The Dynamic Relationship Among the Money Market Mutual Funds, the Commercial Paper Market and the Repo Market

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The Dynamic Relationship Among the Money Market Mutual Funds, the Commercial Paper Market and the Repo Market*

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Abstract

In this paper, we investigate the short-run and the long-run relationship among the financial assets of the money market funds, the commercial paper, and the repurchase agreement markets by undertaking a cointegration analysis of quarterly data over the 1985-2017 period. The evidence suggests that there exists a common long-term cointegrating trend among these three components of the shadow banking system. Any disequilibrium in this long-run relationship among these variables is corrected by movement in the financial assets of the money market funds. The Beveridge-Nelson decomposition from the estimated cointegrating relationship shows that the cyclical component in the money market funds is large and captures the huge swings in these markets during the financial crisis. Our results confirm the narrative evidence presented in Krishnamurthy et al. (2014), who argue that the short-term debt market investment opportunities in the form of the commercial paper and the repo market played a crucial role in the expansion of the balance sheet of the money market funds.
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1 Introduction

There is a consensus among the researchers as well as the policymakers about the central role of the financial intermediaries in causing and exacerbating the financial crisis of 2007-08. Financial intermediaries are the shadow banks that use short-term funds in money markets to purchase assets with long-term maturities.[1] In the financial markets, the shadow banking system is positioned similar to the traditional banking, but with some significant differences. Traditional banks are insured by the FDIC. They also had an exclusive access to the Federal Reserve's discount window during the crisis. However, the shadow banking system was largely unregulated and not backed by a federal agency at least before the financial crisis.[2] Over time, the size of the shadow banking system has become comparable to the traditional banks in the U.S. financial system.[3] The academic literature has also started paying attention to these financial intermediaries since the financial crisis[4].

The central role of the financial intermediaries in the financial crisis was preceded by a significant increase in their financial assets. For example, Figure 1 shows the significant increase in the financial assets of MMFs, the CP and the repo markets over the last 30 years. These three markets play a significant role in the overall shadow banking. The MMFs are one of the biggest cash players in the shadow banking system; the largest portion of this cash is allocated to collateralize the repo and the CP market (Krishnamurthy et al., 2014). Prior to 1970, the MMFs invested mainly in the U.S. Treasury debt. However, since 1970, they became an alternate form of investment to the traditional banks, and a new source of deposits for investors as they offered slightly higher returns than the conventional bank deposits (Anderson et al., 2009). The significant increase in financial assets of the MMFs also coincided with the development of the CP and the repo markets. Anderson et al. (2009) explain that huge increase in the assets of the MMFs led to an increase in the share of the MMFs in the CP market from 18% in 1980 to almost 40% in 2008. At the same time, the simultaneous development of the CP and the repo markets facilitated the growth of the MMFs, as they became an important source of investments for the MMFs. Krishnamurthy et al. (2014) show that 20% of total MMFs assets were used to provide funding for repos and security lenders, and the MMFs

[1] Assets with long-term maturities are credit card loans, residential mortgages and auto loans. (Krishnamurthy et al. (2014)).

[2] Given the extraordinary impact of the recent crisis, the U.S. Treasury department created a temporary guarantee program (TGP) for Money Market Funds.

[3] Gorton et al. (2010) show that before the 2007-2008 financial crisis the assets of the shadow banking system were as large as the asset of traditional banks.

[4] See for example, Gorton and Metrick (2012), Gorton et al. (2010), and Krishnamurthy et al. (2014) among others.

cover half of the repo funding.[5] These two markets provided a market for the private sector debt that was considered relatively safe, flexible and paid interest. Since a large portion of MMFs cash is allocated to collateralized the repo and the CP markets, it is reasonable to assume that there is a link among these three players. In fact, historically the MMFs have been the biggest source of financing in the commercial paper market and one of the leading private players in the Repo Market[6]. The simultaneous development in these markets poses an interesting question: did development in the short-term debt market (Repo and CP) lead to an increase in demand for funds and hence the explosion in the size of MMFs; or the MMFs search for yield pushed the supply of funds to these short-term debt market and lead to a significant increase in the financial assets of commercial paper and the repo market?

Most of the work in the existing literature on shadow banking focus on the recent financial crisis episode and provide a narrative explanation for the causes of the crisis and the role of different markets in propagating it. For example, Kacperczyk and Schnabl (2009) show that MMFs have an incentive to take on risks, and are vulnerable to runs if the risks materialize by examining the risk taking behavior of MMFs during the period that just preceded the financial crisis. Similarly, Covitz et al. (2009) document the run in the asset backed commercial real estate market in 2007. It is well understood that the imbalance in the financial system were building up much earlier, and hence it is imperative to understand the dynamic behavior of different parts of the shadow banking system. Our work is an attempt to bridge this gap in the context of the relationship among MMFs, repo and the CP market. To do so, in the first stage we examine whether these three markets move together in the long-run by examining the existence of a shared common trend or cointegration among these variables using a sample period that span from 1985:Q1 through 2017:Q1[7]. In the second step, we examine which of these variables adjust to correct for the disequilibrium in the short-run by using vector error correction methodology. Using the information from the long-run cointegration model, we also decompose the movements in the financial assets of the MMFs, the CP, and the repo markets into a trend and a cycle. This allows us to measure the extent of

[5]Krishnamurthy et al. (2014) consider the total quantity of repo funding provided by the MMFs between 2006-2010.

[6]See Table 4 in Schmidt et al. (2016).

[7]In this paper, we do not consider the role of the Securities Lender (SL) in these markets as presented in Krishnamurthy et al. (2014). Data limitation is main the reason why we do not include SLs in our analysis. Risk Management Association, which is the source of Krishnamurthy et al. (2014) study only provides data from 2008. Moreover, Keane (2013) states that "Data on securities lending are fragmented and cannot be found comprehensively through any one source". He also suggests that "there are no broad classes of institutional market participants that engage only in securities lending". Secondly, the overall size of SL in small as compared to MMFs. Accroding to the balance sheet data of Brokers and Dealers in Table L.208 of Flow of Funds, it is only around 20 percent of the MMFs.

movement in these variables that are permanent and transitory.

Not surprisingly, our results show that the financial assets of the MMFs, the CP, and the repo markets do move together in the long-run. The interesting finding from our analysis is that any deviation from this long-run equilibrium is corrected by the subsequent movements in the financial assets of the MMFs for the full sample period. These results shed some light on the question about the simultaneous development of the MMFs, the CP, and the repo markets, and whether the explosive growth in the financial assets of the MMFs also led to the development of the CP and the repo markets. Our results suggest that though their financial assets do move together in the long-run, it is only the MMFs that respond to any deviations, while the CP and the repo market do not participate in the error correction process. These results are robust to the exclusion of post-crisis period. However, if one just takes into account the post-crisis sample period (2009-2017), we find that the disequilibrium in the cointegrating relationship is corrected by subsequent movements in the MMF as well as the CP market. This result seems to suggest that the CP market became more responsive to the developments in the other two markets in our analysis in the post-financial crisis sample period.

The results are further reinforced by the multivariate Beveridge-Nelson trend-cycle decomposition where we find that the MMFs have the biggest cyclical component for the full sample period. This is not surprising since only the MMFs move to correct for any disequilibrium in the short-run. The estimated cycle from the cointegrating relationship also captures the huge swings in these markets in the period around the financial crisis. In fact, our results from the BN decomposition show that conditional on the long-run relationship among these three variables, the financial assets of the MMFs before the Lehman Collapse were 40 percent above its long-run trend.

The remainder of this paper is structured as follows: in section 2, we provide a background on the shadow banking system, the MMFs, the CP, the repo markets and the data used in the empirical analysis. Section 3 provides methodological issues and the empirical evidence. Finally, the conclusions are presented in section 4.

2 Background and Data

2.1 The Shadow Banking System

Traditional banks (deposit banks) involve in maturity transformation where they use deposits to fund loans that are of long-term nature. The traditional banks receive deposit money which can be withdrawn at any time by the depositors. Further, these deposits are guaranteed by the Federal Deposit Insurance Corporation. From the loan transactions the banks earn interest income and the loan borrowers in turn promise to repay them. There are three main differences between the traditional banks and the shadow banks. First, when the shadow banks are faced with an emergency situation, such as investors wanting to redeem, they cannot borrow from the Federal Reserve. Second, they are not regulated like traditional banks and don't have access to deposit insurance from the FDIC. However, at the midst of financial crisis, the U.S. Treasury did extend support to the MMFs through the Treasury's Guarantee Program (TGP). While this program does act as a form of insurance to the MMFs, the principal motive of this program is to provide a temporary guarantee to protect the shareholders of the MMFs.[8] Third, the traditional banks pay for deposit insurance and pass on a part of this cost along to the depositors.[9] In contrast, in case of the shadow banking system such insurance cost do not exist, and therefore, they have a cost advantage over traditional banks in that sense (Gorton et al., 2010).

