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Risk Management and the Money Multiplier

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Abstract

The conventional model of bank liquidity risk management predicts a negative relation between the risk free rate and the money multiplier. We extend that model to reflect credit, or loan book, risk. We find that credit risk model predicts a positive correlation between the risk free rate and the money multiplier, other things constant. In the pre-financial crisis period the liquidity risk view fits the data better whilst in the post-crisis period, the credit risk management model is more appropriate in explaining the relationship between the money multiplier and the risk free rate. In addition, the model implies that the money multiplier should increase with stock market return and decline with its volatility. We provide evidence that this is indeed the case.

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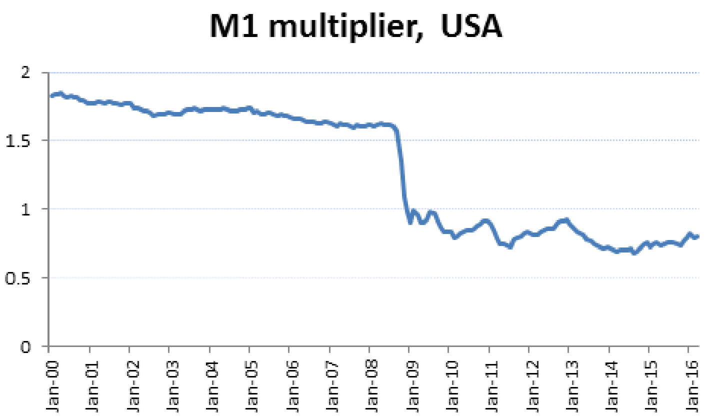
1. Introduction

The effectiveness of monetary policy depends in part on control over broad money, loosely speaking the money created by the banking system. However, the central bank has direct influence only over narrow money. Consequently, central banks have a keen interest in understanding the determinants of the (broad) money multiplier (see e.g., Williams (2011) and Goodhart (2009) for recent, policy-oriented discussions of the multiplier).[1]

Understanding the money multiplier became especially important following the recent financial crisis. A sharp fall in the multiplier occurred as banks contracted their lending portfolios and increased their holdings of reserves. That elevated level of reserves holdings continues eight years after the crisis and provides grounds for suspicion that there may have been a change in banks' investment behaviour[2].

Figure 1: Structural break in the money multiplier



Our paper suggests that the main purpose of holding reserves has switched from liquidity management to credit risk management.

To support that contention we model the relation between the money multiplier and the risk free rate. We extend the conventional liquidity management model proposed by Orr and Mellon (1961)[3]. That original model suggested that banks hold reserves solely for liquidity purposes. The reserves holding then declined with the opportunity cost reflected in the loan interest rate and it increases with the penalty rate which we model as a premium over the risk free rate. In this framework, an increase in the risk

[1] The importance of the money multiplier has been debated in a huge literature. Recent contributions inlcude: Bernanke and Blinder (1988), Freeman and Kydland (2000) and more recently still Abrams (2011).

[2] No doubt tighter liquidity guidelines imposed by regulators and other developments mentioned in Section 2.1 also have an impact.

[3] See also Selgin (2001).

free rate makes penalty rates larger and increases the punishment for insufficient reserves holding. To avoid costly penalties banks hold more reserves. Therefore, the liquidity risk management model predicts that the money multiplier negatively depends on the risk free rate.

In this paper we extend that model to introduce a role for solvency considerations; banks face uncertainty both because liquidity is difficult to forecast but also because their loan portfolio may perform poorly. Consider the case where banks keep reserves solely to manage credit risk. We assume that banks maximize profits subject to a solvency constraint. That means that the probability of being insolvent is not to exceed some limit. In an economy with a low reserve requirement ratio, the solvency constraint is binding, and the relation between the risk free investment and risk free rate is negative. The risk free asset is used to hedge solvency risk. When the return on the safe asset increases, it allows for increased investment in risky assets without violating the solvency constraint. This leads to an increase in the money multiplier–the opposite effect to the case when liquidity concerns are the only issue.

