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The missing spillover of base expansion into monetary aggregates: Is there a puzzle?

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A B S T R A C T

The seeming impotence of monetary base expansion to influence money growth during the global financial crisis and the European sovereign debt crisis, can be regarded as a puzzle. A possible explanation is that central banks have used unconventional monetary policies to pursue dual objectives: to stabilize the financial system and to stimulate the economy. While achieving the latter objective may result in a positive spillover of base money into money growth, this does not necessarily hold for the former objective. This paper aims to disentangle these effects by estimating a state space model in which the monetary base is adjusted for distortions arising from the instability in financial markets. We find that stress in money and bond markets, measured by various indicators, has significantly affected the relationship between base growth and money growth in the EA, but not in the US.

1. Introduction

A key assumption in the literature on the monetary transmission mechanism is that central banks control the monetary base and, through this, are able to influence the short-term nominal interest rate (Ireland, 2005). Orthodox models of the money supply process emphasize that the supply of base money constrains the development of the money supply, as the monetary base supports the amount of deposits in a fractional reserve banking system. Palley (1994) discusses competing approaches to the money supply process. In recent years, unconventional policy measures by major central banks have led to a strong increase in their balance sheets and in the monetary base, as central banks replaced short-term interest rates with asset purchases as their main policy instrument. This development has stimulated research into the transmission of central banks' balance sheet expansion to the economy.

A large and growing literature has documented the effects of unconventional monetary policy on financial markets. The surveys by Williams (2011), Cecioni et al. (2011), Joyce et al. (2012) and the IMF (2013) find that unconventional monetary policy has been successful in reducing yields and risk premia in financial markets. A recent paper by Gibson et al. (2016) shows that the ECB's asset purchase programs had a modest yet significant effect on sovereign spreads and covered bond prices. A more limited literature focuses on the macroeconomic effects. Gambacorta et al. (2014) find that the output effects of unconventional monetary policy are comparable to those of conventional changes in interest rates. Using a Qual VAR model, Meinusch and Tillmann (2016) find a modest effect of quantitative easing on economic activity. Other studies include Chung et al. (2012) and Lenza et al. (2012).

In estimating the macroeconomic effects, a major complication is that the crisis response of central banks was, certainly at the start of the global financial crisis, not solely geared towards stimulating economic growth, but also towards preventing an implosion of the financial system (Gambacorta et al., 2014). While achieving the latter objective may have avoided an even deeper recession, it

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may not by itself result in strong economic growth. Giannone et al. (2012) document how intermediation through the ECB's balance sheet replaced interbank transactions, when concerns about the solvency of counterparties rendered the financial markets dysfunctional. This substitution effect may have disrupted the relationships between the monetary base, monetary aggregates and other macroeconomic variables that one would expect to exist in normal times. Carpenter and Demiralp (2012) therefore point to the need to disentangle the endogenous response of central bank assets to the crisis from monetary policy actions aimed at macroeconomic objectives. These macroeconomic objectives may vary across central banks. For example, the Maastricht Treaty lays down price stability as the overriding objective of ECB policy. In contrast, the mandate of the Federal Reserve is more balanced between achieving price stability, economic growth and employment.

The multiple objectives of central bank intervention during the crisis may explain why the sharp increases in the monetary base have failed to spill over into broader monetary aggregates. ECB (2011) documents the sharp decline in money multipliers. Carpenter and Demiralp (2012) and Fawley and Neely (2013) point to the recent discrepancies between base growth and increases in financial intermediation. Van den End (2014) calls the impotence of base expansion to influence money growth a puzzle and attributes the breakdown of the money multiplier to the liquidity trap. At the zero lower bound, the low opportunity costs of holding liquidity may induce banks to hoard reserves instead of lending them out (Krugman, 1998). Note that this effect is unrelated to the effect of solvency concerns on central bank intermediation discussed in Giannone et al. (2012).