Pozsar et al. (2010) define shadow banks to include finance companies, asset-backed commercial paper (ABCP) conduits, structured investment vehicles (SIVs), credit hedge funds, MMFs, securities lenders, limited-purpose finance companies (LPFCs), and government-sponsored enterprises (GSEs). Figure 1 presents the shadow banking system in the U.S. We can see that in the U.S. shadow banking system, the CP and the repo markets appear on the asset side and MMFs on the liability side. Investors bring their money to the shadow banking system and get shares from the MMFs.[10] The MMFs provides an important short-term funding source in the shadow banking system and this funding goes into conduits and the repo market (Pozsar et al., 2010; Krishnamurthy et al., 2014; Anderson et al., 2009). On the other side, the

[8] While it is true that the principle intent of such program is to temporarily safeguard the interests of MMFs stockholders, it is not completely inconceivable for investors to expect similar treatment in the future, often known as the problem of moral hazard.

[9] It is important to note that the extent to which the banks can pass on the cost of insurance to the depositors depends on the degree of elasticity that the banks face, with the remainder of the cost borne by the banks, like any other indirect taxes.

[10] Investors can also invest in the shadow banking system through the securities lender. But, It is important to note that we lack data on the Security Leander, and thus we only focus on the MMFs as a borrower.

borrowers provide financial assets and collateral to the shadow banking system. Thus, the relationship between the lender and the borrower has an additional layer of complexity as compared to the traditional banks.

The unraveling of the financial system during the financial crisis also led to defaults in the short-term debt market linked to this asset class. Gorton et al. (2010) explain that the developments in the subprime market led to the collapse of the MMFs, the CP, and the repo markets, as well as the overall shadow banking system. As shown in Figure 2, the financial assets of the MMFs, the CP, and the repo markets grew exponentially before the financial crisis, but declined significantly during the financial crisis.

2.2 Money Market Funds

One of the main players in the U.S. shadow banking system is the MMFs. At the end of 2013, the MMFs managed over $2.68 trillion in assets which is 16.72 percent of all the total mutual fund assets in the U.S., and 8.6 percent of the mutual fund assets worldwide.[11] Figure 2 presents the time-series behavior of the MMFs from 1985 to 2017. It shows the rapid growth in the MMFs in 1998-2008 period with only a short dip in the 2002-2005 period. While the industry has expanded and reached the peak of 3.76 trillion in October 2008, its financial assets had dropped to 2.63 trillion in June 2017.

Rule 2a-7 of the Investment Company Act (1940) regulates the MMFs in the U.S. Under this rule, the quality, maturity, and diversity of investments in the money market fund portfolios are defined. Short-term yield, liquidity, and stability cause the MMFs to become a pool of cash management vehicle for retail and institutional investors. Stable price per share, $1.00 per share under standard industry practice, has caused the MMFs to become similar to bank deposits. This characteristic causes the MMFs to be a low-risk investment asset which satisfies stability. However, unlike traditional banks, MMFs do not explicitly have the Federal insurance. Apart from stability, each investment should satisfy quality, diversification, and maturity, which leads the MMFs to invest in short-term, high credit quality, and well-diversified instruments. The MMFs transfers these risks to outside by securitization in the CP market and the repo market and became the biggest source of funding for these markets (Krishnamurthy et al., 2014; Anderson et al., 2009; Adrian et al., 2010).

[11]The data is collected from Investment Company Institute according to which the total financial asset of the MMFs is $2.7 trillion, whereas the total financial assets of mutual funds in the U.S. is $16.14 trillion, and the corresponding assets equal $31.38 trillion for the whole world.

Under rule 2a-7, the MMFs could have potentially curtailed the spreading of risks before the financial crisis of 2007-2008. However, that become very limited in the stressful conditions that the markets faced in September 2008. Lehman's failure and uncertainty in the financial system led MMFs to face significantly high level of outflows. The huge outflows greatly inhibited the MMF's ability to maintain liquidity. The liquidity stress, in turn, made investors transfer their assets from the prime MMFs to other secure funds. As a result of the stress in the market, the MMFs were unable to maintain a stable $1.00 net asset value, which is one of the important conditions required to prevent a run on the MMFs.

Given the importance of the MMFs, the academic literature has also started paying attention to its role in the financial system. Kacperczyk and Schnabl (2009) study the recent financial crisis by examining the risk-taking behavior of the MMFs. They show that the financial crisis has revealed that the MMFs have an incentive to take on risks, and are vulnerable to runs if the risks materialize. The MMFs which took more risks were more prone to runs. Duygan-Bump et al. (2013) consider one of the ways to respond to these kinds of risks. They used the difference-in-difference approach to illustrate the role of the ABCP money market fund liquidity facility (AMLF) during the financial crisis. Their findings highlight that the AMLF can help to stabilize asset outflows from the MMFs and also decrease asset-backed-commercial-paper yields. Schmidt et al. (2016) study the run on the MMFs during the period of September and October of 2008 at a daily frequency. They emphasize that the MMFs which promised higher yields and less liquid securities were taking more risk and faced runs. These studies show that the MMFs faced runs which played an important role during the financial crisis.

2.3 The Commercial Paper Market

In the U.S., dealers and corporations are the main issuers of the CP. The issuers of the CP finance their projects or increase their capital base and in return investors receive interest which is the difference between the purchase price and the face value of the CP. There are three types of investors in the CP market. Type one purchases the CP at issuance and holds them till maturity. Type two purchases the CP to trade in secondary markets. Type three investors prefer to purchase newly issued CP from the same issuer while their holding of the CP matures. There is a liquidity risk for which the issuers could not refinance maturing the CP.

In the 1970s, the MMFs occupied a significant share in the overall mutual funds industry, which in turn became a big part of investments in the CP market. Investment in the CP market is also consistent

with the mandate of the MMFs, as it satisfies one of the main requirements for MMFs of being a low-risk investment and has short-term maturity horizon. Inventory in the CP led to the creation of asset-back commercial papers (ABCP). ABCP are the CP which are backed by some underlying asset. Conduits are managed by commercial banks and large institutional investors such as the MMFs, and securities lenders finance short term ABCP that conduits issue by purchasing long term assets.[12]

Most studies that investigate the run on the financial system (traditional and shadow banking system) show that a shock to the financial system leads to increased risk (Ivashina and Scharfstein, 2010; Campello et al., 2010, 2011). Covitz et al. (2009) consider run on ABCP market by using micro-level data. They find that the run on ABCP in 2007 is related to weaker liquidity support and lower ratings which in turn aggravated the macro-financial risks.

Anderson et al. (2009) explain the run on the CP market during the financial crisis. They show that the MMFs invested in the CP as they provided revenue at low risk before the financial crisis. However, the bankruptcy of the Lehman Brothers caused a run on the CP market, which in turn had adverse effects on the money market fund investments. Kacperczyk and Schnabl (2009) explain that there are three reasons for the collapse and run on the CP market namely, adverse selection, using other source of financing, and the MMFs. These findings suggest that the CP and the MMFs are related to each other. However, these studies do not explain how these two markets move together over different horizons, which is one of the main objectives of the current paper. While these papers provide good insights into the interlinked runs in the CP market and the MMFs, it is also important to recognize the potential connections with the repo market as it is another important source of assets of the MMFs.

2.4 The Repo Market

The CP and the repo markets are two important components of the shadow banking system, especially for the MMFs (as a main cash player in the shadow banking system). The repo agreements (or simply securities contract) are a form of the short-term funding facility, as they are simply the agreement of sale and future repurchase of a financial asset at a specified price. This asset in most cases is Treasury securities, but over time it has changed, and other short-term debt instruments which are linked to the subprime mortgage are now a part of the financial asset over which repo are undertaken. Cash-rich financial market players such as the MMFs and securities lenders, lend to the borrowers and receive securities as collateral

[12]See Anderson et al. (2009) and Acharya et al. (2013)

that are greater than the amount of the loan and the difference between the two amounts is called a haircut. This loan is repaid along with the interest rate, commonly known as the repo rate.

There are two segments of the repo market: bilateral repo and tri-party repo. Figure 1[DOUBLE CHECK] shows the connection of these two segments of the repo market within the shadow banking system. Bilateral or over-the-counter repos are often between cash lenders (the MMFs and securities lenders) and borrowers (hedge funds and prime brokerage) directly. Whereas, under the tri-party repos a clearing bank often acts as a controlling channel for the repo transactions. In the U.S., JPMorgan Chase and Bank of New York Mellon act as the clearing banks or tri-party agents that manage different aspects of the repo agreement, such as, haircut, repo rate, and type of collateral. Pozsar et al. (2010) and Krishnamurthy et al. (2014) show the MMFs and securities lenders provide more than half of the short-term funding in both the bilateral and tri-party repo markets. Adrian et al. (2013) explain the MMFs provides between a quarter and third funding in the tri-party repo market. Since MMFs are the main class of cash lender in the repo market and the data for all cash parties in the repo is limited, we focused on the MMFs funding in the tri-party repo market.[13]

Most of the existing research in the shadow banking system has examined the behavior of these financial intermediaries individually and have focused mainly around the financial crisis. **?**, He and Xiong (2012), Gennaioli et al. (2013), and McCabe (2010) consider the role of the MMFs during the financial crisis and modeled runs in the MMFs. Parlatore Siritto (2015) presents a model to analyze the impact of the regulations on the shadow banking system. Kacperczyk and Schnabl (2013) explain the risk-taking behavior of MMFs during the financial crisis. Kacperczyk and Schnabl (2009), Duygan-Bump et al. (2013), and Anderson et al. (2009) study the role of CP market during the financial crisis. Krishnamurthy et al. (2014), Gorton et al. (2010), and Copeland et al. (2010) model the run on the repo market.[14] Krishnamurthy et al. (2014) find that the repo market segments that were dependent upon the financing from the MMFs collapsed after the financial crisis of 2008. They showed that the repo market is a small portion that could not be the only reason for the collapse of the shadow banking system, but they do highlight the importance of the repo market in the shadow banking system. This is in contrast to Gorton et al. (2010) view which hypothesized that the repo was one of the main reasons for the financial crisis.