We test the relation between changes in the money multiplier and changes in the T-bills rate. We find that there is a strong negative and significant relation in the pre-crisis period and strong, positive and robust relation in post-crisis period. That is consistent with our suggestion that liquidity risk was more important for banks before the crisis, but less important than credit risk after the crisis[4]. That could be because of continuous QE–like support for liquidity[5] and a simultaneous increase in business risk in the post crisis period. An interesting implication of the model is that an increase in the target interest rate for policy is not necessarily deflationary as it could be consistent with a boost to bank lending and hence broad money, other things constant. The model also predicts that the money multiplier should depend positively on the stock market return and negatively on stock market volatility. The model seems consistent with the data.

The rest of the paper has the following structure. Section 2 sets out and extends the standard model of banks. Here banks face risks from deposit withdrawals and from solvency concerns. We then focus on two special cases. The first when only liquidity risks are present and the second when only solvency risks are present. The latter version of the model predicts that the money multiplier should depend positively on the risk free rate and the stock market return and negatively on stock market volatility. Section 3

[4]Figures 3 and 4 in the Appendix indicate a structural change in the dynamics of at the time of the crisis: Checkable deposits did not grow much but were rather volatile before the crisis, but started growing in the post-crisis period.

[5]For a review of QE measures in OECD countries, see Gambacorta et al. (2014).

tests the model empirically on the pre- and post-crisis data indicating that solvency was less of an issue pre-crisis but a dominating factor post-crisis. Section 4 concludes.

2. Model of bank facing liquidity and solvency risks

Constructing a model to formalize the bank's problem in the face of solvency *and* liquidity risks takes a little work. A representative bank starts the period with an amount of deposits, D, from households (retail deposits). The bank may lend to a productive firm who has investment opportunities. It is impossible for the banks (or the firms) to tell ex ante how profitable the firm will be. However, banks do know what the average return will be on a dollar lent. Let B^c denote a bank's risky corporate loans portfolio with average stochastic gross return, R_t^c.

Whatever the banks do not lend to the corporate sector, is kept in the form of reserves $R = D - B^c$. Part of these reserves are needed to meet liquidity demands such as deposit withdrawal. Let y be the liquidity demand to deposits ratio. That ratio is a stochastic variable with cumulative distribution function G. If reserves are larger than the bank's liquidity needs, the bank can lend the difference on the interbank market and earn the risk free rate $r^f > 0$ per unit invested. Otherwise the bank needs to borrow at rate $r^f(\Delta + 1)$ where $\Delta > 0$ is some transaction cost associated with borrowing on the interbank market. Thus, at the end of the period a representative bank will earn expected income of $E_t\left\{\max(R - yD, 0)r^f + B^cR^c - \min(0, R - yD)\left(r^f + \Delta\right)\right\}$ and will face costs of D. Here we assume that no interest is paid on the deposits.

If there were no other constraints facing the bank, its optimal program would simply be

$$\max_{B^c, R,} \Pi = E\left[\max(R - yD, 0)r^f + B^cR^c + R - \min(0, R - yD)r^f(1 + \Delta) - D\right]. \quad (2.1)$$

We recover the solution to this problem below as a special case of the more general problem we are setting out in this section. However, in addition to liquidity shocks we assume that banks manage their balance sheets so that there is also a target probability for solvency. Specifically, banks desire to be solvent with probability $1 - \alpha$, where α is the probability of default. Thus, the bank is assumed to respect the following constraint:

$$\Pr\left\{\left[\max\left((r - y), 0\right)r^f + (1 - r)R^c + r - r^f(1 + \Delta)\max((y - r), 0) - 1\right] < 0\right\} \leq \alpha. \quad (2.2)$$

where we define $r = R/D < 1$, the reserve ratio.

That constraint includes two stochastic variables, R^c, the risky return, and y, the liquidity shock. Therefore we need to work with a joint distribution function. Let $g(y, R^c)$ denote the joint density of y and R^c. One can now transform the solvency constraint into a more convenient mathematical form. We consider 2 cases.