The puzzle of the missing spillover from base to money growth has renewed interest in the ways central banks and the banking system interact to create money. Since the demise of monetary targeting in the 1980s, the study of monetary aggregates has played a minor role in the macroeconomic research agenda. Empirical studies have had difficulty uncovering a stable demand for money function and a stable relationship between base money and broader monetary aggregates (Baghestani and Mott, 1997). In addition, Carpenter and Demiralp (2012) list institutional reasons why broader monetary aggregates may be unrelated to base money. They conclude that an increase in reserves is unlikely to trigger an increase in lending and that the textbook money multiplier does not offer any insights on the implications of monetary policy for money growth. Last but not least, the advent of Neo-Keynesian macroeconomic models has marginalized the role of money (Woodford, 2000; Svensson, 2008). However, Thornton (2014) questions the usefulness of Neo-Keynesian models in analysing the effectiveness of unconventional monetary policies, due to the absence of an explicit role for money.

The present paper aims to contribute to our understanding of the interaction between central banks and the banking system by incorporating measures of financial market stress in a model for the monetary base. We hypothesize that the monetary base may have been distorted during the global financial crisis and the European sovereign debt crisis, when central banks took over part of the intermediation that was previously channelled through the interbank markets. Incorporating measures of financial market stress may allow us to disentangle the immediate response of base money to the crisis from the relationship between base and money growth that would prevail in normal times.

This study juxtaposes the effect of base expansion on money growth in the United States (US) and the Euro Area (EA). This choice reflects differences in the design of unconventional monetary policies and is also inspired by Cukierman's (2014) observations on the different nature of monetary base expansion in these areas. Cukierman (2014) observes that prior to 2015, the ECB's bank reserves moved up and down with the liquidity needs of the banking system. This contrasts with the strong upward trend in US bank reserves induced by Federal Reserve policy, aimed at stimulating the economy.

The initial responses of the ECB and the Fed to the outbreak of the crisis were qualitatively similar. Both central banks acted to alleviate the short-term liquidity needs of a banking system in crisis. In both cases, this was done by cutting the policy rate and injecting liquidity in the interbank market. In 2009, however, the Fed started large-scale asset-purchasing aimed at achieving its macroeconomic objectives. In contrast, ECB policy remained geared towards stabilizing the EA banking system, which suffered both from the fallout of the subprime crisis and from the credit risk on peripheral sovereign debt. Aloy and Dufrénot (2015) provide a more detailed comparison of the Fed's and the ECB's strategies during the crisis.

A key distinction in understanding the responses of the ECB and the Fed is that, unlike the US, the EA experienced a second recession shortly after the Great Recession (Reichlin, 2014). Due to the (over)exposure of EA banks to peripheral public debt, the sovereign debt crisis further increased the risks to the banking system. Unlike the Fed, the ECB therefore continued to operate through the banking system, most notably through its Long-Term Refinancing Operations (LTRO). An important consideration for the ECB to focus on liquidity provision to the banking system has also been that, in contrast to the US, financial intermediation in the EA is dominated by banks (Reichlin, 2014). In 2015, as the EA only slowly recovered from the second recession and deflationary risks increased, especially in southern EA countries, the ECB finally embarked on an asset purchase program aimed at its macroeconomic objective. A major aim of this paper is to find out whether these differences in the course of the crisis and the monetary policy response between the US and the EA manifest themselves in the relationship between base money and monetary aggregates.

Our sample includes the global financial crisis and the European sovereign debt crisis and runs from January 2002 to June 2017. We employ a state space model for the monetary base that takes into account the non-stationarity of the base and that incorporates time-varying coefficients. The latter feature allows the model to identify if and when financial market stress has spilled over into the monetary base. We next extract the part of the monetary base that is unrelated to financial market stress and use regression analysis to estimate its relationship with narrow and broad monetary aggregates.

We find a marked difference between the US and the EA in the effect of the crisis on the spillover of base expansion into money. Indicators for financial stress are at times strongly related to the monetary base in the EA. For the EA, adjusting the base also restores the relationship between base growth and money growth. In contrast, no such effect can be discerned for the US. The next section describes the data and the methodology. Section 3 discusses the empirical results. We finally provide a number of conclusions.

