation in $ELM$ and yield spread across funds. This is worth exploring. This section uses panel data regressions in an effort to better understand why these cross-sectional differences arise.[18]

## 5.1 Is Yield Spread a Good Measure of Credit Risk?

As noted earlier, Hull and White (2000) argue that arbitrage ensures that the CDS premium on a bond should, under "ideal" conditions, equal the spread between a risky bond's yield and the yield on a risk-free bond with an identical maturity. If this condition approximately holds for a fund across its entire portfolio, rather than constructing a credit risk measure from CDS premiums as we have done in this paper, regulators and investors can simply look to a fund's yield spread $(\bar{r} - \bar{r}_g)$, which can readily be determined from data published by third-party providers such as iMoneyNet.com and Crane data.

As Hull and White (2000) point out, however, there are reasons why the difference between the CDS premium on a bond might not equal the difference between the yield on a risky bond and the risk free rate. One is that the arbitrage condition assumes identical tax treatment for risk-free (i.e., Treasury) and private sector bonds, which is generally not the case. The arbitrage condition also assumes that the recovery rate used to calculate the CDS premium is the same recovery rate the market is using, which might not be true. The Hull-White arbitrage condition also assumes that the yield curve is flat, which is generally not the case during our

[18]Unlike as in the previous section, where results were asset-weighted, in this section small funds are given the same weight as very large funds. Therefore, to ensure that panel data results are not skewed by a number of small funds for which we were unable to match the majority of portfolio securities to default probabilities, we further clean the dataset used in this section. In any given month, we remove funds for which less than 70 percent of fund assets could be matched to default probabilities. The total assets of these omitted funds amount to 10 percent of industry assets.

sample period. Any of these conditions may not hold in our setup, meaning that $ELM$ might not equal the fund's yield spread $(\bar{r} - \bar{r}_g)$.

There are other reasons $(\bar{r} - \bar{r}_g)$ might differ from $ELM$. These stem from our particular data set. In theory, to construct $(\bar{r} - \bar{r}_g)$, we should match each of a fund's portfolio securities to a government security with an identical maturity. This is cumbersome and, more importantly, is not a measure readily at hand to investors or regulators who wish to gauge a fund's credit risk. Consequently, we use a simpler approach, approximating $\bar{r}_g$ as the (simple) average gross yield on all government money market funds. Both $\bar{r}$ and $\bar{r}_g$ are readily available from data providers, such as iMoneyNet and Crane Data.[19] But this means we are calculating $(\bar{r} - \bar{r}_g)$ with error.

Measurement error could also arise in $(\bar{r} - \bar{r}_g)$ because of amortized cost accounting. We are using gross fund yields, as reported to iMoneyNet, to approximate $\bar{r}$ and $\bar{r}_g$. These measures are based on funds' valuation of their portfolio securities at amortized cost, whereas the "idealized" relationship, $ELM = \bar{r} - \bar{r}_g$, should be calculated from yields based on current market values (i.e., from mark-to-market values). Consequently, our measure of a fund's yield spread will lag behind and be less variable than a fund's true credit risk (Figure 10).

Slippage might also occur because $ELM$ is itself measured with noise. Some of the securities prime funds hold are collateralized, asset-backed, or possess credit enhancements, all of which reduce credit risk. However, our analysis generally ignores these credit-enhancing features. For example, as indicated in Section 3, we treat asset-backed commercial paper as equivalent to unsecured commercial paper. This could potentially lead us to overestimate $ELM$.

Despite the potential for slippage, the question remains: is the relationship close enough that $(\bar{r} - \bar{r}_g)$ is a simple, yet useful, guide to a fund's credit risk? The answer appears to be "yes", though within limits. Figure 11 displays a scatter plot $ELM$ against $(\bar{r} - \bar{r}_g)$. Most data points are located near the 45 degree line and there is a strong positive (0.7) correlation between the two variables. On the other hand, roughly 10 percent of the observations sit at least 10 basis points above or below the 45 degree line. As a rough guide to a fund's credit risk, however, this may be a small price to pay given the complexity and data requirements of calculating a

[19] To adjust for numerous data entry errors in Form N-MFP fund yields, we import yield information from iMoneyNet. We use iMoneyNet yield information wherever reasonable.

CDS-based measure of credit risk such as *ELM*.

### 5.2 The Effects of the SEC's 2010 Reforms on Credit Risk

As noted in the introduction, to increase the resilience of money market funds to shocks in the wake of the financial crisis, in 2010 the SEC implemented wide-ranging reforms of money market funds. Among other things, these reforms lowered the maximum allowable *WAM* for money market funds from 90 to 60 days. A fund's *WAM* is determined by taking the asset-weighted average of the minimum of the final legal maturity of each of the fund's securities or the number of days until the next interest rate reset on that security (if the security is a floating rate instrument). Some research has found that the SEC's 2010 *WAM* restrictions reduced the interest rate risk that money market funds take on. For example, using Monte Carlo simulations, the SEC (2012) found that the new, lower 60-day limit for fund *WAM*s reduced the probability of a fund breaking the dollar. But the effect in that study stems from a reduction in interest rate risk.

To date, there has been relatively little if any empirical study of how the SEC's 2010 reforms affected the credit risk of money market funds. In 2010, the SEC imposed for the first time a maximum weighted average life (*WAL*), which the SEC set at 120 days. A fund's *WAL* is determined by the taking the asset-weighted average of the final *legal* maturity (in days) of each of a fund's securities. The SEC also imposed liquidity standards requiring money market funds to hold at least 10 percent of their assets in securities that are deemed to be liquid within 1 day and another 20 percent in securities that are deemed to be liquid within 7 days, for a total of 30 percent in "weekly liquid assets." The liquidity standards, by encouraging funds to hold greater amounts of Treasury and agency securities, presumably lowered the (private sector) credit risk that prime money market funds may take on. In addition, if the term structure of CDS premiums is upward sloping, as is typically the case for high quality credits, the new liquidity and *WAL* conditions would also have helped limit the credit risk of prime money market funds by pushing money market funds' portfolios inward along the term structure of CDS premiums.

This section seeks to assess the effects of the SEC's 2010 reforms on fund *WAL* and liquidity on the credit risk in prime money market fund portfolios. We would prefer to have data on prime funds' holdings, liquidity, and $WAL$s both before and after January 2010, the month the SEC adopted its reforms. The SEC, however, did not require funds to begin reporting on Form N-MFP until November 2010. Before November 2010, only quarterly portfolio holdings are available for money market funds, which for various reasons are not easily collated. Moreover, $WAL$ and liquidity standards did not exist before the SEC amended Rule 2a-7 in January 2010. As a result, before November 2010, money market funds did not generally report such measures.

Consequently, to examine the effects of the SEC's 2010 reforms on money market funds' credit risk, we conduct a counterfactual. This counterfactual proceeds by undertaking panel data regressions of $ELM$ on funds' weekly liquid assets ($LIQ$), funds' weighted average lives ($WAL$), and other fund characteristics. Using the regression results, and taking $LIQ$ and $WAL$ during the period of January 2011 to December 2012 as the benchmark, the counterfactual asks how prime funds' credit risk might have differed had liquidity been lower and $WAL$ been higher, as would presumably have been the case before January 2010.