The first case is when the liquidity shock is smaller than reserves, $y < r$. In that case violation of the solvency (2.2) will occur if $(r-y)\,r^f + (1-r)R^c + r - 1 < 0$ which may be rewritten as

$$R^c < 1 + \frac{(y-r)\,r^f}{(1-r)}. \tag{2.3}$$

As a result, for any realization of the liquidity shock y, one may compute the conditional probability of default

$$\Pr\left[R^c < 1 + \frac{(y-r)\,r^f}{(1-r)}\right] = \int_{-\infty}^{1+A_R} g(y, R^c)\, dR^c,$$

where $A_R(r,y) \equiv \frac{(y-r)r^f}{(1-r)}$. And so, the probability of default given that the liquidity shock is smaller than reserves is

$$\Pr\left[R^c < 1 + \frac{(y-r)\,r^f}{(1-r)};\ \text{and } y < r\right] = \int_0^r \left(\int_{-\infty}^{1+A_R} g(y, R^c)\, dR^c\right) dy. \tag{2.4}$$

The second case is when the liquidity shock is larger than reserves, $y > r$. In that case a similar manipulation shows that the probability of default when the liquidity shock exceeds reserves is

$$\Pr\left[R^c < 1 + r^f(1+\Delta)\,\frac{(y-r)}{1-r};\ \text{and } y > r\right] = \int_r^1 \left(\int_{-\infty}^{1+A_R(r,y)(1+\Delta)} g(y, R^c)\, dR^c\right) dy. \tag{2.5}$$

It follows, then, that the total probability of default is the sum of (2.4) and (2.5), and the solvency constraint (2.2) may be written as

$$\int_0^1 \left(\int_{-\infty}^{1+A_R} g(y, R^c)\, dR^c\right) dy + \int_r^1 \left(\int_{1+A_R(r,y)}^{r \atop 1+A_R(r,y)(1+\Delta)} g(y, R^c)\, dR^c\right) dy = \alpha \tag{2.6}$$

2.1. Liquidity management

In the run up to the financial crisis it has become widely accepted that many financial institutions were badly undercapitalized, financial regulation too lax and many institutions too risky as they anticipated bailouts. In this section, we capture these factors by ignoring the solvency constraint. So, as noted above, whatever banks do not lend to the corporate sector, is kept in the form of reserves $R = D - B^c$. Recall, that if reserves are larger than the liquidity requirements, the bank can lend on the interbank market earning the risk free rate $r^f > 0$. Otherwise they need to borrow at rate $r^f(\Delta + 1)$, where $\Delta > 0$. If there are no other constraints facing the bank, its optimal program is a special case of (2.1) above

$$\max_{B^c,R,} \Pi = E\left[\max(R - yD, 0)r^f + B^c R^c + R - \min(0, R - yD)r^f(1 + \Delta) - D\right]. \quad (2.7)$$

Denoting by r the reserve to deposit ratio, the problem (2.7) can be written as

$$\max_r \frac{\Pi}{D} = r^f \int_0^r (r - y)dG(y) + (1 - r)ER^c + r - r^f(1 + \Delta)\int_r^1 (y - r)dG(y) - 1. \quad (2.8)$$

where $dG(y) = \int_{-\infty}^{+\infty} g(y, R^c)\, dR^c$ is marginal density of y.

The first order condition with respect to the reserve ratio is

$$\frac{\partial}{\partial r}\frac{\Pi}{D} = r^f G(r) - ER^c + 1 + r^f(1 + \Delta)(1 - G(r)) = r^f(1 + \Delta) - ER^c + 1 - \Delta G(r) \quad (2.9)$$

and an internal solution exists if and only if condition (2.10) is true.

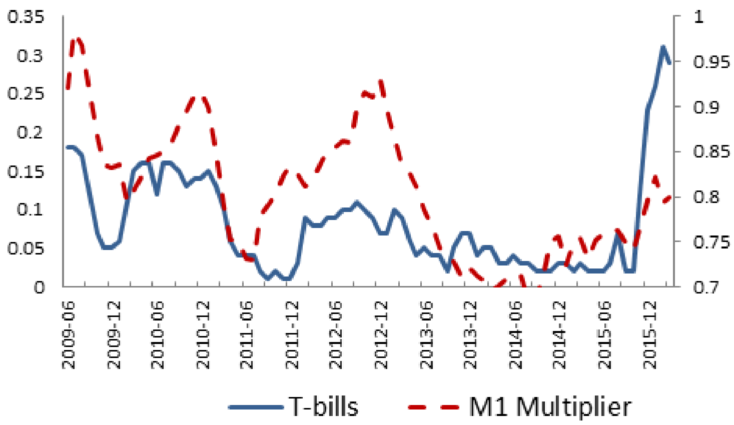
$$1 > G(r) = 1 - \frac{ER^c - (1 + r^f)}{\Delta} > 0. \quad (2.10)$$