2. Data and methodology

In a fractional reserve banking system, a narrow money definition (*M1*) is most likely to be closely related to the monetary base (Baghestani and Mott, 1997). In the practice of monetary policy making, however, broad monetary aggregates have played a more important role in recent decades. For example, in order to assess monetary developments, the ECB uses a reference value for *M3*-growth, not *M1*-growth. In contrast, the Fed has abandoned the publication of data for *M3*. In estimating the relationship between base and money growth, we will use both a narrow and a broad monetary aggregate. Monthly EA series for *M1* and *M3* and the monetary base (*MB*) are retrieved from the ECB's website. The corresponding data for the US are from the Board of Governors of the Federal Reserve System. As the US series for *M3* ends in 2006, we use *M2* instead. The monetary data have been seasonally adjusted using the *X-12* procedure. Log levels are denoted in lower-case letters (*mb, m1, m2* and *m3*). In order to account for the possible effect of the zero lower bound on money growth (Van den End, 2014), we include a short-term interest rate, measured by the 3-month London interbank rate (*is*).

As an indicator for money market stress, we include the spread between the interbank rate (LIBOR) and the risk free overnight indexed swap (OIS) rate (denoted *spread*). We use a euro and a dollar spread for respectively the EA and the US. The LIBOR-OIS spread is a closely watched indicator of distress in money markets and has been used in previous crisis research (Taylor and Williams, 2008; Reichlin, 2014; Cui et al., 2016). It can be argued, however, that this measure is affected by the unconventional monetary policies and by the huge drop in interbank lending since the start of the crisis (Taylor, 2016; Dutkowsky and VanHoose, 2017). These post-Lehman developments in policies and markets question whether the interbank rate is still operative. For this reason, we also include a composite measure of financial stress (denoted *fsi*). For the US, we use the Financial Stress Indicator published by the Federal Reserve Bank of St Louis, which is composed of a variety of interest rates, yield spreads and other indicators. For the EA, we take the Country Level Indicator of Financial Stress from the ECB. This measure incorporates information on yields and spreads, as well as information from the stock and currency markets (Duprey et al., 2017). We also collected bank credit default swap (CDS) indices from Thomson Reuters for both the US and the EA (denoted *bankcds*), which are available from 2004. As a CDS transfers the risk of bank default it reflect market perceptions of the soundness of financial institutions. In the empirical literature, bank CDS rates are commonly used as a proxy for bank stability (see e.g. Chiaramonte and Casu, 2013).

For the EA, we include a measure of sovereign risk. This choice reflects the strong interconnectedness of sovereign and banking risk. Since the start of the crisis, the 'diabolic loop' between banking and sovereign risk is increasingly viewed as a financial stability risk (Mody and Sandri, 2012; Acharya and Steffen, 2015; Acharya et al., 2014). Our measure of sovereign risk is the spread between the average 10-year bond yield of four distressed EA counties (Ireland, Italy, Portugal and Spain) and the yield on 10-year German bunds. This variable is denoted *sovspread*. We exclude Greece from *sovspread* as Greek bond yields at times have been extremely high and would unduly dominate our measure. In contrast to the EA, the creditworthiness of the US sovereign has not been in serious doubt during the crisis. Also, there are no concerns about the sovereign-bank nexus in the US. We therefore exclude this variable for the US. Except for estimates involving *bankscds*, the sample period starts in January 2002, coinciding with the introduction of euro banknotes and coins in the EA. The sample ends in June 2017.

Figs. 1 and 2 plot the monetary aggregates for respectively the EA and the US. All series are indexed to 100 in January 2002 (*not* in