In some of these regressions, we separate $LIQ$ into the part that is invested in government securities (i.e., those that are Treasury or agency securities or repo-backed by Treasury and agency securities), $GOVLIQ$, and the remainder, $NONGOVLIQ$. In some regressions, we also replace $WAL$ with $NONGOVWAL$, which is the $WAL$ of the fund's non-government securities. Following Chernenko and Sunderam (2014), we include in these regressions the log of fund assets and the percentage of fund assets in institutional share classes. These researchers indicate that these variables are potentially associated with higher levels of credit risk. To control for time-varying global financial risks, we include in the regressions the averages of 5-year CDS premiums for banks in each of four different regions: Europe, Japan, Australia, and the U.S. Finally, we include the residuals from a regression of $ELM$ on $(\bar{r} - \bar{r}_g)$ as a control variable to mitigate the influence of measurement error in $ELM$.[20] For brevity, we report only the coefficients on the variables measuring the impact of the 2010 reforms. Full results are available

[20]As noted in the previous section, $ELM_{f,t}$ is measured with error, which could lead to coefficient standard errors that are "too big." Also measurement error in $ELM$, if correlated with the explanatory variables, could bias coefficient estimates (Hyslop and Imbens, 2001). One way to treat such endogeneity is to find a proxy variable for the unobserved measurement error. We run the regression: $ELM_{f,t} = \alpha D_t + \beta(\bar{r}_{f,t} - \bar{r}_{g,t}) + \varepsilon_{f,t}$, where $D_t$ are date fixed effects. We include the residuals from this regression as a proxy for the measurement error in $ELM_{f,t}$. These residuals have non-zero and significant correlation coefficients with several of the explanatory variables, signaling that endogeneity may indeed be a problem. Any such endogeneity is likely alleviated by the inclusion of these residuals among the control variables.

on request.

Results of these panel data regressions are shown in Figure 12. Columns (1) and (2) consider the effects of weekly liquidity. Column (3) considers the joint effects of $LIQ$ and $WAL$. Columns (4) includes both $LIQ$ and $NONGOVWAL$. Finally, column (5) repeats the regression in column (4), but replaced the dependent variable $ELM$ with the yield spread $(\bar{r} - \bar{r}_g)$.

Column (1) indicates that greater liquidity is associated with lower credit risk. The coefficient on $LIQ = -0.203$ and is statistically significant, which means that in a cross-section of funds, funds with greater liquidity, as measured by the SEC's weekly liquidity standard, have a lower $ELM$.[21] To assess whether imposing a liquidity standard lowered prime fund credit risk, we approximate weekly liquidity before and after the SEC's 2010 Reforms from iMoneyNet data (Figure 13).[22] According to the iMoneyNet definition, prime funds' (simple) average weekly liquidity rose from 31 percent of assets over 2006-2007 to 48 percent of assets over 2011-2012. If $LIQ$ rose by that amount (i.e., 17 percent) in response to the SEC's 2010 reforms, the regression indicates that the average prime fund's credit risk would have declined by 3.4 basis points, a reduction of about 22 percent relative to the asset-weighted average level of $ELM$ of 15 basis points from January 2011 to December 2012.

The results in column (2) indicate that most of this estimated decline would have arisen because, to meet the new liquidity standard, prime funds increased their holdings of Treasury and agency securities or repo securities backed by Treasury and agency debt. Not all of the credit effect, however, is due to increased holdings of such securities. The results indicate that a prime fund that met the new weekly liquidity standard by increasing its holdings of *non-government* securities maturing in under 5 business days ($NONGOVLIQ$) would also have experienced a reduction in credit risk. For example, the results indicate that a prime fund's $ELM$ would have declined 1.1 basis points for a fund that raised $NONGOVLIQ$ from 31 to 48 percent of assets.

[21] Under the amendments to Rule 2a-7 that the SEC adopted in 2010, funds must also hold 10 percent of their assets in cash, U.S. Treasury securities or securities that convert to cash the next business day. The percentage of fund assets held in these securities constitutes the fund's "daily liquidity." For brevity, we do not show regressions using daily liquidity. However, the coefficient on daily liquidity is negative and is economically and statistically significant.

[22] Due to data limitations, the iMoneyNet measure is indicative of, but not identical to, the SEC's definition of weekly liquidity. The SEC measure (i.e., $LIQ$) and the iMoneyNet measure of weekly liquidity differ in that the iMoneyNet measure excludes all U.S. agency securities maturing within 60 days and double counts U.S. Treasury securities maturing within 7 days. Despite these differences, the iMoneyNet measure is usually within 2 percentage points of $LIQ$.

Column (3) examines the joint effect of $LIQ$ and $WAL$ on a fund's credit risk, as measured by $ELM$. The coefficient on $LIQ$ remains negative and statistically significant, indeed little different from its level in column (1). The coefficient on $WAL = .036$ and is statistically significant, indicating that reducing a fund's $WAL$ reduces its credit risk and this effect is independent of changes in a fund's weekly liquid assets. This regression can be used to evaluate the independent effect of the SEC's 2010 imposition of a $WAL$ limit on the credit risk of prime funds. The 2010 reforms capped a money market fund's $WAL$ at 120 days. Before the 2010 reforms, $WAL$ limits did not exist, funds did not publish $WAL$s, and hence, the reduction in fund $WAL$s as a result of the SEC's 2010 reforms is unknown. However, before and after 2010, money market funds were generally prohibited from holding securities with a remaining life of more than 397 days. Thus, we judge the current 120 day $WAL$ limit against a hypothetical fund with a $WAL$ of 260 days (about half way between 120 and 397 days). Before the SEC's 2010 reforms, a fund could have held such a portfolio if the securities were floating rate instruments with a weekly interest rate reset; the fund's $WAM$ would have been 7 days, which would not have violated the then-prevailing $WAM$ limit of 90 days. The regression indicates that the SEC's imposition of a $WAL$ limit in 2010 would have reduced the credit risk on the hypothetical fund by 5 basis points ($.036 \times (120 - 260)$). We do not know if this is an extreme example. But it does suggest that a $WAL$ limit can help mitigate a prime fund's credit risk.

The regression in column (3), however, masks an important detail: a prime fund could have a large portion of its assets in longer-dated Treasury securities, resulting in a high $WAL$ (and a high level of weekly liquidity) but very low credit risk (assuming, as we do, that Treasury securities have no default risk). Because of this, the true effect of $WAL$ on a fund's credit risk could be distorted. To check for this possibility, column (4) replaces a fund's $WAL$ with the $WAL$ calculated only by using a fund's non-government securities (i.e., excluding Treasury, agency, and repo securities that are backed by Treasury and agency collateral), which we call $NONGOVWAL$. The coefficients on both $LIQ$ and $NONGOVWAL$ are statistically significant. Moreover, the size of the coefficient on $NONGOVWAL$ is, if anything, bigger than it was in column (3). This indicates that a reduction in a fund's $WAL$ arising from *non-government* securities significantly lowers a fund's credit risk, independent of the Rule 2a-7 minimums on funds' weekly liquidity. The regression in column (5), which replaces $ELM$ with $(\bar{r} - \bar{r}_g)$, shows that these effects continue to hold if we instead use a fund's prime-to-government yield spread as the measure of a fund's credit risk.