[13]See Krishnamurthy et al. (2014), Pozsar et al. (2010), and Adrian et al. (2013)

[14]Gorton et al. (2010) define "Securitized Banking" as a combination of securitization and repo. Studying the 2008-2009 subprime housing market crisis, their findings suggest that changes in liquidity and risk of collateral in the repo market led to a run on the repo market. This is potentially one of the risk propagation mechanisms that played a role in financial crisis.

We argue that examining the role of these financial intermediaries separately may be an important objective in itself, but we also need to understand the dynamic relationship among these dominant players in the shadow banking system. As Gorton et al. (2010), Krishnamurthy et al. (2014), and Anderson et al. (2009) show the MMFs, the CP, and the repo are key elements of balance sheet of the shadow banking system and the development of the MMFs during 1980s did support the growth of CP and repo markets. Our paper tries to fill this gap by examining the long-run and the short-run relationship among the MMFs, the CP, and the repo markets. The rationale for the relationship among these markets is straightforward. In the U.S. shadow banking system, the CP and the repo markets appear on the asset side and MMFs on the liability side. The MMFs provides an important short-term funding source in the shadow banking system and this funding goes into commercial paper market and the repo market. As explained earlier, around 50% of the assets of MMFs are in the form of CP and repo[15]. Therefore, it is perfectly natural to examine the dynamic relationship among these markets.

2.5 Data

We use 32 years of quarterly data from 1985 to 2017 for the MMFs, the CP, and the repo markets. Data is obtained from the Board of Governors of the Federal Reserve System. For the MMFs, we collect the level of total financial assets. Figure 2 shows that the MMFs grew slowly until 1990, but registered significant expansion during the later half of the 1990s as well as in the 2005-2008 period. The size of this market was $2.47 trillion at the beginning of 2007, and in September of 2008 it reached the peak of around $3.76 trillion. Figure 2 reflects that the MMFs started becoming unattractive very quickly after the collapse of the Lehman Brothers in September 2008. In June 2017, total financial assets stood at $2.63 trillion, which was significantly lower than the peak reached during the period of financial crisis.

Very similar behavior can be found in the case of the CP market. At the beginning of 2007, CP were the largest U.S. short-term debt instruments, but during the financial crisis of 2007-2008 the CP market faced significant stress. Figure 2 shows the boom and the bust in the outstanding CP. Until 2005, the total amount of outstanding CP was relatively stable. Between early 2005 and the summer of 2007, the

[15]It would be conceivable to argue about the role played by the other components of the asset side of MMFs in its overall evolution. However, it should be noted that other than CP and repo, most of the investment of MMF is in very safe asset like Treasury notes and certificate of deposits. We make the assumption that MMFs search for yield leads to a much bigger variation in its holdings of CP and repo as compared to the other ultra safe assets. Moreover, the econometric methodology adopted in this paper does not suffer from the omitted variable problem because of the superconsistent nature of the estimates as argued in the next section.

amount of outstanding CP nearly doubled, reaching a peak of $2.10 trillion. However, with the onset of the financial crisis it started to decline and stood around $1.85 trillion in the third quarter of 2007. The collapse in the CP market happened before the decline in the financial assets of the MMFs.

The aggregate amount of repo funding provided to the shadow banking system (from the MMFs) is also reported in Figure 2.[16] At the end of 2007, the total amount of repo stood at its peak around $605.90 billion, which started to decline with the failing of Lehman Brothers. The evidence in figure 2 suggests that the collapse of the MMFs and the repo occurred around the same time, while the collapse of the CP market started one year prior to this time. Table 1 provides the descriptive statistics of the data. These initial statistics show that on an average the CP and the repo market together ($1.21 trillion) is about 80 percent of the MMFs average of $1.51 trillion. This provides a very preliminary evidence of the potentially strong interconnections that exists between the three markets. In terms of the overall fluctuations measured by the standard deviations, the findings presented in Table 1 suggest that the repo market is more volatile as compared to the other two markets.

3 Dynamic Relationship in the Shadow Banking System

3.1 The Long-Run Relationship

The MMFs are one of the biggest players in the shadow banking system. The CP and the repo markets are the two most important avenues of investments for the MMFs. A significant portion financial asset of MMFs are channelized into the CP and the repo markets. This unique nature of interconnections between the three markets would have implications on the size and development of these markets. Thus, testing and studying the nature of long-run relationship between these markets would provide us with new insights into the operations of the shadow banking system.

In order to study the long-run cointegrating relationship, it is important to first test whether each variable passes the unit root test. Table 2 summarizes the results of the unit root test. We find that the levels of MMFs, CP, and repo markets contain a unit root, whereas the null hypothesis of the existence of unit root is rejected for the first difference form of these variables.

Let mmf, cp, and $repo$ represent the natural logs of the total financial assets of MMFs, CP, and repo

[16]Data for repo markets has been obtained from the Flow of Funds Accounts that the Federal Reserve Board releases (Table Z.1) (Krishnamurthy et al., 2014).

markets respectively. Given these variables are non-stationary in levels, the following equation 1 presents the long-run relationship among the three variables:

$$mmf_t = \beta_0 + \beta_1 cp_t + \beta_2 repo_t + \epsilon_t$$

where, β_0, β_1, and β_2 are the coefficients of the constant, *cp*, and *repo* respectively. If there exists a common long-run trend between mmf, *cp*, and *repo* and they comove in the long-run, then the estimated cointegrating residual $\hat{\epsilon}_t = mmf_t - \hat{\beta}_0 - \hat{\beta}_1 cp_t - \hat{\beta}_2 repo_t$ should be stationary. To check for stationarity of estimated residuals the standard unit root test is applied. Here, the coefficients $(\beta_0, \beta_1, \beta_2)$ of equation 1 constitute the cointegrating vector of the system which reflects how the three markets move together in the long run.

One would expect that an increase in cp_t and $repo_t$ would have a positive impact on mmf_t. Consequently, both β_1 as well as β_2 are expected to have a positive sign. This is because in the shadow banking system, the CP and the repo markets are a part of the asset side, whereas the MMFs are on the liability side of the balance sheet of the system as a whole. At the same time, higher trading activity in the CP and the repo markets provides a perfect ground for expanding activity by the MMFs industry. The narrative provided by Krishnamurthy et al. (2014) and others also support this viewpoint that the CP and the repo markets play a crucial role in the expansion of the balance sheet of the MMFs. Further, the relative size of β_1 and β_2 would provide the information about the relative influence of the CP and the repo markets on the MMF's activity in the long-run.

To estimate the cointegrating relationship among the MMFs, the CP, and the repo markets, we adopt the Stock and Watson (1988) dynamic ordinary least squares (DOLS) methodology[17][18]. Given the possibility of serial correlation in the error term, we use Newey-West heteroscedastic autocorrelation consistent standard errors. More specifically, the following DOLS is estimated with one lag selected based on the

[17]DOLS was adopted in this paper since it has been shown by Stock and Watson (1988) that Engle-Granger (1987) method of estimating cointegrating vector may provide biased estimate in finite sample if the error term is serially correlated. DOLS augments the original Engle-Granger (1987) cointegration equation by leads and lags of the first difference of the right hand side variables.

[18]The estimates $\beta's$ are consistent despite the fact that the explanatory variables and error terms are correlated. This follows from Stock and Watson (1988), as they show that the estimates from cointegrating parameters are superconsistent i.e. the true parameter converges to the true values at rate T rather than at rate $\sqrt{T}$ as in ordinary least squares.

Schwartz criterion:

$$mmf_t = \beta_0 + \beta_1 cp_t + \beta_2 repo_t + \sum_{i=0}^{1} \gamma_i \Delta cp_{t-i} + \sum_{i=0}^{1} \delta_i \Delta repo_{t-i} + e_t$$

Panel A in Table 3 shows that the null hypothesis of the existence of unit root in the estimated cointegrating residual ($\hat{\epsilon}_t = mmf_t - \hat{\beta}_0 - \hat{\beta}_1 cp_t - \hat{\beta}_2 repo$) is rejected. Panel B and Panel C in Table 3 summarize the results of the cointegration from Johansen (1991) and Engle and Granger (1987). Based on the Johansen test, there is at least one cointegrating vector between the MMFs, CP, and the repo markets. Also, the results of the Engle-Granger test show that the null hypothesis of unit root in the residual from the regression of the *mmf* on the *repo* and *cp* is rejected, suggesting the existence of a cointegrating relationship between the three variables.