The left-hand inequality of (2.10) simply implies that the expected return on commercial loans is higher than the risk free rate. If that condition is violated, there follows, in effect, a flight to quality where banks do not make commercial loans and instead keep all assets in the form of reserves. The right-hand inequality means that the risk premium for commercial lending should be smaller than the penalty premium Δ. If that is not the case, commercial lending is so profitable that reserves are kept at their minimum level.

It is straightforward to see that when condition (2.10) is satisfied, the reserve ratio increases with the risk free rate and penalty Δ. Therefore, when banks are solely concerned with liquidity risk management, our model implies a negative relation between the risk free rate and the money multiplier.

However, in the months after the financial crisis there was, arguably, a decline in Δ due to the adoption of so-called Quantitative Easing (QE) and other liquidity-oriented policies, notably remuneration of reserves (Williams, 2011). Also, the Fed Funds rate was reduced almost to zero. Therefore, one should have observed an increase of the money multiplier. However, the money multiplier did not recover after the crisis. Moreover, one can clearly observe a positive relation between the money multiplier and the risk free rate as shown in Figure 2.

Figure 2: T-bills rate and M1 money multiplier (right axis)



The counterfactual prediction of the model in this time period indicates that a sole focus on liquidity management issues is misleading. In other words, the simple view of banking behavior implicit in the traditional liquidity management model, i.e., (2.7), is missing issues that have become important in practice. Williams (2011) notes

> [N]ow banks earn interest on their reserves at the Fed .... This fundamental change in the nature of reserves is not yet addressed in our textbook models of money supply and the money multiplier. ...[I]f the interest rate paid on bank reserves is high enough, then banks no longer feel such a pressing need to "put those reserves to work." In fact, banks could be happy to hold those reserves as a risk-free interest-bearing asset, essentially a perfect substitute for holding a Treasury security. If banks are happy to hold excess reserves as an interest-bearing asset, then the marginal money multiplier on those reserves can be close to zero.
>
> In other words, in a world where the Fed pays interest on bank reserves, traditional theories that tell of a mechanical link between reserves, money supply, and ultimately inflation no longer hold. In particular, the world changes if the Fed is willing to pay a high enough interest rate on reserves. In that case, the quantity of reserves held by U.S. banks could be extremely large and have only small effects on, say, M1, M2, or bank lending.

We suggest that indeed there is a relationship between bank lending and remuneration of reserves. In particular, if safe assets generate some income that provides some insurance for risky investments and allows for more lending without compromising solvency.

The solvency issue in banking sector became more important in the post-financial crisis era. There has been (and will continue to be for a few more years) increasing formal capital requirements on banks. Moreover, tighter financial regulations are accompanying a political backlash against financial bailouts. And, at least in some countries, bailouts may be less likely in the near future as governments repair public sector balance sheets following the great recession. Such considerations complicate the analysis of the money multiplier further.

We now focus on the bank's problem when the solvency constraint is binding.

2.2. Credit risk management

To isolate the effect of the solvency constraint, we assume that there is certainty as regards the liquidity shock. If Δ is zero, and the liquidity needs, y, is known, the constraint (2.6) specializes to the case where

$$\Pr\left\{R^c < 1 - \frac{(r-y)\,r^f}{(1-r)}\right\} \le \alpha. \tag{2.11}$$

The bank's profit maximisation problem then reduces to

$$\max_{r,} E\frac{\Pi}{D} = (r-y)r^f + (1-r)ER^c + r - 1. \tag{2.12}$$

It is easy to see that constraint (2.11) is binding if $\frac{\partial}{\partial r}E\frac{\Pi}{D} < 0$, which is equivalent to $ER^c > r^f + 1$.