To put these effects in context, it would be preferable to test whether $ELM$ declined for the average fund after the SEC enacted its 2010 reforms. That is not possible because our primary data source, the SEC's N-MFP report, did not exist before November 2010. However, because of the reasonably strong correlation evidenced in Figure 11, we can use $(\bar{r} - \bar{r}_g)$ to proxy $ELM$ before and after January 2010. Figure 14 shows box and whiskers plots of $(\bar{r} - \bar{r}_g)$ from January 2005 to December 2013 for all prime funds reporting to iMoneyNet. There is not much evidence of a decline in the *average* yield spread after January 2010: the median and interquartile range of $(\bar{r} - \bar{r}_g)$ changed little in 2010-2013 compared to 2005-2006 (i.e., before the housing and financial crises). Considering that, on average, funds held less liquidity before the reforms (Figure 13), one explanation for the lack of change in yield spreads is that issuers were perceived to have lower credit risk in the years before the crisis.[23] This offset upward pressure on yield spreads generated by longer average maturities. Nevertheless, the number of funds in the extreme tails (represented with dots) has fallen dramatically since 2010, reflecting that the distribution of fund returns has become compressed. A plausible explanation is that the SEC's 2010 reforms succeeded in pushing funds with outlying credit risks toward the center of the distribution. Therefore, even if the 2010 reforms, alone, did not substantively change the credit risk of the median fund, they may have dramatically lowered the credit risk of funds in the upper-tail of the distribution.[24] Thus, for example, according to the model in Figure 12 and assuming no change in issuer credit quality, a hypothetical fund with an $ELM$ of 40 basis points before the SEC's 2010 reforms that increased its weekly liquidity from 18 to 35 percent (i.e., the bottom quartile in Figure 13) and reduced its $WAL$ by 120 days is predicted to reduce its $ELM$ by 7.2 basis points. This would represent an 18 percent decline in that hypothetical fund's $ELM$.

In sum, the results in Figure 12 indicate liquidity and credit risk are closely tied. The liquid-

[23]For example, 1-year CDS premiums on JPMorgan Chase, a substantial issuer of short-term debt to prime MMFs, averaged just 8 basis points over 2005-2006 compared to 43 basis points over 2011-2012.

[24]This observation is consistent with SEC (2012), who study the distribution of funds' weighted average maturities (WAM) pre- and post-reform. They write: "The report documents that the reduction in maximum weighted average maturity (WAM) from 90 to 60 days did not cause all funds to lower their WAMs. Instead, the largest effect was on funds that had WAMs above 60 days. For example, the 95th percentile decreased from approximately 70 days at the end of 2009 to approximately 55 days at the end of 2010."

ity requirements and $WAL$ limits imposed under the SEC's 2010 reforms both independently served to reduce the credit risk in prime money market funds.

## 6 Conclusion

This paper develops a metric for assessing credit risk in prime money market funds, "expected loss-to-maturity" or $ELM$. It is an estimate of the CDS needed to insure a prime fund's portfolio against credit losses. Using this new metric, we study the evolution of credit risk in prime funds through the turbulent markets of 2011-2012.

Contrary to some earlier work, our results suggest that an increase in prime funds' average credit risk in 2011 is not primarily attributable to funds' European bank exposure. Beginning in June 2011, prime money market funds' efforts to reduce both the size and maturity of their investments in European banks largely counteracted the effect of rising European bank credit risks. At the same time, prime funds' shifted assets toward banks in the Asia/Pacific region, which also had sharply rising CDS premiums as fears of eurozone contagion and global economic conditions worsened. This shift is primarily responsible for the jump in prime funds' average $ELM$ over late-2011. Still, the rise in average $ELM$ to 21 basis points in November 2011 (compared to an average of 15 basis points over 2011-2012), was small compared to the increases in 5-year CDS premiums on large financial institutions over the same period.

The concept of $ELM$ can also be used to assess the cost of insuring a fund against mounting correlated losses. Using a t-copula approach to account for correlated defaults, we calculate by Monte Carlo the cost of insuring a fund against losses of more than 50 basis points and up to 300 basis points. The cost of this "break the dollar" insurance, $BDI(50, 300)$, averaged 7 basis points over 2011-2012. This is substantially lower than the average cost of insuring the fund against any and all loses (15 basis points). Interestingly, this estimate for $BDI$ is in the range of fees the U.S. Treasury assessed under its 2008-2009 temporary guarantee program (6 to 8.8 basis points at an annual rate).

Finally, we find evidence that the SEC's 2010 reforms, which imposed new and stricter portfolio maturity requirements and required funds to hold a given percent of their funds in liquid assets, reduced credit risk in prime funds. More broadly, our results suggest that regulators and fund managers can influence the credit risk of fund portfolios by altering the maturities of portfolio securities.

## Appendix 1: Monte Carlo Simulation of $BDI(0,300)$ and $BDI(50,300)$

1. Using default probabilities collected from RMI, for each issuer $i$ in the fund's portfolio:

   (a) Set $p_i(0) = 0$

   (b) Linearly interpolate $p_i(T_j)$ for all days $T_j$, where $T_j \in \{1, 2, \ldots, 720)$ and $T \notin \{30, 60, 90, 180, 270, 360, 540, 720\}$

   (c) Calculate the annualized default probability $\widetilde{p}_i(T_j) = 1 - \left[1 - p_i(T_j)\right]^{360/T_j}$

2. Create the correlation matrix $\Lambda$ to be used in the copula. Following Tarashev and Zhu (2008), we approximate the correlation matrix $\Lambda$ as $corr(\Delta lnD_i, \Delta lnD_j)$ where $\Delta lnD_i$, is the (log) distance-to-default. They show that $corr(\Delta lnD_i, \Delta lnD_j) \approx corr[\Delta\Phi^{-1}(\widetilde{p}_i), \Delta\Phi^{-1}(\widetilde{p}_j))]$ where $\Phi^{-1}(\bullet)$ is the inverse cumulative normal distribution, and $\Delta\Phi^{-1}(\widetilde{p}_i)$ is month-to-month change in $\Phi^{-1}(\widetilde{p}_i)$. As described in Section 3, we have 24 months of data, 8 different maturities per month, and about 100 unique "high level" issuers. Without some restrictions, $\Lambda$ would be very large. Consequently, we assume that $\Lambda$ is constant across time and maturities. We also set to zero any correlation with a *p-value*$>$ .10; in effect, we are assuming that if a correlation is not statistically significant at the 10 percent level, it is zero.

3. Do $m = 1$ to $M$ simulations for each fund:

   (a) Draw a vector of $k = 1, 2, \ldots K$ random variates $z_k$ from a multivariate t-distribution $t_v(0, \Lambda)$, which has a mean vector of zero, a correlation matrix of $\Lambda$ and $v$ degrees of freedom. To do this, we must use a Cholesky decomposition of $\Lambda$, which requires $\Lambda$ to be positive definite. To ensure that $\Lambda$ is indeed positive definite, we follow Rebonato and Jackel (1999) adjusting the eigenvalues of $\Lambda$ as necessary by very small amounts.

   (b) Calculate $u_k = t^{-1}(z_k)$ where $t^{-1}(\bullet)$ is the inverse cumulative t-distribution.

   (c) For each issuer $i$ for each date, set:

$$Y_i^{T_j} = 0 \quad if \quad u_k > \widetilde{p}_i(T_j)$$
$$Y_i^{T_j} = 1 \quad if \quad u_k \leq \widetilde{p}_i(T_j)$$

When $Y_i^{T_j} = 1$, issuer $i$ is assumed to have defaulted before security $j$ matures. This is equivalent to testing whether $t_k < T_j$ where $t_k$ is a simulated time-to-default on issuer $i$ and $T_j$ is the remaining maturity on security $j$. Since $u_k$ is calculated on the basis of $\widetilde{p}_i(T_j)$, this is equivalent to assuming that if a security does not default before maturity, the fund simply rolls that security over into an identical issue. If the security defaults, the fund suffers a loss and such losses are accumulated, but the defaulted security is not replaced by a comparable security. Thus, this approach has elements in common with the BIS approach of assuming a "constant risk portfolio" when measuring Incremental Risk Capital.