Table 4 presents the DOLS estimates for the 1985-2017 period in columns 2-3 along with the p-values. The results clearly show that all coefficients in the vector (β_0, β_1, β_2) which capture the cointegrating relationship are highly significant. This implies that the MMFs, the CP, and the repo markets share a statistical significant common long-term trend among them. Further, evidence in Table 4 reveals some interesting dynamics of the shadow banking system. Evidence suggests that for the 1985-2017 period, a one percent increase in the size of the CP market leads to an increase in the size of the MMFs by 0.55 percent in the long run. Whereas, the MMFs are estimated to expand in the long run by 0.56 percent for every one percent increase in the repo market. However, contrasting behavior (as discussed separately in the section below) emerges once the influence of the recent financial crisis is excluded. Based on these results one can conclude that any deviations from the long-run relationship between these three markets ($\hat{\epsilon}_t > 0$ or $\hat{\epsilon}_t < 0$), will induce a movement in at least one of these markets such that it will restore the shared long-run relationship. Figure 3 presents the estimated residuals obtained from the DOLS methodology. This figure shows how the short-term deviations in the cointegrated system have behaved over time. We find that right before the financial crisis the size of the MMFs was below the long-term cointegrating trend but this was quickly corrected with the onset of crisis.

The presence of a common cointegrating trend among MMFs, CP, and the repo markets can have important policy implications. For example, the impact of measures like the Treasury's Guarantee Program for the MMFs can potentially extend beyond the MMFs market. The explicit interconnections estimated in this paper allows us to understand the extent of propagation mechanism between the policy action and

the three most important markets of the shadow banking system.

3.2 The Short-Run Relationship

The Engle-Granger representation theorem provides the vector error-correction model (VECM) representation of the cointegrated system. The VECM representation is based on the idea that if there exists a long-run relationship among integrated variables, then at least one of the variables moves to correct for any short-run disequilibrium. The VECM as posited by Engle and Granger (1987) has the following representation:

$$\triangle Y_t = \nu + \Gamma(L)\triangle Y_{t-1} + \alpha\hat{\beta}' Y_{t-1} + \epsilon_t$$

where, $\Delta Y_t = (\Delta mmf_t, \Delta cp_t, \Delta repo_t)'$ represents the vector of the first differences of the three variables and $\Gamma(L)$ represents a finite-order distributed lag operator. The vector of adjustment parameters is given by $\alpha = (\alpha^{mmf}, \alpha^{cp}, \alpha^{repo})'$. More specifically, the number of lags is chosen based on the Schwarz criterion and then the following system of equations is estimated:

$$\Delta mmf_t = \gamma_{10} + \gamma_{11}^{mmf}\Delta mmf_{t-1} + \gamma_{12}^{cp}\Delta cp_{t-1} + \gamma_{13}^{repo}\Delta repo_{t-1} + \alpha^{mmf}\hat{\beta}' Y_{t-1} + e_{mmf,t} \quad (1)$$

$$\Delta cp_t = \gamma_{20} + \gamma_{21}^{mmf}\Delta mmf_{t-1} + \gamma_{22}^{cp}\Delta cp_{t-1} + \gamma_{23}^{repo}\Delta repo_{t-1} + \alpha^{cp}\hat{\beta}' Y_{t-1} + e_{cp,t} \quad (2)$$

$$\Delta repo_t = \gamma_{30} + \gamma_{31}^{mmf}\Delta mmf_{t-1} + \gamma_{32}^{cp}\Delta cp_{t-1} + \gamma_{33}^{repo}\Delta repo_{t-1} + \alpha^{repo}\hat{\beta}' Y_{t-1} + e_{repo,t} \quad (3)$$

The last period disequilibrium is represented by $\hat{\beta}' Y_{t-1} = mmf_{t-1} - \hat{\beta}_0 - \hat{\beta}_1 cp_{t-1} - \hat{\beta}_2 repo_{t-1}$. The statistical significance of coefficients ($\alpha' s$) indicate that the corresponding variable corrects in the current period in response to the previous period's shock which disturbed the long-term equilibrium. If at least one of the $\alpha' s$ is significantly different from zero then we can conclude that Y_t is cointegrated.

The VECM results are presented in Table 5 (columns 2-4) for the 1985-2017 period. The results show that α^{mmf} is statistically significant, whereas α^{cp} and α^{repo} are not. It means any deviation of the CP and the repo markets from the shared long-run trend will be corrected by the MMFs, while the CP and the repo markets do not participate in the error correction process. Further, the speed of adjustment for the MMFs is -0.07 which implies a half-life of little less than three years. Thus, while there is a shared long-run relationship between the MMFs, the CP, and the repo markets, the error-correction is only done by the MMFs and it is a fairly sluggish adjustment process. The slow adjustment is consistent with what

international finance and finance researchers have found for the exchange rate and the stock markets. For example, researchers have found that even though dividend and stock prices may tend to move together in the long-run, the speed of error-correction is usually very sluggish. The purchasing power parity literature also reports similar findings for the speed of error correction in case of exchange rates.[19]

Evidence in Table 5 (columns 2-4) also suggests that lagged values of change in the MMFs have a positive impact on the current growth rate both in the CP and the repo markets. However, the reverse is not necessarily the case. The current value of the MMFs is positively affected by the lagged values of the CP and the repo markets, the coefficients are not statistically significant. The intuition for such a behavior could lie in the dynamics of the shadow banking system. Since the MMFs is one of the biggest investors in the CP and the repo markets, growth in the MMFs industry would provide a higher incentive to the issuers of CP and repo securities. The growth in the MMFs thus provides a positive impetus to the other two markets. Overall our findings show that if there is any short-run disequilibrium in the long-run relationship among these three markets, MMFs move subsequently to restore the equilibrium.

3.3 Beveridge-Nelson Decomposition

Given that there exists a cointegrating relationship between the MMFs, the CP, and the repo markets, we can use this information to perform a trend-cycle decomposition. This exercise will further help us understand the trend and cyclical component in all the three variables that are a part of one cointegrated system. In particular, it allows us to measure the extent of movement in these variables that are permanent and transitory in nature. Furthermore, it can also reinforce the results found in the above sections.

The cointegration results suggest that among the three markets, it is the MMFs that error corrects, whereas the CP and the repo markets do not. If that is the case then the cyclical component of the MMFs should be able to identify these dynamics between the three markets. We adopt a state-space approach of the Beveridge and Nelson (1981) to estimate the permanent and transitory components of an integrated time series which Cochrane (1994) and Morley (2002) provided. Based on the equations 4, 5 and 6, we

[19]For example, see Frankel and Rose (1996) and Cochrane (1994).

define the Beveridge-Nelson (BN) decomposition as:

$$\begin{bmatrix} \Delta mmf_t - \mu \\ \Delta cp_t - \mu \\ \Delta repo_t - \mu \\ \hat{\beta}' Y_t \end{bmatrix} = \begin{bmatrix} \gamma_{11}^{mmf} & \gamma_{12}^{cp} & \gamma_{13}^{repo} & \alpha^{mmf} \\ \gamma_{21}^{mmf} & \gamma_{22}^{cp} & \gamma_{23}^{repo} & \alpha^{cp} \\ \gamma_{31}^{mmf} & \gamma_{32}^{cp} & \gamma_{33}^{repo} & \alpha^{repo} \\ \gamma_{41}^{mmf} & \gamma_{42}^{cp} & \gamma_{43}^{repo} & \alpha \end{bmatrix} \begin{bmatrix} \Delta mmf_{t-1} \\ \Delta cp_{t-1} \\ \Delta repo_{t-1} \\ \hat{\beta}' Y_{t-1} \end{bmatrix} + \begin{bmatrix} e_{mmf,t} \\ e_{cp,t} \\ e_{repo,t} \\ e_{Y,t} \end{bmatrix} \tag{4}$$

In this model, $\Delta mmf_t - \mu$, $\Delta cp_t - \mu$, and $\Delta repo_t - \mu$ are demeaned mmf, cp and $repo$ and $\gamma_{41}^{mmf} = \gamma_{11}^{mmf} - \beta\gamma_{21}^{mmf} - \beta\gamma_{31}^{mmf}$, $\gamma_{42}^{cp} = \gamma_{12}^{cp} - \beta\gamma_{22}^{cp} - \beta\gamma_{32}^{cp}$, $\gamma_{43}^{repo} = \gamma_{13}^{repo} - \beta\gamma_{23}^{repo} - \beta\gamma_{33}^{repo}$, $\alpha = 1 - \alpha^{mmf} - \alpha^{cp} - \alpha^{repo}$, and $e_{Y,t} = e_{mmf,t} - e_{cp,t} - e_{repo,t}$.

The stated model can be compactly written as:

$$\Delta X_t = F\Delta X_{t-1} + \nu_t \tag{5}$$

The BN cycle is $-F(I-F)\Delta X_t$ and the trend component is $X_t + -F(I-F)\Delta X_t$. Figures 4 and 5 show the results from BN decomposition for the MMFs, the CP, and the repo markets. Figure 4 shows the trend and actual for these variables, whereas the cyclical component for each variable is presented in Figure 5.

Figure 4 shows that for both the markets (CP and repo) the trend and the actual significantly overlaps as compared to the overlap of the trend and the actual of the MMFs. This is true particularly for the period around the crisis. The difference between the trend and the actual level (Figure 5) shows that the cyclical component in case of the CP and the repo market is fairly small as compared to the MMF's cycles. This further supports the evidence found earlier that the MMFs adjust for any deviations caused to the long-run relationship. Among these three markets, the actual behavior of the repo market is the closest to its trend line (Fig. 4). Further, the MMFs cycle shows some evidence of sustained deviations from the zero-mean line. This corroborates with the slow adjustment process found for the MMFs in the cointegrated VAR model. Thus, the overall results are consistent with the evidence found from the cointegration exercise.