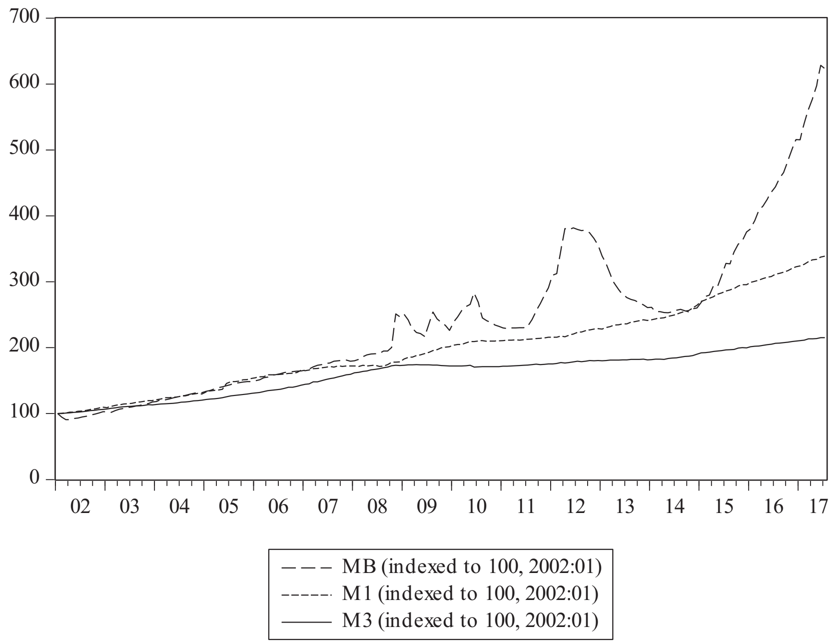


Fig. 1. Monetary aggregates, Euro area.

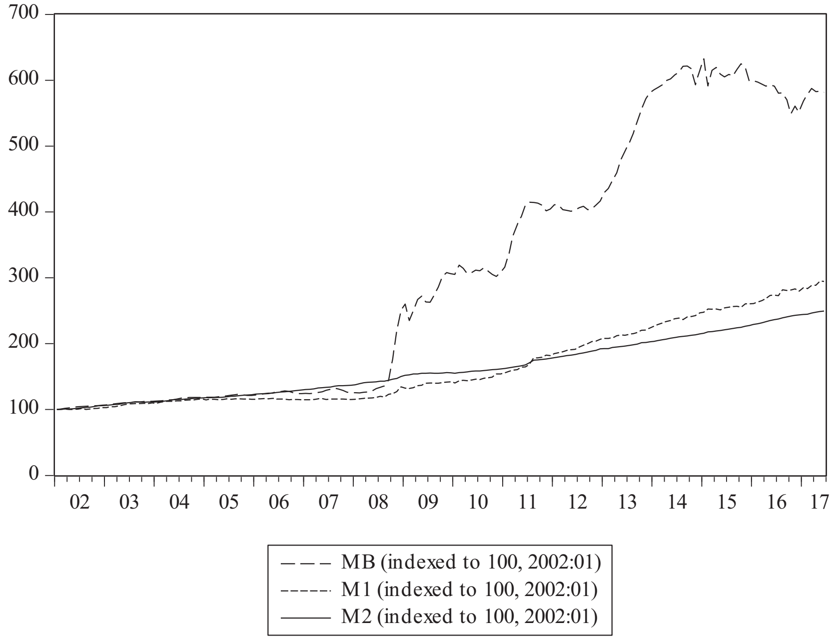


Fig. 2. Monetary aggregates, United States.

log scale). They show the effect of unconventional monetary policies on the development of the monetary base and the lack of responsiveness to this in the monetary aggregates. The figures also show a marked difference in *MB* between the EA and the US. In the US a series of three strong surges (in 2008, 2011 and 2013) characterizes *MB*. In contrast, EA *MB* is hump-shaped between 2010 and 2014, reflecting the uptake and redemption of LTRO lending in 2012. From 2015 we can see the upsurge in *MB* following the start of the ECB's asset purchasing program. By that time *MB* in the US has levelled off.