(d) For each fund for each date, from $m = 1$ to $M$:

   i. calculate $Loss = \left[\sum_{i=1}^{I} \sum_{j=1}^{J} w_{ij}(1 - R_i)Y_i^{T_j}\right]$

   ii. for $m = 1$, set $A_{m-1} = 0$

   iii. if $Loss > 50$ basis points, deliver $A_m \leftarrow [A_{m-1} + \min(Loss - l, u)]$

   iv. else if $Loss \leq 50$ basis points, deliver $A_m \leftarrow [A_{m-1} + 0]$

(e) End of $m$ loop.

4. Set $BDI(l, u) \leftarrow \frac{A_M}{M}$

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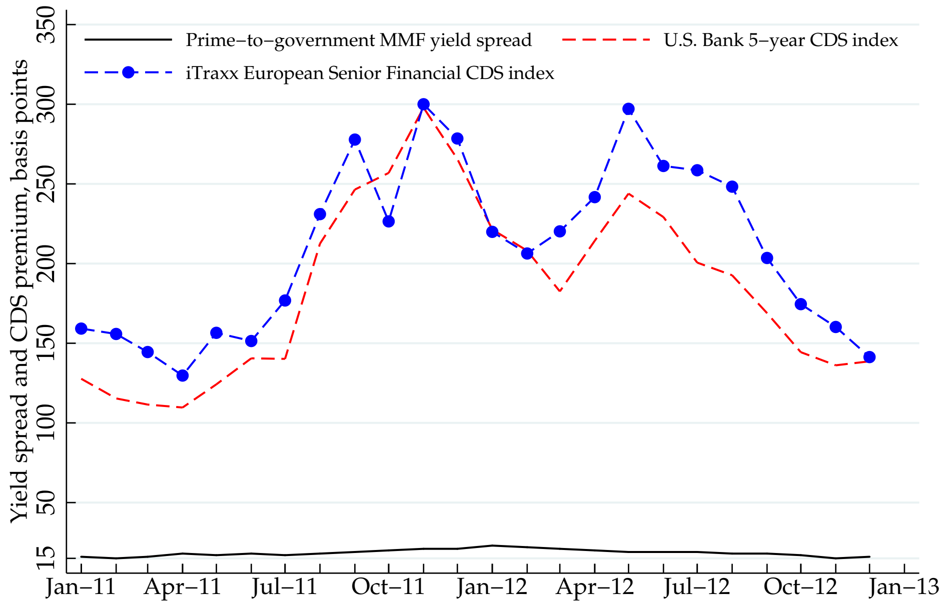
Figure 1: Yield Spread between Prime and Government MMFs



Source: iMoneynet.com; Bloomberg

Figure 2: Prime MMF Securities Holdings, January 2011

| *Security type category* | *Assets* (billions of $) | *% of prime fund assets* |
|---|---|---|
| *Total* | 1343.7 | 100.0% |
| *Commercial paper (CP) & Other Notes* | 414.3 | 30.8% |
| Financial CP | 197.0 | 14.7% |
| Asset-backed CP | 111.2 | 8.3% |
| Other CP | 30.7 | 2.3% |
| Variable rate demand notes | 9.8 | 0.7% |
| Other notes | 65.5 | 4.9% |
| *Bank CDs* | 477.3 | 35.5% |
| *Treasury and agencies* | 180.6 | 13.4% |
| Agency securities | 68.4 | 5.1% |
| Treasuries | 112.2 | 8.4% |
| *Repurchase Agreements* | 216.2 | 16.1% |
| Treasury & agency repo | 34.3 | 2.6% |
| Treasury repo | 91.4 | 6.8% |
| Other repo | 90.5 | 6.7% |
| *Other* | 55.4 | 4.1% |
| Other instruments | 55.1 | 4.1% |
| Municipal securities | 0.2 | 0.0% |

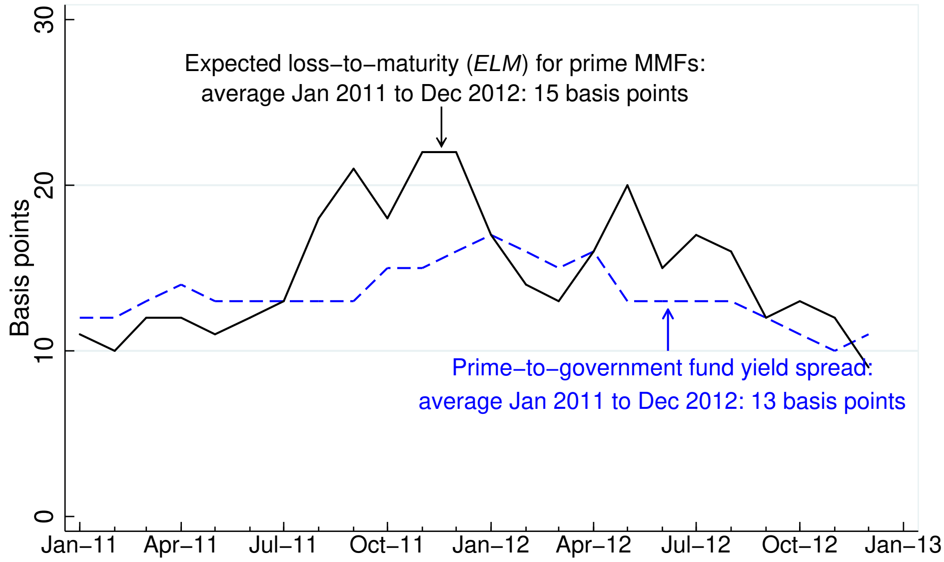
Source: authors' tabulation of SEC Form N-MFP reports

Figure 3: Securities Held by Prime Money Market Funds, By Region/Country

January 2011, Billions of dollars

| *Region/Country* | *Assets* (billions of $) | *% of prime fund assets* |
|---|---:|---:|
| *Total* | $1,343.7 | 100.0% |
| *Americas* | 479.6 | 35.7% |
| USA | 379.0 | 28.2% |
| Canada | 100.4 | 7.5% |
| Chile | 0.3 | <0.1% |
| *Europe* | 695.4 | 51.8% |
| France | 200.0 | 14.9% |
| UK | 147.3 | 11.0% |
| Germany | 110.9 | 8.3% |
| Netherlands | 67.2 | 5.0% |
| Switzerland | 54.8 | 4.1% |
| Sweden | 44.2 | 3.3% |
| Norway | 15.9 | 1.2% |
| Italy | 15.3 | 1.1% |
| Belgium | 13.7 | 1.0% |
| Denmark | 12.3 | 0.9% |
| Spain | 12.0 | 0.9% |
| Luxembourg | 0.8 | 0.1% |
| Austria | 0.6 | <0.1% |
| Finland | 0.1 | <0.1% |
| Ireland | 0.1 | <0.1% |
| *Asia/Pacific* | 163.4 | 12.2% |
| Australia/New Zealand | 84.9 | 6.3% |
| Japan | 78.3 | 5.8% |
| Korea | 0.1 | <0.1% |
| *Other* | 5.3 | 0.4% |

Figure 4: Expected Loss-to-Maturity (*ELM*) for Prime MMFs




Note: prime−to−government yield spread is calculated as the simple average gross yields on prime funds less simple average of 30−day gross yields on government money market funds
*Source*: iMoneyNet.com; authors' calculations