3.4 The Role of the Recent Financial Crisis

Given the extraordinary influence of the recent financial crisis on the shadow banking system, it is important to check for robustness of the results, and also understand the role of crisis. Are the results robust to the exclusion of the crisis period or are they driven by this extraordinary event? At the same time, this exercise also helps us understand the change in the dynamics of the shadow banking system. To achieve this objective, we perform the above exercise for the sub-sample that runs from the first quarter of 1985 through the second quarter of 2007.[20]

Table 4 (columns 4-5) presents the DOLS estimates of the cointegrating vector along with the associated p-values. The results show that the cointegrating relationship between the MMFs, the CP, and the repo markets is robust to the exclusion of the effects of the recent financial crisis. The cointegrating vector remains statistically significant. However, it is interesting to find that the magnitude of the DOLS coefficients for the CP and the repo markets differ for the sub-sample as compared to the full sample estimates. For the full sample period, the elasticity of MMFs financial asset with respect to repo and the CP were almost the same. In contrast, if we exclude the period of financial crisis the elasticity of the response of MMFs to the CP and the repo markets is 0.98 and 0.26 respectively. Thus, the elasticity of CP market on the MMFs in the normal periods is nearly four times as compared to the repo market. This shows the degree of portfolio reshuffling witnessed in the shadow banking industry from the CP market to the repo market in the crisis period.

Figure 6 shows the behavior of the estimated cointegrating residual for the 1985-2007 sample period. Evidence suggests that in the late 1980s the MMFs operated below the long-term cointegrating trend but by the early 1990s it quickly recovered. In contrast, the MMFs grew above the trend in the early 2000s but nose-dived in 2005. This behavior is qualitatively similar to the results obtained when the crisis period is included in our estimation process (Fig. 3); though perhaps the adjustment process is relatively smoother when the crisis period is excluded. This evidence confirms that the estimated cointegrating residual is robust to the financial crisis.

For the short-term error correction model, the main results are both qualitatively as well as quantitatively robust to the exclusion of the crisis period. These results of the VECM are presented in columns

[20]It can also be argued that the dynamic relationship among these variables may have also changed in 1994 given the changes in the MMF industry around that time period. We check whether there was a break in the cointegration vector in 1994 using Hanson (2002) method and we do not find a break in the cointegration vector in 1994.

4-5 of Table 5. We find that, again only the adjustment coefficient of the MMFs (α^{mmf}) is statistically significant. While the CP and the repo markets do not participate in the error correction process, since both α^{cp} and α^{repo} are insignificant. Furthermore, even quantitatively, the speed of adjustment done by the MMFs remains unchanged at -0.06, same as the full sample period estimate.

Overall, the results show that the cointegrating vector as well as the error correcting coefficients remain robust and do not change with the exclusion of the financial crisis period. The robustness test results also highlight the changing dynamics that occurred in the shadow banking industry over time, particularly in and around the period of financial crisis.

We also use information from the cointegration witnessed in the 1985-2007 period to decompose the series into the BN trend and cycle. The results are presented in Figures 7 and 8. These graphs show that there is no qualitative change in the trend-cycle of each variable for the sample that excludes the crisis period (Fig. 7-8) as compared to the full sample (Fig. 4-5). The cyclical component of the MMFs shows evidence of periods of sustained deviations from the zero-mean line. This is consistent with the slow error correction process of the MMFs in the VECM. Quantitatively, we find that right before the crisis the cyclical component of the MMFs (Fig. 8) is slightly larger than the full sample estimates of the MMFs cycle (Fig. 5). This evidence brings forth the extent of stress that was faced in the shadow banking system due to the financial crisis.

It can also be argued that the relationship among these markets may have changed fundamentally since the financial crisis. This becomes especially importance since there has been significant changes in the way these markets are regulated. Moreover, there was significant involvement of the Federal Reserve in these markets during the crisis. To examine this hypothesis, we estimate our model for the last 8-years of our sample (2009-2017). Since the sample size is only 34, these results should be taken with a grain of salt. However, the estimated model may still provide light on the interesting underlying changes in these markets. The estimated cointegrating vector is very similar to the pre-crisis period. We find the elasticity with respect to the financial asset of CP market is 0.92 whereas it is only 0.15 for the repo market. The interesting finding relates to the short-run error-correction. As shown in the last panel of Table 5, we find that in the post-crisis phase, in addition to the MMF adjusting to correct for the disequilibrium, the financial assets of the CP market also participate in the error correction. This may reflect the changes that have taken place in the MMF and the CP market since the financial crisis.

4 Conclusion

There is a consensus on the important role played by the financial intermediaries that are a part of the shadow banking system during the last recession. The money market funds, commercial papers, and repurchase agreements are three main players at the center of the shadow banking system. In this study, we examine the long-run and the short-run relationship among these markets by using a time-series econometric approach. Our results show that the money market funds, the commercial paper and the repo markets move together in the long-run. Further, any deviation in the shared long-run equilibrium forces the money market funds to error-correct to restore the equilibrium relationship on this long-run path. The results suggest that financial assets of money markets in the short-run do respond to dynamic movements in the commercial papers and the repo market. The results presented in this paper confirm the narrative evidence presented in Krishnamurthy et al. (2014) and others who argue that the short-term debt market investment opportunities in the form of the CP and the repo markets played a crucial role in the expansion of the balance sheet of the MMFs. We also find some changes in the relationship in the post-financial crisis period where the commercial papers market in addition to the money market funds also adjust to correct for the short-run disequilibrium.

Further, we use the information from the cointegrating relationship to estimate the permanent and transitory components of an integrated time series. Our results from the trend-cycle decomposition show that the cycle of the money market funds is significantly larger than the estimated cycles in the CP and the repo market. The estimated cycle captures the boom and the bust in the financial assets of these markets very well.

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Table 1: Descriptive Statistics

Variable	Mean	Median	Max	Min	Std. Dev.
MMF	1637.00	1829.90	3757.30	242.00	1021.44
CP	993.50	1021.20	2109.40	247.60	454.95
Repo	266.26	209.79	855.63	17.85	220.11

Note: The table provides descriptive statistics for the money market funds (MMFs), commercial paper (CP) and repurchase agreements (repo) in billion of dollars.

Table 2: Unit Root Test

Variable	PP P-Value
MMF	0.98
CP	0.93
Repo	0.35
ΔMMF	0.01
ΔCP	0.01
$\Delta Repo$	0.01

Note:Δ denotes the first difference. PP denotes the Phillip Perron test

Table 3: Cointegration Test

Panel A : Cointegration results from the DOLS approach

	Full sample (1985-2017)	Sub-sample (1985-2007)	Sub-sample (2007-2017)
	PP P-Value	PP P-Value	PP P-Value
Residual	0.00	0.00	0.00

Panel B : Cointegration results from Engle and Granger (1987)

	Full sample (1985-2017)	Sub-sample (1985-2007)	Sub-sample (2007-2017)
	PP P-Value	PP P-Value	PP P-Value
Residual	0.02	0.08	0.01

Panel C : Cointegration results from Johansen (1991)

	Full sample (1985-2017)		Sub-sample (1985-2007)		Sub-sample (2009-2017)	
	Number of Cointegration Vectors					
	None	At most 1	None	At most 1	None	At most 1
Eigenvalue	0.20	0.06	0.21	0.13	0.67	0.18
Trace statistic	37.85	9.16	34.13	12.81	55.69	11.07
0.05 critical value	35.01	18.39	29.79	15.49	35.01	18.40
P-Value	**0.02**	0.56	**0.01**	0.12	**0.00**	0.38

Note: This table represents the cointegration results for the full sample as well as the small sample. Panel A reports the estimates of the unit root for the residual of DOLS. Panel B and C show the estimates from Johansen(1991) also Engle and Granger(1987). PP denotes the Phillip Perron test.