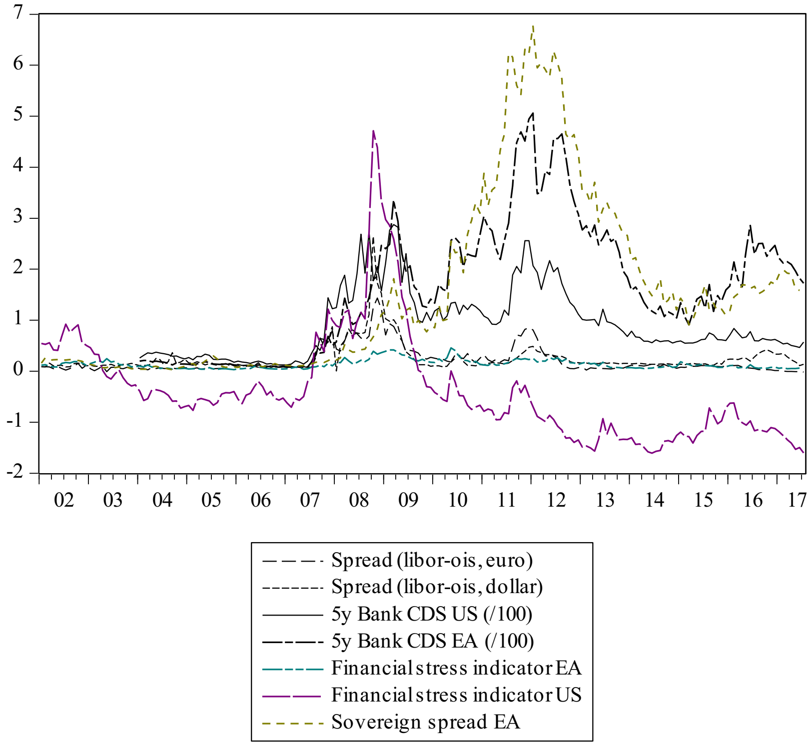


Fig. 3. Stress indicators.

Table 1
Descriptive statistics.

	2002–2007		2008–2017	
	μ	σ	μ	σ
Euro area				
dmb	0.94	1.53	1.10	3.84
dm1	0.76	0.89	0.59	0.55
dm3	0.65	0.35	0.26	0.40
spread	0.11	0.14	0.27	0.30
sovspread	0.13	0.07	2.40	1.72
fsi	0.09	0.05	0.16	0.10
bankcds (/100)	0.17	0.11	2.24	1.01
United States				
dmb	0.33	0.68	1.35	3.82
dm1	0.20	0.60	0.82	1.13
dm2	0.44	0.29	0.53	0.38
spread	0.16	0.13	0.32	0.36
Fsi	−0.14	0.53	−0.49	1.27
bankcds (/100)	0.30	0.24	1.18	0.62

Note: bankcds starts in 2004.

Fig. 3 plots the financial stress indicators used in this paper. Two periods of financial unrest can be discerned. In late 2008, when money markets froze at the height of the global financial crisis, Libor-OIS spreads and the US financial stress indicator peak. In the period 2011–2012, when the sovereign debt crisis called into question the viability of the monetary union, the sovereign spread and the bank CDS rates peak. The EA financial stress indicator also peaks in May 2010, when the Greek crisis manifested itself.

Table 1 reports the means and standard deviations for the growth rates of the monetary variables and the stress indicators. The descriptive statistics are split into a pre-crisis period (running from January 2002 to December 2007) and a period including the crisis (starting on January 2008). A few observations on Table 1 can be made. First, the growth rate of EA monetary aggregates has been lower during than before the crisis. Weak money growth during a recession is in itself unsurprising, as a slowdown in economic activity may put a break on credit and money creation. However, the small increase in *MB*-growth (from 0.94 to 1.10) suggests that the monetary policy stance of the ECB has not been overly accommodative. In contrast, US base growth has increased fourfold following the start of the crisis. *M1*-growth also increased strongly in the US. Second, both in the EA and the US, the volatility of *MB*-growth has increased sharply since 2008, reflecting the more active balance sheet management of central banks. However, the volatility of the other monetary aggregates has remained on the pre-crisis level, except for *M1* in the US. Finally, the crisis is reflected in higher means and standard deviations of most financial market stress indicators, as one would expect. An exception is the US financial stress indicator. After peaking in 2008–2009, it has declined to such an extent that the pre-crisis average is higher than the average during the period 2008–2017.