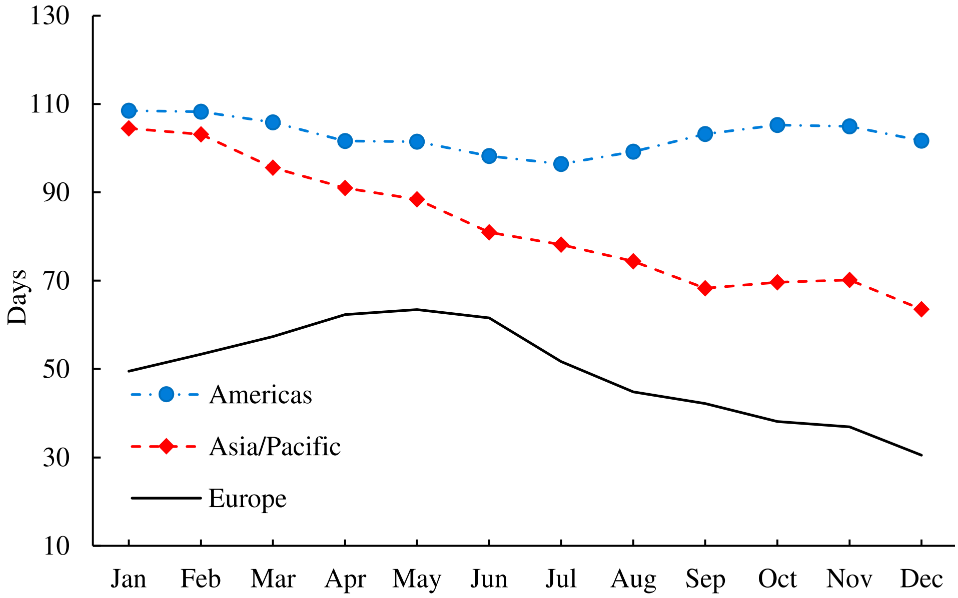
Figure 5: Assets of Prime Money Market Funds, By Region/Country, 2011

| | Total assets | Percent of Fund Assets | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | North America | | | Asia/Pacific | | | Europe | | | | |
| Month | $, billions[1] | Total[2] | US | Canada[3] | Total[2] | Aus/NZ | Japan[4] | Total[2] | France | Germany | Other |
| Jan | 1,464.4 | 37.4% | 30.1% | 7.3% | 11.6% | 6.1% | 5.5% | 51.0% | 15.1% | 7.9% | 28.0% |
| Feb | 1,527.7 | 36.3% | 29.2% | 7.1% | 11.1% | 5.7% | 5.4% | 52.6% | 14.2% | 8.2% | 30.2% |
| Mar | 1,484.0 | 38.4% | 30.7% | 7.7% | 11.4% | 6.1% | 5.4% | 50.1% | 14.0% | 6.6% | 29.6% |
| Apr | 1,522.9 | 37.0% | 29.1% | 7.8% | 11.3% | 6.1% | 5.2% | 51.7% | 15.2% | 6.7% | 29.9% |
| May | 1,552.7 | 35.4% | 27.7% | 7.7% | 11.2% | 6.4% | 4.8% | 53.4% | 16.0% | 7.3% | 30.2% |
| Jun | 1,448.0 | 37.9% | 29.4% | 8.5% | 11.6% | 6.6% | 4.9% | 50.5% | 15.2% | 6.2% | 29.1% |
| Jul | 1,398.1 | 40.2% | 31.6% | 8.6% | 11.8% | 6.9% | 4.8% | 48.0% | 14.0% | 5.5% | 28.5% |
| Aug | 1,463.8 | 42.7% | 33.5% | 9.1% | 13.1% | 7.3% | 5.8% | 44.3% | 11.1% | 5.9% | 27.2% |
| Sep | 1,407.7 | 45.1% | 35.2% | 9.9% | 14.7% | 7.7% | 7.0% | 40.2% | 7.8% | 5.4% | 27.0% |
| Oct | 1,400.0 | 46.1% | 36.5% | 9.6% | 14.7% | 7.7% | 7.0% | 39.3% | 6.8% | 5.2% | 27.2% |
| Nov | 1,382.1 | 47.7% | 37.1% | 10.6% | 15.7% | 7.9% | 7.8% | 36.6% | 4.0% | 5.3% | 27.3% |
| Dec | 1,365.5 | 48.6% | 37.3% | 11.3% | 17.5% | 8.3% | 9.1% | 34.0% | 3.3% | 4.2% | 26.4% |

[1] Excludes funds not registered under the Securities Exchange Act of 1933 and funds in master/feeder arrangements. Also excludes municipal securities holdings of prime money market funds.
[2] The total of percentages for North America, Europe, and Asia/Pacific regions do not add to 100 percent because of rounding and a small amount of supranational assets not reported in the table.
[3] Includes a small amount of investments in issuers with headquarters in Latin America.
[4] Includes a small amount of investments in issuers outside of Japan and Australia/New Zealand with headquarters in other Asia/Pacific countries.

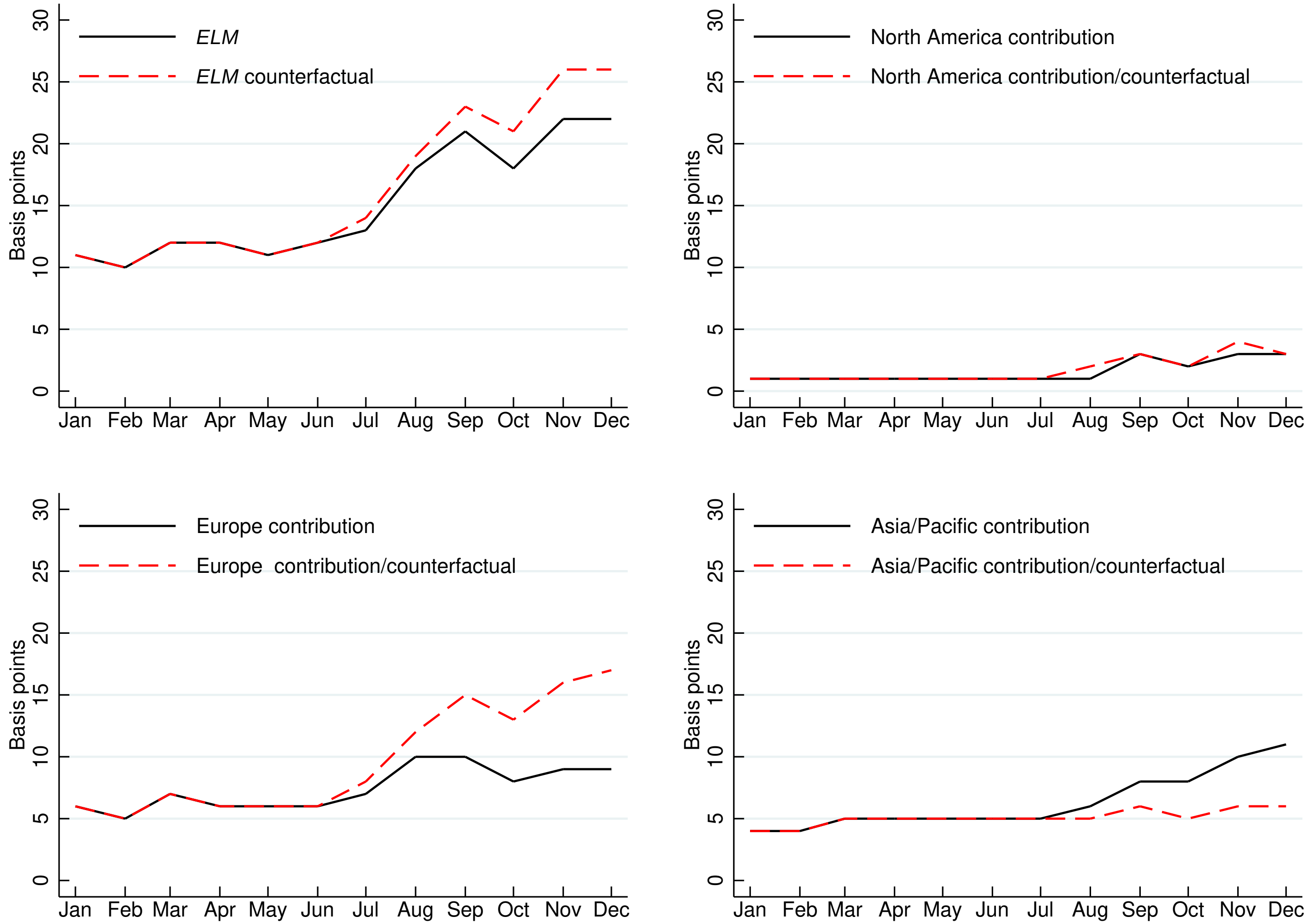
Source: authors' tabulation of SEC Form N-MFP reports.