Table 4: The DOLS estimate of the Co-integrating Vector

	Full sample (1985-2017)		Sub-sample (1985-2007)		Sub-sample (2009-2017)	
Coefficient	Value	P-Value	Value	P-Value	Value	P-Value
β_0	**3.47**	0.00	**4.02**	0.00	**6.41**	0.00
β_1	**0.55**	0.00	**0.98**	0.00	**0.92**	0.00
β_2	**0.56**	0.00	**0.26**	0.00	**0.15**	0.00

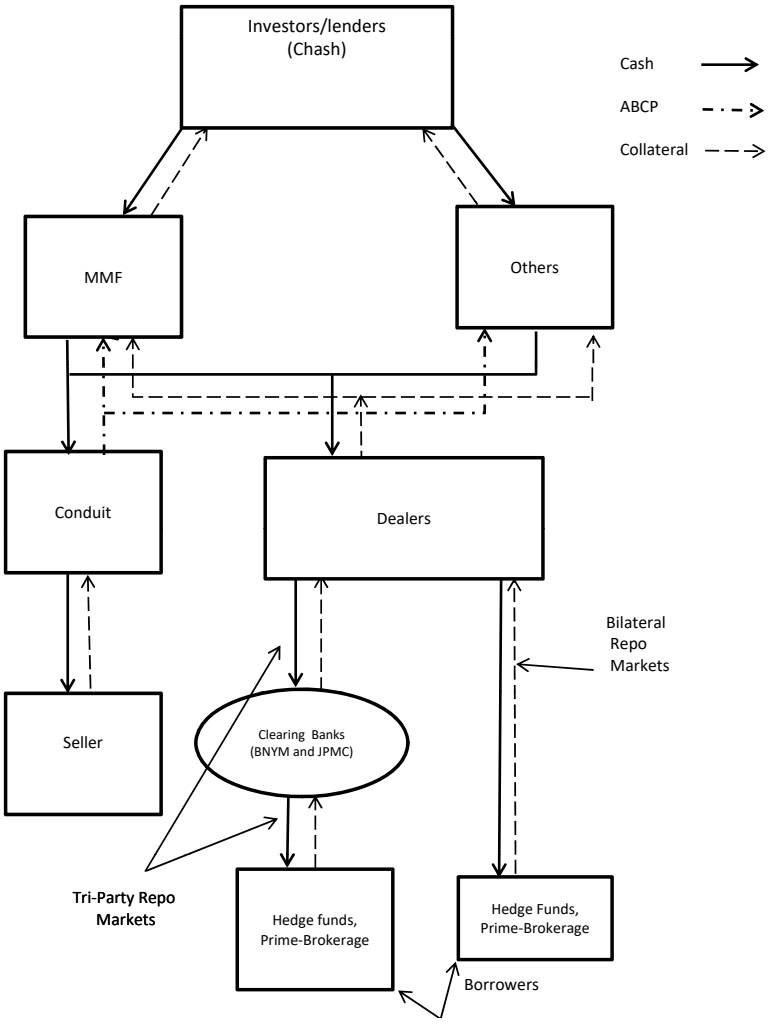
Note: The table reports DOLS estimates for the full sample as well as for the sub-sample which excludes the period of crisis. β_0, β_1, and β_2 represent the coefficients of equation 2.

Table 5: Estimates from the VECM model

	Full sample (1985-2017)			Sub-sample (1985-2007			Sub-sample (2009-20017)		
Dependent Variable	Δmmf	Δcp	$\Delta Repo$	Δmmf	Δcp	$\Delta Repo$	Δmmf	Δcp	$\Delta Repo$
Δmmf_{t-1}	0.49	0.35	0.74	0.38	0.07	0.74	0.35	2.37	0.29
	(0.00)	(0.01)	(0.00)	(0.00)	(0.29)	(0.00)	(0.05)	(0.00)	(0.36)
Δcp_{t-1}	0.06	0.09	0.12	0.33	0.77	0.31	0.08	-0.93	-0.01
	(0.22)	(0.32)	(0.36)	(0.00)	(0.00)	(0.23)	(0.16)	(0.00)	(0.48)
$\Delta repo_{t-1}$	0.01	-0.06	-0.21	0.01	-0.05	-0.31	0.10	-0.14	-0.07
	(0.61)	(0.32)	(0.01)	(0.73)	(.08)	(0.00)	(0.05)	(0.13)	(0.39)
$\hat{\beta}' Y_{t-1}$	**-0.07**	-0.01	0.08	**-0.06**	0.01	0.09	**-0.23**	**1.13**	-0.10
	(0.00)	(0.75)	(0.22)	(0.02)	(0.53)	(0.14)	(0.05)	(0.00)	(0.42)
R^2	0.42	0.08	0.15	0.42	0.57	0.18	0.61	0.66	0.02

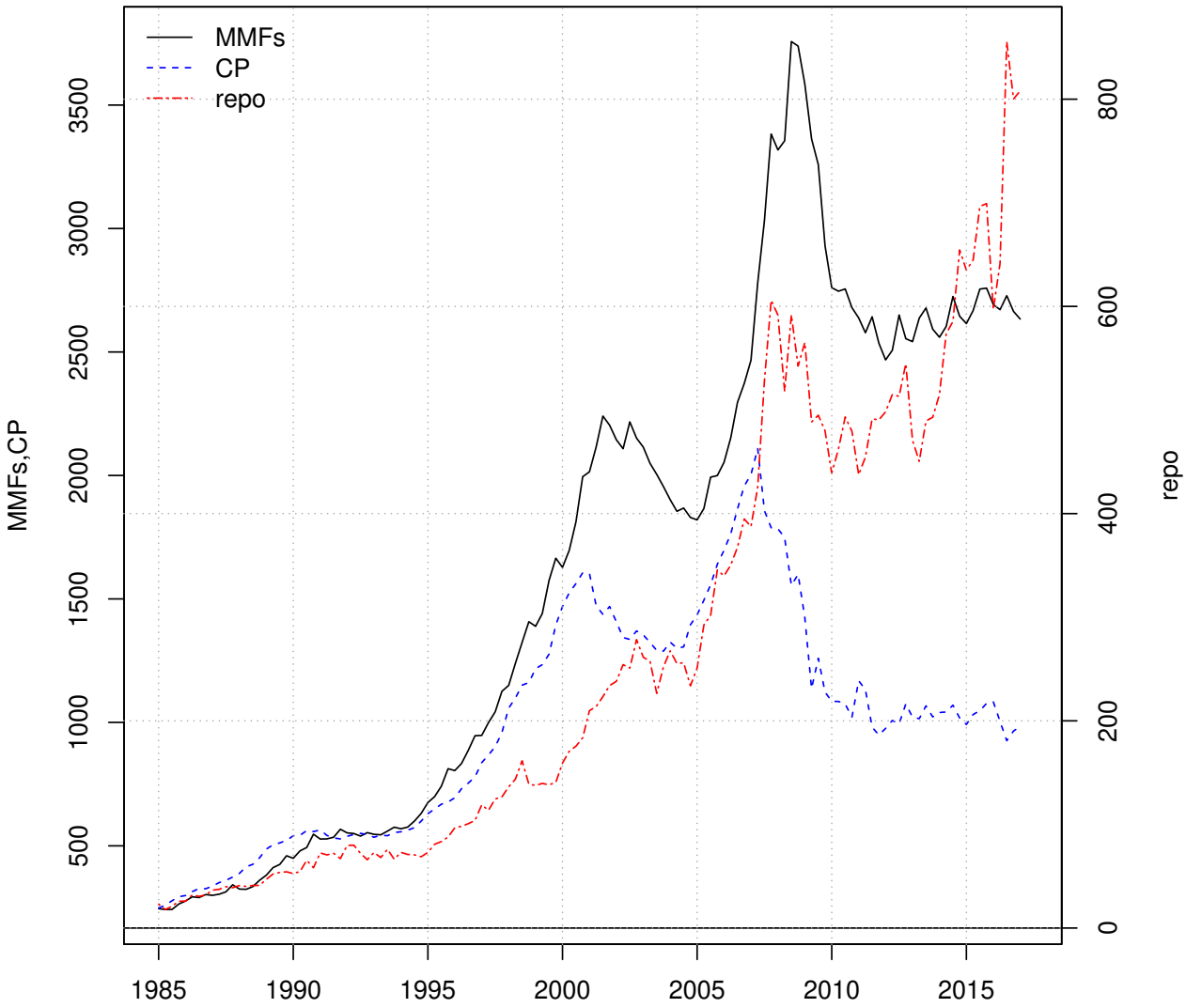
Note: The table reports the estimates (and the associated P-values) from the VECM (Equation 4, 5, and 6) for the full sample as well as for the sub-sample which excludes the period of crisis. Second last row shows the adjustment coefficient of the lagged value of the estimated co-integrating residual.

Figure 1: The Shadow Banking System



Sources: Krishnamurthy et al. (2014) and Copeland et al. (2014).
This figure presents a broader outline of the shadow banking system. The money market funds and others (Securities lender etc.) receive cash from investors and in return pay a share of the money market funds ($1 NAV) or securities to the lender. Their cash provides funds for commercial papers or goes to the repurchase agreements market and in return receives asset back securities. Their findings can go to the dealer or the conduit. If they go to the Conduit for special purpose they will receive a financial asset which is called ABCP. If they go to the dealer, it can provide funds for the Hedge funds or Prime-Brokerage which called repurchase agreements (repo). The repo between dealers and hedge fund or prime-brokerage without clearing banks are bilateral repo. The repo between the hedge funds or prime-brokerage when there are clearing banks (BNYM or JPMC) are Tri-Party repo.

Figure 2: Financial asset of the MMFs, the CP, and the Repo markets



Notes: The graph shows the volume (levels) of financial assets of the money market funds, the commercial paper and the repo market in billion of dollars for the 1985-2017 period.