Now define the conditional cumulative probability function of risky return by $F_y(X) = \int_{-\infty}^{X} g\left(y, R^c\right) dR^c$. Then (2.11) with equality is identical to $1 + r^f - \frac{(1-y)r^f}{(1-r)} = F_y^{-1}(\alpha)$ or

$$(1-r) = \frac{(1-y)\,r^f}{(1+r^f) - F_y^{-1}(\alpha)}. \tag{2.13}$$

It follows that

$$\frac{\partial}{\partial r^f}(1-r) = (1-y)\,\frac{1 - F_y^{-1}(\alpha)}{\left(1 + r^f - F_y^{-1}(\alpha)\right)^2}$$

and the proportion of loans $(1-r)$ increases with r^f if and only if

$$1 - F_y^{-1}(\alpha) > 0. \tag{2.14}$$

Condition (2.14) is satisfied if and only if the bank is solvent at $R^c = 1$. So, in this version of the bank's problem, the reserves increase with expected liquidity requirements, but in both cases (high y and low y) reserves decline in the risk free rate.

3. Risk free rate and the money multiplier

Our model of pure credit risk management discussed in the previous section predicts that the money multiplier positively depends on the risk free rate. That is because safe assets may be used for hedging against risky lending. Ceteris paribus, when the risk free rate is higher, the cash flow from the safe asset is larger and more risky lending is possible without violation of the solvency constraint. That simple model predicts that the money multiplier ought to increase in the risk free interest rate and one would expect an increase in the money multiplier. Inspecting the data post 2009, there does appear to be some positive co-movement in the money multiplier and the risk free rate in the USA.

To back up that casual empiricism, we also estimated various econometric models. The relation between the M1 multiplier and the T-bills rate is positive, significant and robust to model specification. Table 1 shows that the M1 multiplier follows a very persistent, heteroskedastic process and indeed the movement of the money multiplier is positively related to the movement of the 3 month T-bills rate.

Table 1: Money Multiplier and T-bills rate post-crisis period

Dependent variable M1 multiplier from St. Louis FED database Sample: August 2008 - March 2016.						
Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
intercept	0.154****	0.095****	0.126****	0.152****	0.081****	0.064**
m1(-1)	0.788****	0.872****	0.831****	0.988****	1.177****	1.242****
T-bills rate	0.105****	0.0673***	0.060****	0.095****	0.222****	0.149****
m1(-2)				-0.192****	-0.283****	-0.327***
T-bils rate(-1)					-0.19****	-0.125***
Variance equation						
	EGarch(1,0)	Garch(0,1)	IGarch(1,1)	EGarch(1,1)	EGarch(1,1)	IGarch(1,1)
C(1)	-8.11****	5.51E-05***	0.19****	-11.11****	-0.33***	0.125****
C(2)	1.11****	0.858****	0.79****	0.893****	-0.27*	0.875****
C(3)				-0.43***	0.93****	
R^2	0.953	0.940	0.948	0.962	0.966	0.965
Akaike	-4.266	-4.417	-4.304	-4.327	-4.707	-4.461
Schwartz	-4.129	-4.279	-4.194	-4.135	-4.487	-4.297
Durbin-Watson	1.113	1.004	1.128	1.4973	2.257	2.165
Log likelihood	201.2	208.2	202.0	206.0	225.5	211.2
IGarch: GARCH = C(1)*RESID(-1)^2 + (1 - C(2))*GARCH(-1) EGarch: LOG(GARCH)= C(1)+C(2)* ABS(RESID(-1)/SQRT(GARCH(-1)))+C(3)*log(Garch(-1)) Garch(0,1): GARCH = C(1) + C(2)*GARCH(-1)						

Before performing the regressions reported in Table 1 we checked the M1 multiplier data and rejected the unit root hypothesis for post crisis period. However, we cannot reject the unit root hypothesis for the complete sample from 1984 onwards. Consequently, we respecified the model in differences. So we define dm1 as the first difference in the money multiplier and dRF as the first difference in the risk free rate. Table 2 shows that the relation between the increase in the money multiplier and the increase in the risk free rate is positive and significant and robust to the choice of the model for the residual process.