Figure 6: Weighted Average Life (*WAL*) for Prime MMFs, 2011, by Region



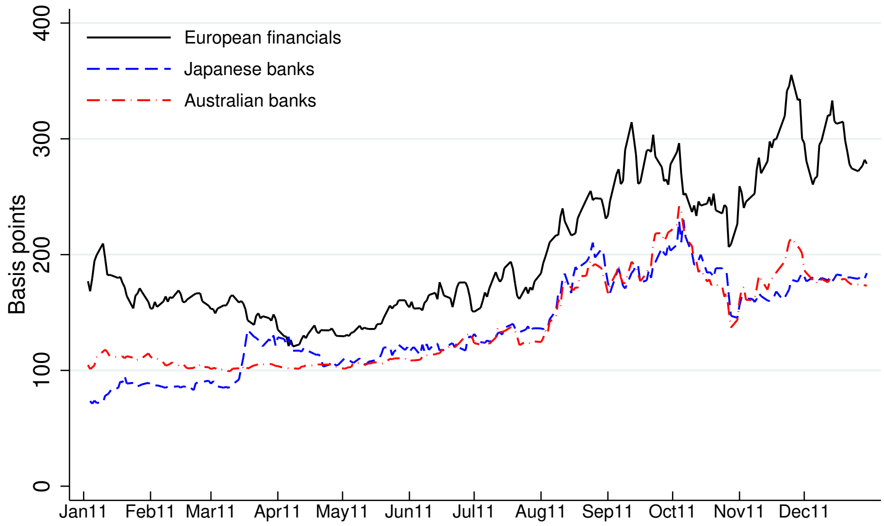

Source: SEC form N-MFP; authors' calculations

Figure 7: *ELM* and Counterfactual *ELM*, 2011, Contributions by Region



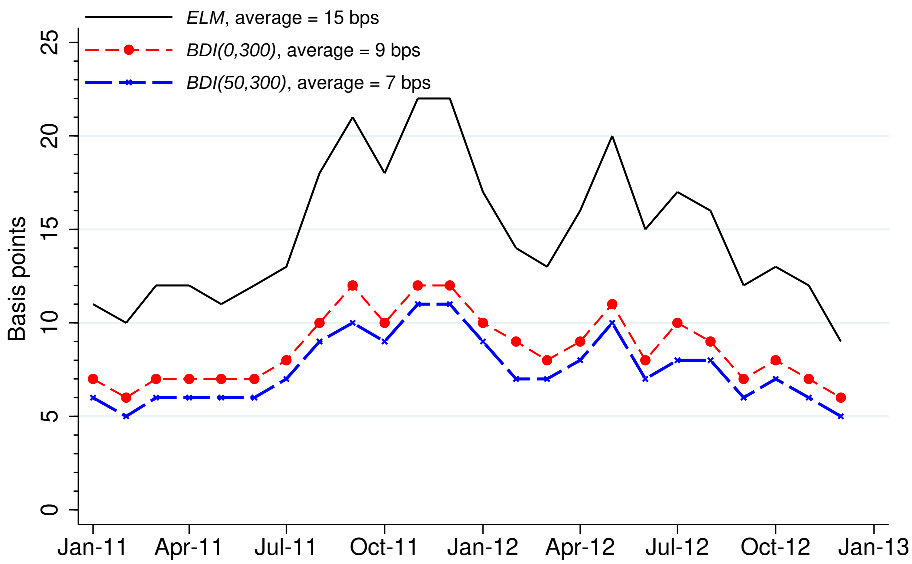

This figure shows actual *ELM* and a counterfactual for *ELM* (upper left panel) constructed on the assumption that prime funds continued to hold throughout 2011 the portfolios they held in May 2011. The other panels in the chart show the contributions of the three regions (North America, Europe, and Asia/Pacific) to *ELM* or to the counterfactual *ELM*, respectively. The contributions of the three regions total to the *ELM* measures in the upper-left panel.

Figure 8: 5-Year CDS Premiums for Banks, by Region, 2011




Note: The CDS premium for European financials is the iTraxx senior financial index for Europe. The CDS premium for large Japanese banks is the simple average of 5-year CDS premiums for Sumitomo Bank and Mizuho Bank. The CDS premium for large Australian banks is the simple average of 5-year CDS premiums for National Australia Bank, Westpac, and ANZ.

Figure 9: Expected Cost of Break-the-Dollar Insurance $BDI(0, 300)$ and $BDI(50, 300)$




Note: the figure plots asset-weighted average *ELM* against asset-weighted averages of *BDI(0,300)* and *BDI(50,300)* for prime funds. Estimates are annualized costs. *BDI(0,300)* and *BDI(50,300)* are calculated by Monte Carlo using a t-copula with 5 degrees of freedom using 50,000 random draws per fund per month.

Figure 10: Distribution of $ELM$ and Yield Spread $(\bar{r} - \bar{r}_g)$ by Fund, Jan 2011-Dec 2012

This figure shows box-and-whisker plots of $ELM$ and yield spread $(\bar{r} - \bar{r}_g)$, respectively, across funds by month. Rectangles represents the interquartile range ($IQR$), which extends from the 25th to 75th percentile, and the median is the horizontal line in the middle of the rectangle. The ends in the lines extending from below and above the rectangle represent the minimum and maximum values in the ranges from $Q1 - 1.5 * IQR$ to $Q1$ and from $Q3$ to $Q3 + 1.5 * IQR$, respectively. If observations exist outside of this range (i.e., in the top or bottom 0.35 percentiles of a normal distribution), they are considered to be outliers and are denoted with a dot.