Fig. 3 suggests the presence of a multicollinearity issue among the stress indicators. Table 2 therefore reports the corresponding correlation coefficients. The high correlation between *sovspread* and *bankcds* in the EA is symptomatic of the 'diabolic loop' between banking and sovereign risk. In addition to the severe multicollinearity problem, our series for *sovspread* is longer. We have therefore decided to drop EA *bankcds* from the model. Table 2 also shows high correlation coefficients between *spread* and *fsi*, both for the US and the EA. For this reason, we will estimate separate models using either one of these variables.

Next, we determine the order of integration of our variables. As the limited time span may result in low power of conventional unit root tests, Table 3 reports statistics for both the ADF, PP and KPSS tests. The test results indicate that the log levels of monetary

Table 2
Correlation across stress indicators.

Euro area			
	sovspread	*fsi*	*bankcds*
spread	0.15	0.70	0.30
sovspread		0.36	0.91
fsi			0.55
United States			
spread		0.83	0.56
fsi			0.52

Note: bankcds starts in 2004.

Table 3
Unit root tests.

	ADF	*p*-value	PP	*p*-value	KPSS
Euro area					
mb	0.22	.97	0.15	.78	1.67***
m1	−0.47	.89	−0.45	.90	1.62***
m3	−1.22	.67	−2.27	.18	1.53***
is	−1.48	.54	−1.21	.67	1.10***
spread	−2.38	.15	−2.56	.10	0.25
fsi	−3.00	.04**	−2.85	.05**	0.23
sovspread	−1.27	.64	−1.39	.59	0.71**
United States					
mb	−0.55	.88	−0.57	.87	1.58***
m1	0.76	.99	1.80	.00	1.59***
m2	0.49	.99	0.50	.99	1.65***
is	−1.03	.74	−1.17	.69	0.67**
spread	−3.79	.00***	−3.62	.01***	0.14
fsi	−2.37	.15	−2.10	.24	0.61**
bankcds	−1.91	.33	−2.28	.18	0.30

Note: Significance levels are indicated as follows: 0.10 (*), 0.05 (**), 0.01 (***).

Table 4
State space estimates.

	Euro area		*United States*	
	Model 1	Model 2	Model 1	Model 2
$\sigma_{\varepsilon 1}$	0.0147	0.0137	0.0226	0.0233
$\sigma_{\varepsilon 3}$	0.0608	0.1237	0.0437	0.0134
$\sigma_{\varepsilon 4}$	0.0083	0.0062	0.0000	0.0000

aggregates are non-stationary, i.e. integrated of order (1). The same holds for *is, sovspread* and for the US *fsi.* The ADF and PP statistics indicate that the EA *spread*, the EA *fsi* and the US *bankcds* are non-stationary, while the KPSS test leads to the opposite conclusion. All tests indicate stationarity for the US *spread* and the EA *fsi*.

In order to disentangle the effect of central banks' efforts to stabilize the financial system from efforts to stimulate economic growth and/or inflation on the monetary base, we estimate a state space model. Our model can cope with the non-stationarity of the