Table 2: Change in M1 money multiplier, post-crisis

Dependent variable dm1=m1-m1(-1) change in money multiplier from St. Louis FED database Sample: September 2008 - March 2016.				
Independent variables	Model 7	Model 8	Model 9	Model 10
dm1(-1)	0.313****	0.273****	0.22****	0.16**
dRF	0.22****	0.311****	0.257****	0.138****
dRF(-1)			0.115****	0.222****
Variance equation				
	Garch(1,1)	EGarch	EGarch	IGarch
C(1)	5.97E-05****	-0.455982****	-0.37****	0.09***
C(2)	0.119395****	-0.360230**	-0.27**	0.91***
C(3)	0.955688****	0.905524****	0.92****	
R^2	0.573751	0.558075	0.663321	0.711335
Akaike	-4.779488	-4.708687	-4.718693	-4.595104
Schwartz	-4.641529	-4.570728	-4.553142	-4.484737
Durbin-Watson	2.070751	1.993389	1.948641	1.966032
Log likelihood	222.4667	219.2453	220.7005	213.0772
IGarch: GARCH = C(1)*RESID(-1)^2 + (1 - C(2))*GARCH(-1) EGarch: LOG(GARCH)= C(1)+C(2)* ABS(RESID(-1)/SQRT(GARCH(-1)))+C(3)*log(Garch(-1)) Garch(1,1): GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)				

3.1. Money multiplier and the stock market

We also investigated the relationship between the money multiplier and stock market behaviour. We refer to the Merton (1974) model for valuing credit risks where it is shown that corporate debt holding is equivalent to a risk free investment less a European call option on common stock. Since banks can diversify their assets we assume that their loan portfolio can be priced against the stock market index.

Consider (2.11) under the assumption that R^c is lognormally distributed, $R^c \sim LN$ (r^c, σ^2). The proportion of loans will be defined as

$$(1-r) = \frac{(1-y)\,r^f}{(1+r^f) - \exp\left(\Phi^{-1}(\alpha) + r^c/\sigma\right)\sigma} \tag{3.1}$$

where Φ is the normal CDF. Therefore, our model predicts that the money multiplier increases with stock market returns and declines with stock market volatility.

We computed market return using S&P250 index and used the VIX data as a proxy for volatility. The regression results in Table 3 also support the predictions of our model during the post-crisis time period.

Table 3: M1 multiplier and the stock market- post crisis period

Dependent variable dm1=m1-m1(-1) change in money multiplier from St. Louis FED database. Sample: September 2008 March 2016.		
Independent variables	Model 11	Model 12
dm1(-1)	0.355****	0.439****
dRF	0.156****	0.137****
dRET(-2)		0.079****
dRET(-3)	0.073***	
dVIX(-1)	-0.00085**	-0.0005***
Variance equation		
	IGarch	EGarch (1,2)
C(1)	0.16****	-7.13****
C(2)	0.84****	2.106****
C(3)		-0.102****
C(4)		0.360****
R^2	0.569279	0.559630
Akaike	-4.464011	-4.70
Schwartz	-4.326052	-4.447
Durbin-Watson	2.077776	2.204
Log likelihood	208.1125	222.2571
IGarch: GARCH = C(1)*RESID(-1)^2 + (1 - C(2))*GARCH(-1) EGarch(1,2): LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + + C(3) LOG(GARCH(-1)) + C(4)*LOG(GARCH(-2))		

3.2. Pre-crisis estimation

We estimated the relation between the money multiplier, the stock market and the risk free rate in the pre-crisis period beginning in January 1990, when data for VIX become available, until June 2008. We found that there was a significant negative trend in the M1 multiplier before the crisis. But more importantly, there is a negative, significant and robust relation between the money multiplier and the risk free rate (Table 4). Viewed through the lens of our model, it appears that in the pre-crisis period credit risk and the solvency constraint were less important than liquidity risk in influencing aggregate bank behaviour. It is tempting to suggest, as we intimated above, that this reflects a presumption of bailouts and lax regulation. In any event, there is a significant positive relation between the money multiplier and the market return and a significant negative relation with the volatility of the stock market.