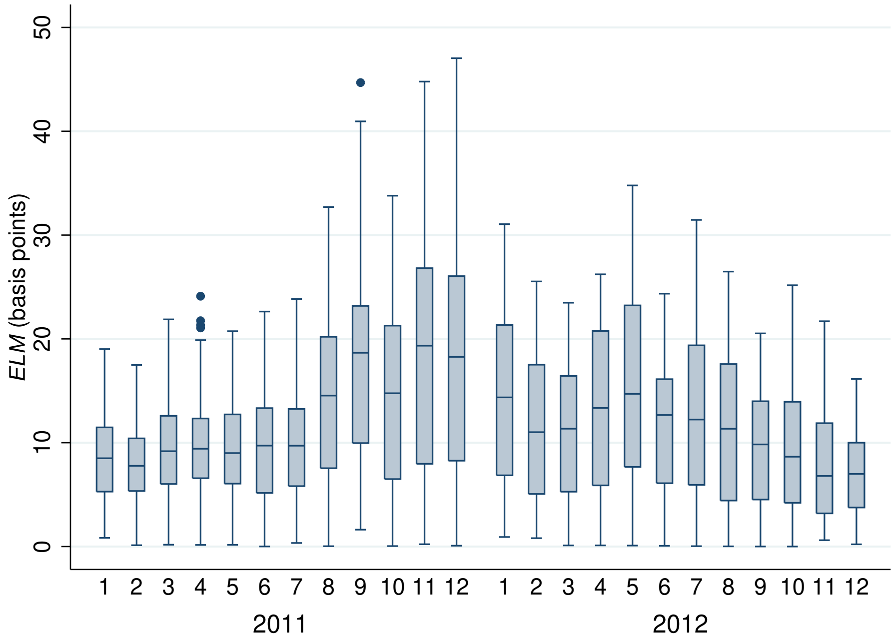
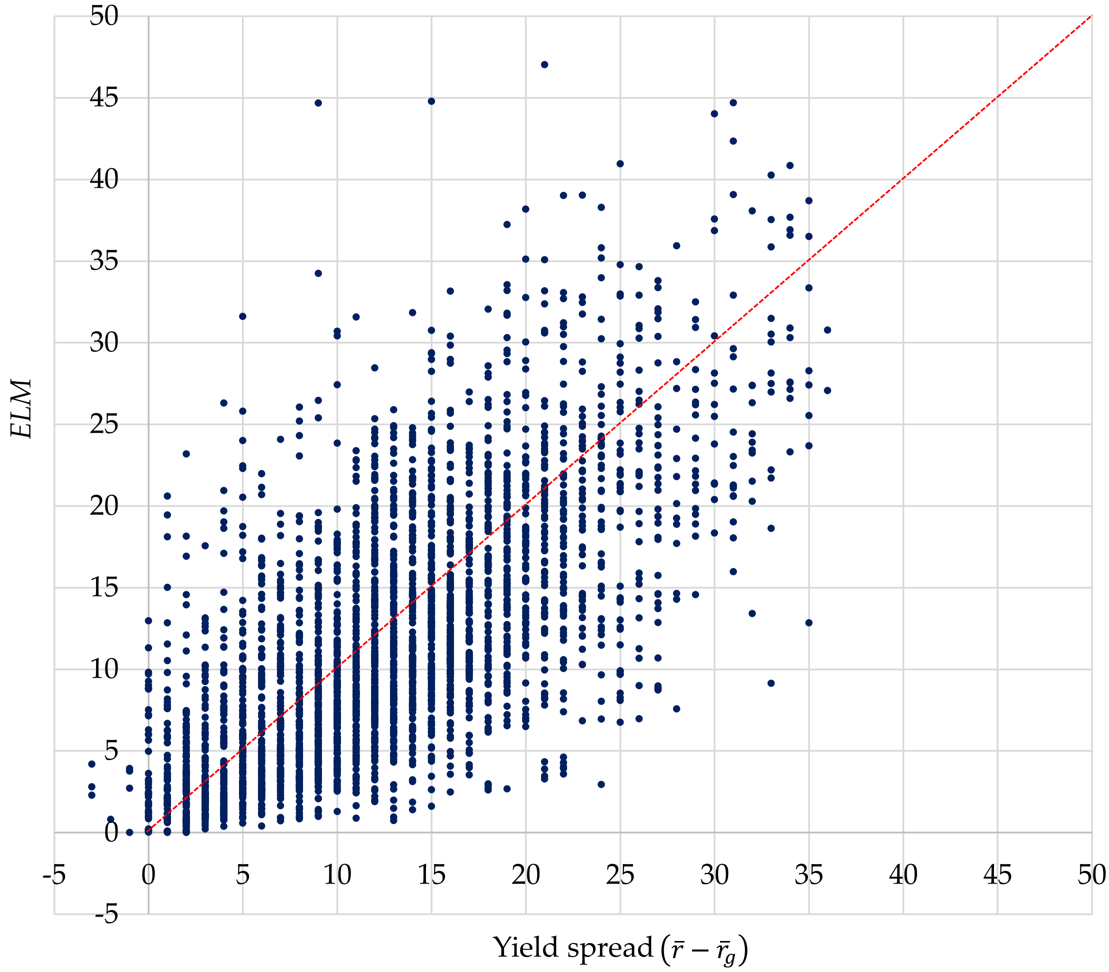


Figure 11: Scatter Plot: *ELM* vs. *Yield Spread* $(\bar{r} - \bar{r}_g)$

*Basis points*




Note: The red dashed line is the 45 degree line.

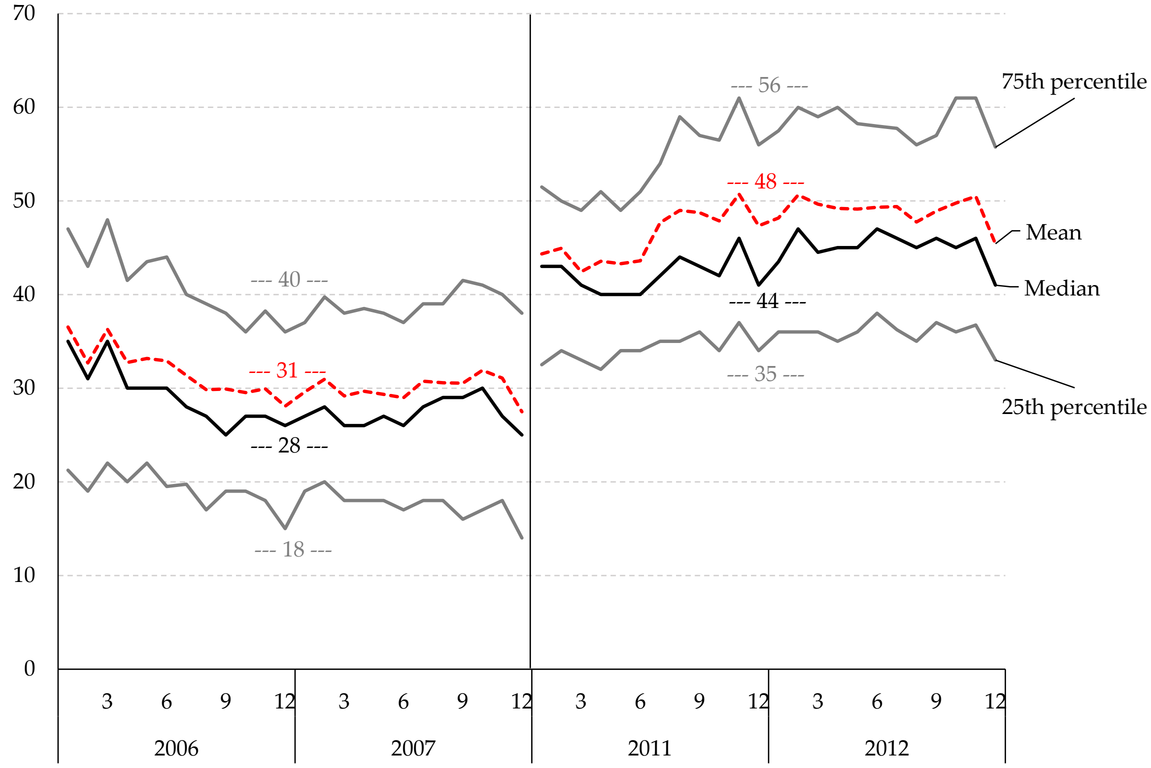
Figure 12: Regressions of *ELM* on Liquidity