Figure 3: Residual from the DOLS (Full sample - 1985-2017)

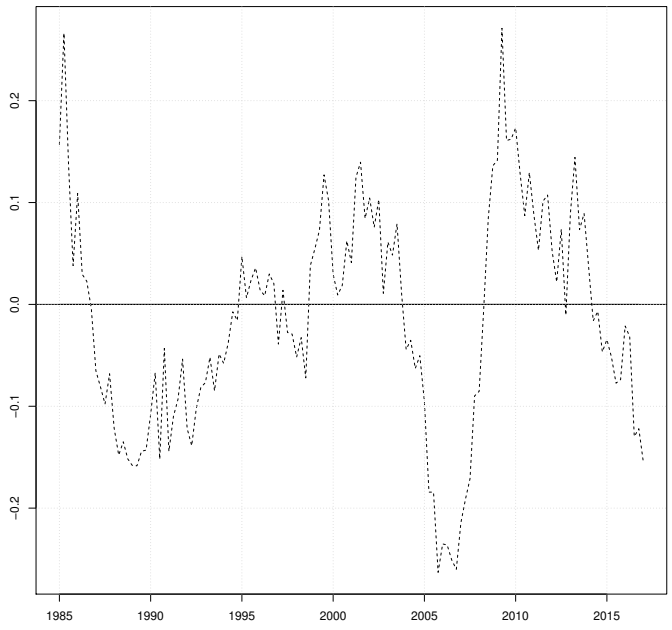
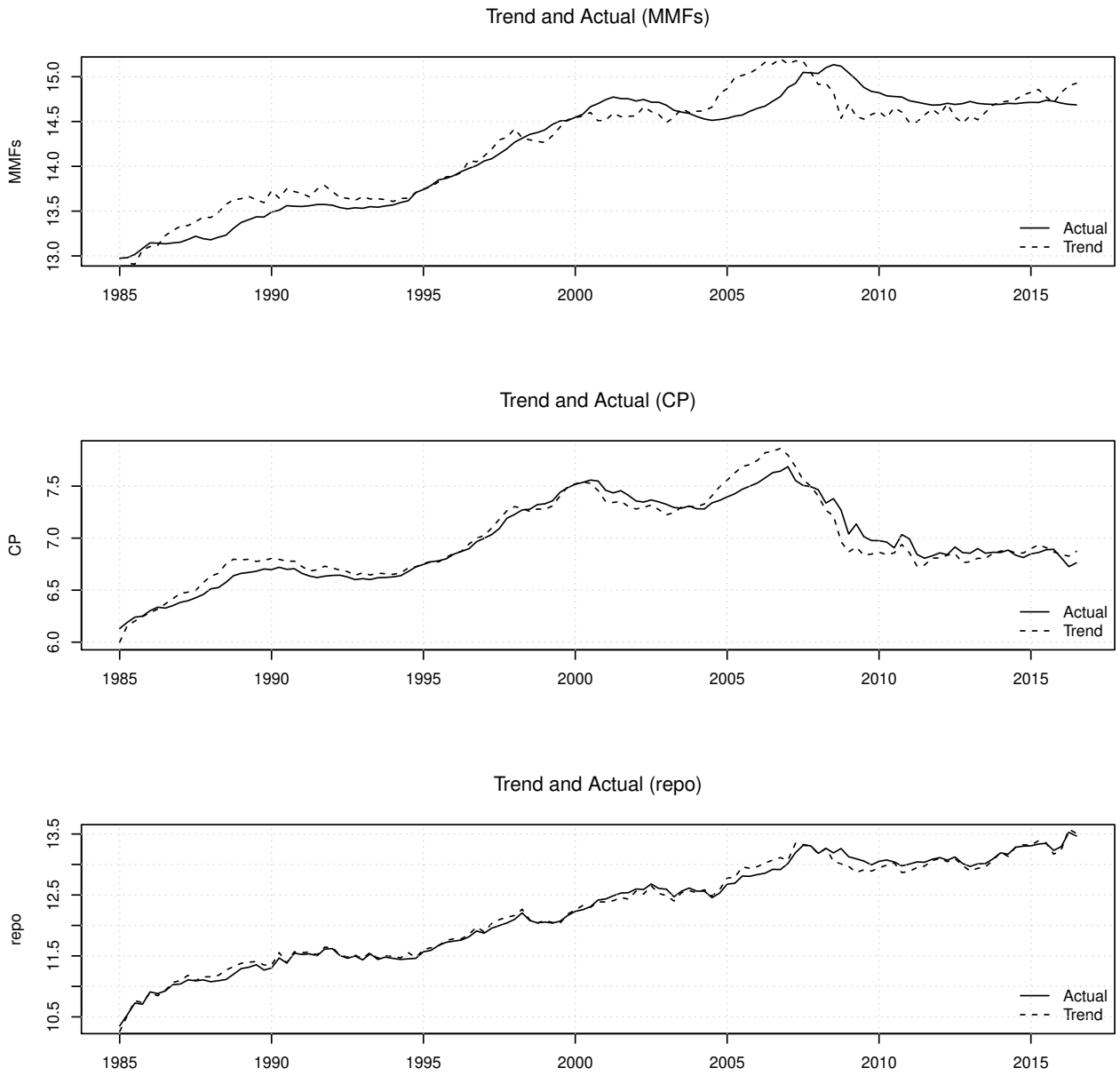
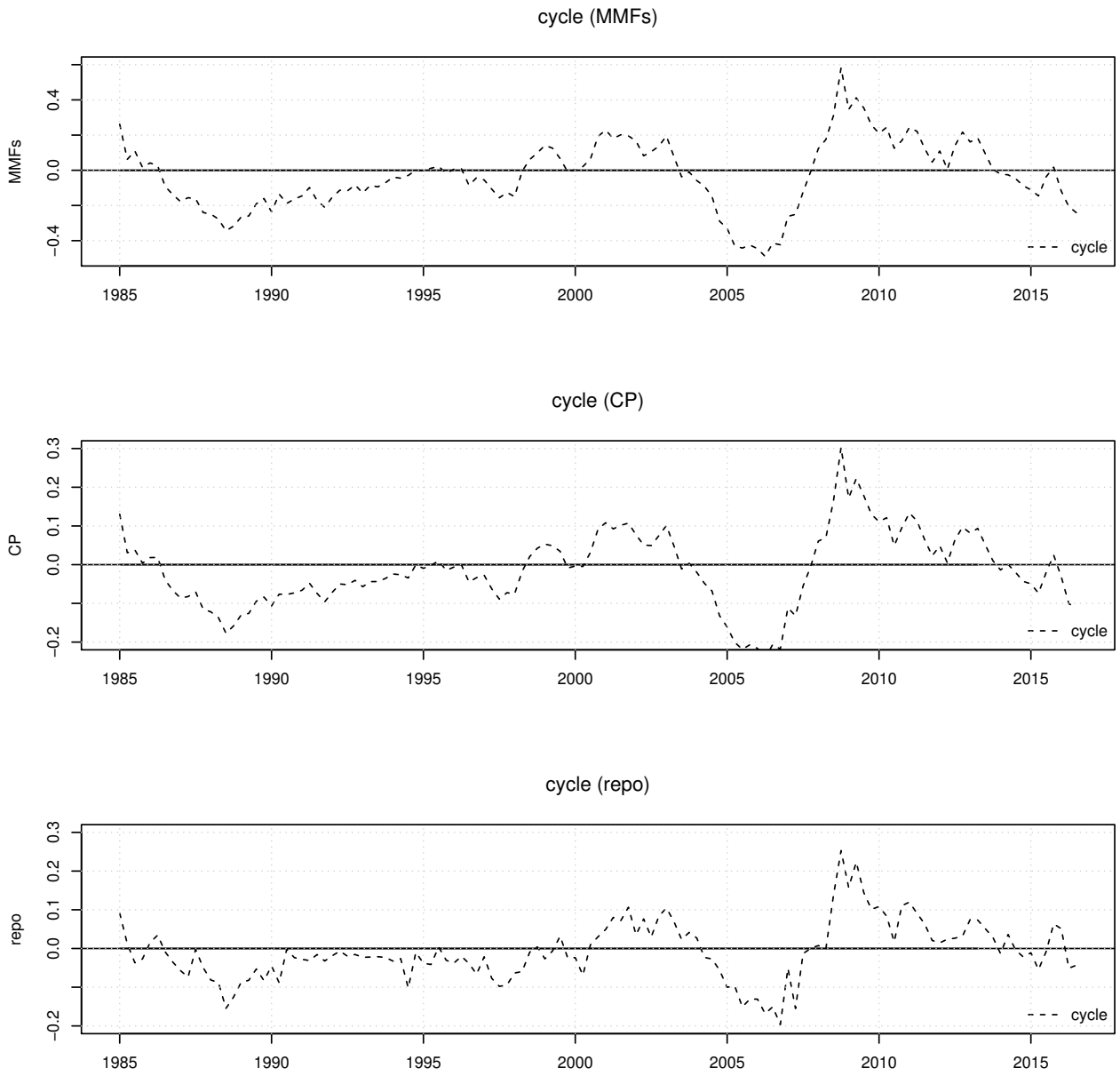


Figure 4: Estimated Trend from the BN decomposition



Notes: The graphs present the trend and actuals of financial assets of the MMFs, the CP and the Repo markets for the period 1985-2017.

Figure 5: Estimated Cycle from the BN decomposition



Notes: The graphs present the cycle of financial assets of the MMFs, the CP and the Repo markets for the period 1985-2017.