Table 4. Money multiplier in pre-crisis period

Dependent variable dm1=m1-m1(-1) change in money multiplier from St. Louis FED database Sample: March 1990 - July 2008.			
Independent variables	Model 13	Model 14	Model 15
intercept	-0.0047****	-0.0043****	-0.0043****
dm1(-1)	0.183***	0.16***	0.147**
dm1(-2)		0.12**	0.141**
dRf(-1)	-0.010****	-0.10***	-0.010****
dRet(-2)	0.022**	0.025**	0.025**
dVIX(-1)	-0.0006***	-0.0006***	-0.00067
	Tarch(1,0,1)	Tarch(1,0,1)	EGarch(1,0)
C(1)	4.23E-05	4.45E-05	-9.226***
C(2)	0.20***	0.21***	0.422****
C(3)	0.59**	0.57***	
R^2	0.100688	0.115	0.111
Akaike	-6.002251	-6.009857	-5.863674
Schwartz	-5.878846	-5.871026	-5.863674
Durbin-Watson	2.010549	2.017438	1.996340
Log likelihood	668.2476	670.0842	672.4786
Tarch(1.0.1): GARCH = C(6) + C(7)*RESID(-1)^2*(RESID(-1)<0) + C(8)*GARCH(-1) EGarch(1,0): LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1)))			

3.3. Filtered regression

We found above that the money multiplier was negatively related to the risk free rate before the crisis (consistent with the liquidity management version of the model), and that relationship became positive after the crisis (consistent with credit risk management version of the model). Now we test our basic hypotheses by HP-filtering the money multiplier and the 3-month T-bills rate. Then we regress the cyclical component of the money multiplier on the cyclical component of the T-bills rate.

Table 5. Cyclical regression

Dependent variable: Cyclical component of M1 money multiplier, m1_C Independent variable: Cyclical component of T-bills rate, Rf_C		
sample	March 1990- July 2008	January 2009-March 2016
m1_C(-1)	0.7738****	0.784****
Rf_C	-0.005***	0.110***
Variance equation		
EGarch (1,1)		
C(1)	-3.585**	-0.252***
C(2)	0.385****	-0.342****
C(3)	0.636****	0.936****
R^2	0.639	0.815
EGarch(1,1): LOG(GARCH)= C(1)+C(2)* ABS(RESID(-1)/SQRT(GARCH(-1)))+C(3)*log(Garch(-1))		

Table 5 shows that the volatility of the risk free rate is significant in explaining the volatility of the money multiplier. As before, the coefficient is negative and significant before the crisis and positive and significant after the crisis.

4. Discussion

In this paper we developed a simple model of bank behavior incorporating uncertainty as regards the profitability of the loan book and liquidity needs. The model appeared to connect with the US data highlighting a number of interesting results.

First, it predicts that the money multiplier is positively related to stock returns and negatively to stock volatility. Therefore stock market movements are an important consideration for monetary policymakers.

Second, the model emphasizing credit risk predicts that the money multiplier increases with the risk free rate. That is in stark contrast to the typical view based on the traditional model of liquidity risk management which our model nests. We tested that result empirically and found evidence of a positive relation between the money multiplier and the T-bills rate in the post crisis period. We also found that the relation was negative in the period 1990-2008. We conjecture that after the crisis, the liquidity constraint was significantly relaxed by various QE programmes. At the same time, credit risk became more important. That may explain the apparent change in the aggregate of banks' lending strategies, and therefore in the behaviour of the money multiplier.

If our conclusion is correct, an increase of the target Fed Funds rate, in combination with QE, may lead to an increase in the money multiplier and may not be followed by deflation.

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5. Appendix

5.1. Distribution of the liquidity shock

It may not only be the behaviour of interest rates that has changed post crisis. The distribution of the liquidity shock, measured as the change in checkable deposits, has changed behaviour. Figure 3 shows that for about 12 years before the crisis, the quantity of checkable deposits was stable. Surely related to QE, it started growing after the crisis.

Figure 3: Checkable deposits, billions of dollars

On Figure 4 we plot the percentage fall in checkable deposits over the previous 12 months conditional on it being positive. It can be seen that deposits have been growing since 2009 and that may indicate that the probability of a liquidity shock has been rather low since the crisis.

Figure 4. Liquidity shock (fall in the deposits)