This figure seeks to assess the effects of the 2010 reforms' maturity and liquidity provisions on the credit risk in prime money market fund portfolios. To do this, we undertake panel data regressions of *ELM* on fund portfolio characteristics across all sample prime funds, analyzed monthly over the 2011-2012 period. Explanatory variables include a fund's weekly liquid assets, *LIQ*, as defined under SEC Rule 2a-7, and a fund's weighted average life, *WAL*. We also study the maturity profile of a fund's "gov" and "nongov" investments, where "gov" investments include only treasury, agency, and repo securities collateralized by treasury and agency securities (*GOVLIQ*); meanwhile, "nongov" investments exclude these security types (*NONGOVLIQ*, and *NONGOVWAL*). To control for time-varying global financial risks (which likely affect the credit risks of prime funds generally), we include the average CDS premiums of banks in Europe, Japan, Australia/New Zealand, and the U.S., separately, in all regressions (not shown for brevity). We also control for (but do not show) the log of fund assets and the percentage of fund assets in institutional share classes. Finally, to treat the possible endogeneity discussed in footnote 20, we include (but do not show) a proxy for the measurement error in *ELM* in regressions (1)-(4). This proxy equals the residuals from a regression of *ELM* on $(\bar{r} - \bar{r}_g)$. In column (5), the dependent variable is yield spread $(\bar{r} - \bar{r}_g)$ and results are similar. Standard errors are clustered by fund. Estimates with a p-value below 0.10, 0.05, and 0.01 are marked with a *, **, and ***, respectively.

| | *ELM* | | | | $(\bar{r} - \bar{r}_g)$ |
|---|---|---|---|---|---|
| Independent variables | (1) | (2) | (3) | (4) | (5) |
| *Constant* | 0.932 | 1.717 | -0.828 | -4.327 | 1.177 |
| | (3.802) | (3.271) | (3.844) | (3.199) | (4.912) |
| *LIQ* | -0.203*** | | -0.172*** | -0.145*** | -0.183*** |
| | (0.021) | | (0.023) | (0.019) | (0.028) |
| *GOVLIQ* | | -0.233*** | | | |
| | | (0.021) | | | |
| *NONGOVLIQ* | | -0.064*** | | | |
| | | (0.022) | | | |
| *WAL* | | | 0.036** | | |
| | | | (0.014) | | |
| *NONGOVWAL* | | | | 0.114*** | 0.107*** |
| | | | | (0.016) | (0.015) |
| *Adj.* $R^2$ | 0.73 | 0.77 | 0.74 | 0.77 | 0.43 |
| *N* | 3,065 | 3,065 | 3,065 | 3,065 | 3,065 |

Figure 13: Weekly Liquidity Pre- and Post-Reform

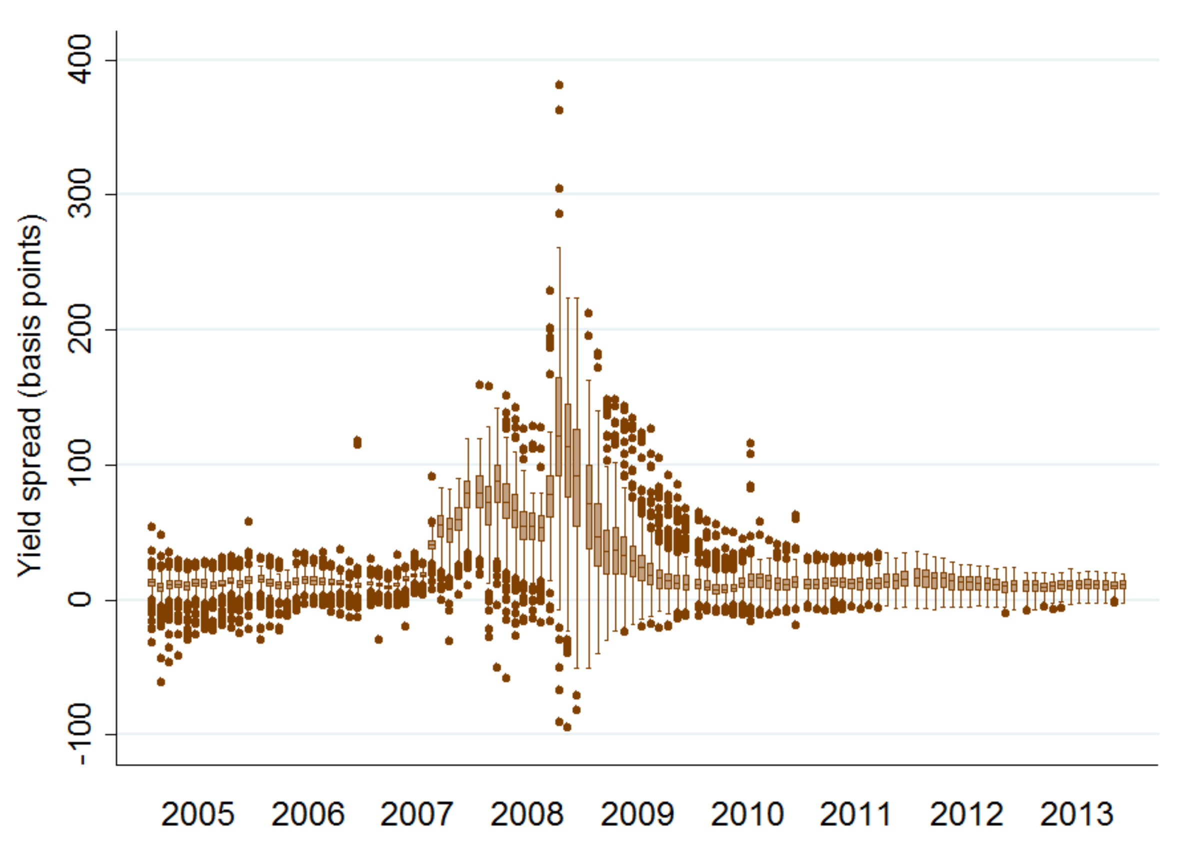
This figure shows the distribution of prime MMFs' weekly liquidity as a percentage assets on a monthly basis over two periods: 2006-2007 (pre-reform) and 2011-2012 (post-reform). Because SEC Form N-MFP is not available before November 2010, in this figure only, weekly liquidity is approximated from iMoneyNet data. It is measured as the sum of investments maturing within 7 days and investments in U.S. Treasury securities. Treasury securities maturing within 7 days are double counted. Investments in U.S. government agency securities are not counted. Tests reveal that this metric is generally within 2 percentage points of actual Rule 2a-7 weekly liquidity ($LIQ$) and is, therefore, a good approximation of weekly liquidity over the two periods being examined.




*Source:* iMoneyNet; authors' calculations.

Figure 14: Distribution of Prime Yield Spread $(\bar{r} - \bar{r}_g)$ Pre- and Post-Reform

This figure shows box-and-whisker plots of yield spread $(\bar{r} - \bar{r}_g)$ across funds, monthly, over 2005-2013. Rectangles represent the interquartile range ($IQR$), which extends from the 25th to 75th percentile, and the median is the horizontal line in the middle of the rectangle. The ends in the lines extending from below and above the rectangle represent the minimum and maximum values in the ranges from $Q1 - 1.5 * IQR$ to $Q1$ and from $Q3$ to $Q3 + 1.5 * IQR$, respectively. If observations exist outside of this range (i.e. in the top or bottom 0.35 percentiles of a normal distribution), they are considered to be outliers and are denoted with a dot.




Note: The sample for this chart includes iMoneyNet's full sample of prime money market funds (i.e. this sample is larger than the sample used in Figure 10, which includes only those funds for which *ELM*s could be calculated). Four outlying yield observations from iMoneyNet were omitted due to possible errors. All yields are gross, simple, and annualized.

*Source:* iMoneyNet; authors' calculations.