Figure 6: Residual from the DOLS (Sub-sample - 1985-2007)

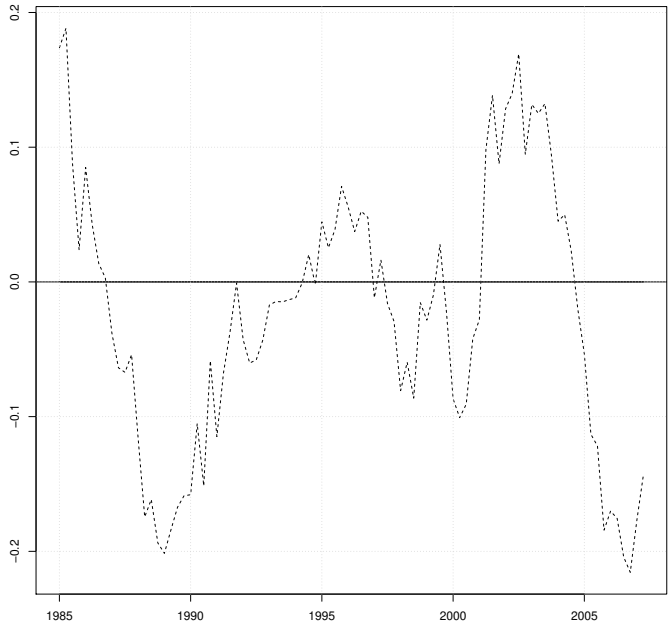
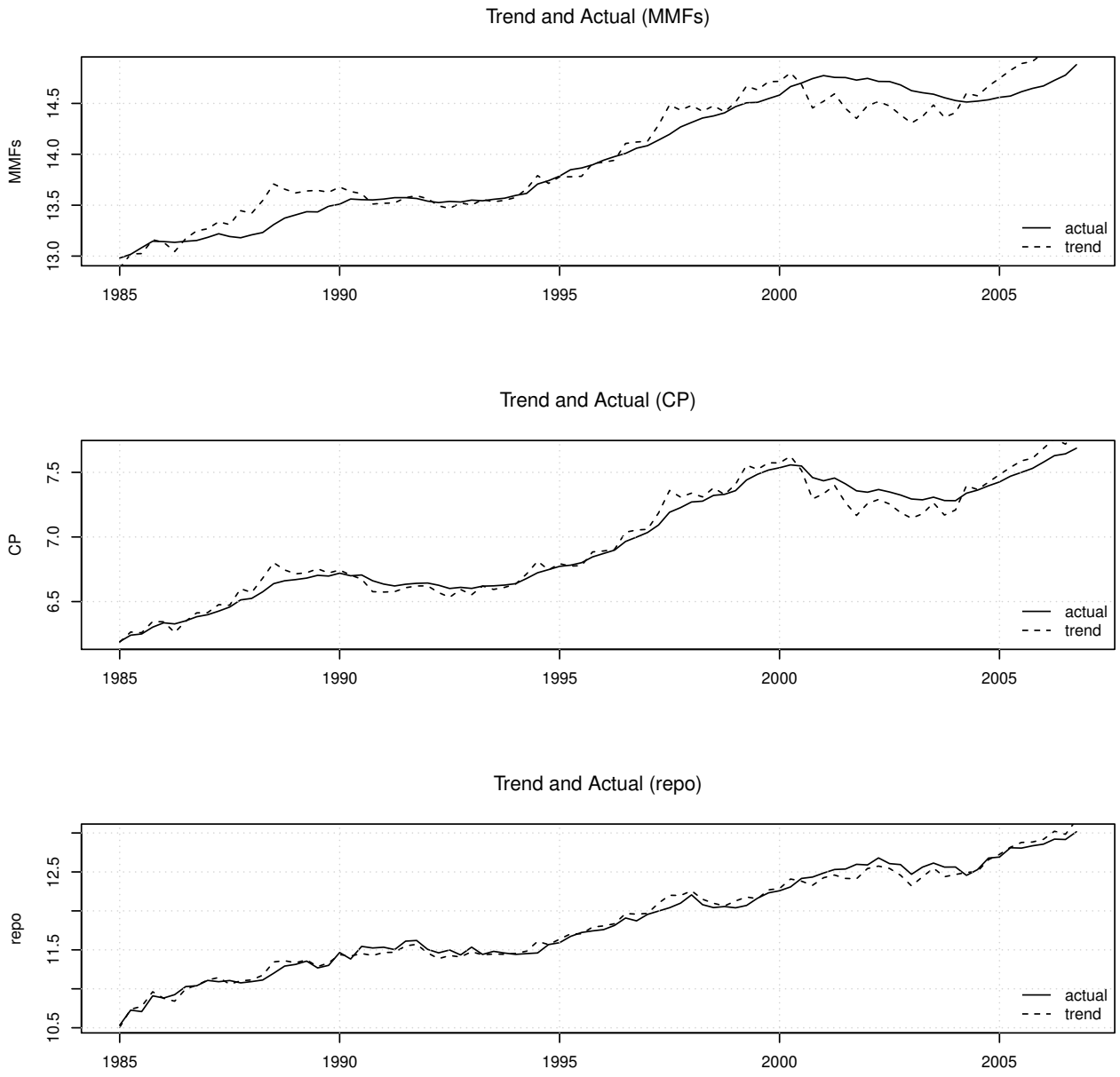
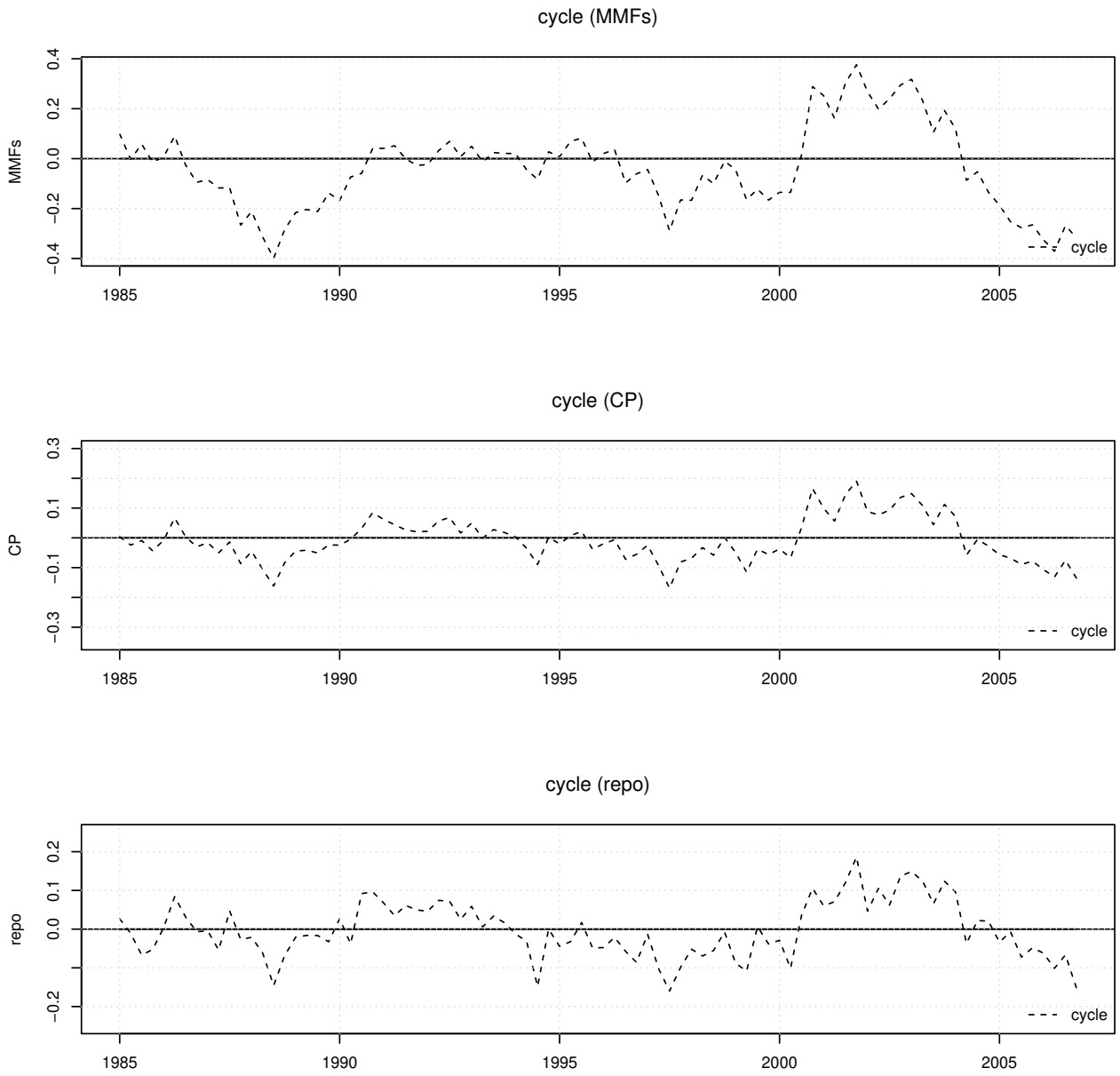


Figure 7: Estimated Trend from the BN decomposition (excluding crisis)



Notes: The graphs show the estimated BN trend for financial assets of the MMFs, the CP and the Repo markets for the period excluding the recent crisis 1985 to 2007.

Figure 8: Estimated Cycle from the BN decomposition (excluding crisis)



Notes: The graphs show the estimated BN cycle for financial assets of the MMFs, the CP and the Repo markets for the period excluding the recent crisis 1985 to 2007.