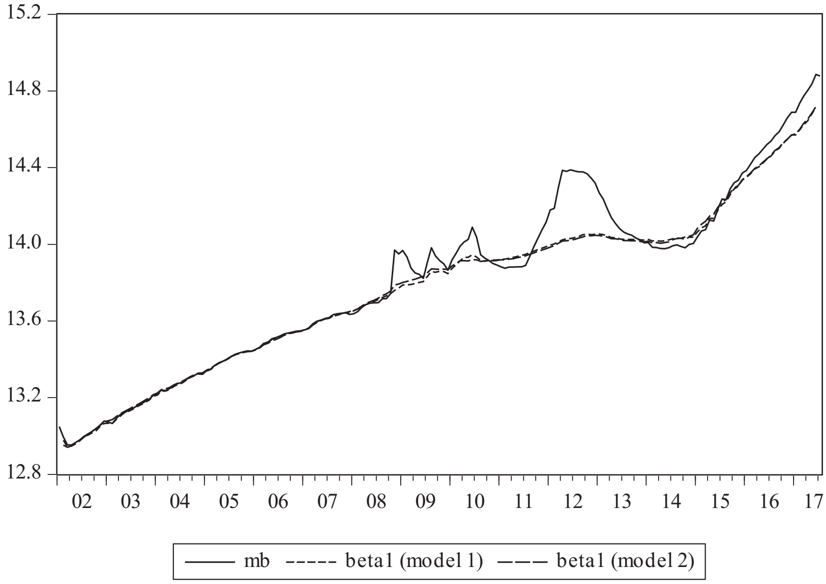
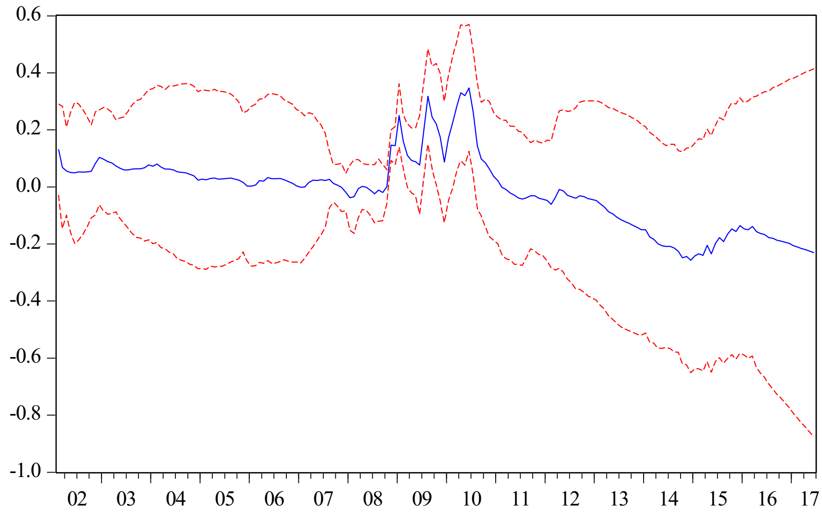
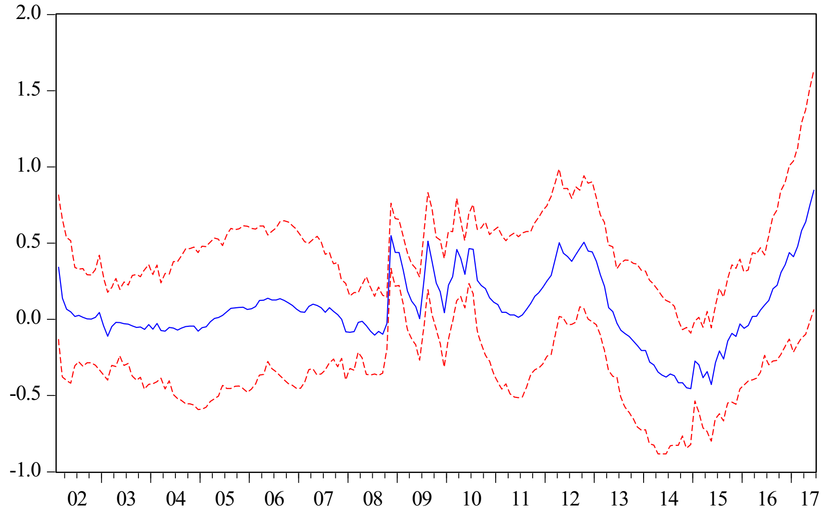


Fig. 4. β_1 versus *mb*, Euro area.



A: Model 1



B: Model 2

Fig. 5. β_3, Euro area.

monetary aggregates and incorporates time-variation in the relationship between financial stress variables and the monetary base. The model will include two stress indicators per estimation, reflecting the different nature of the two crises (at least in the EA) and the correlation coefficients in Table 2. The model is in Eqs. (1)–(4):

$$mb_t = \beta_{1t} + \beta_{3t} si_{1t} + \beta_{4t} si_{i2} \tag{1}$$

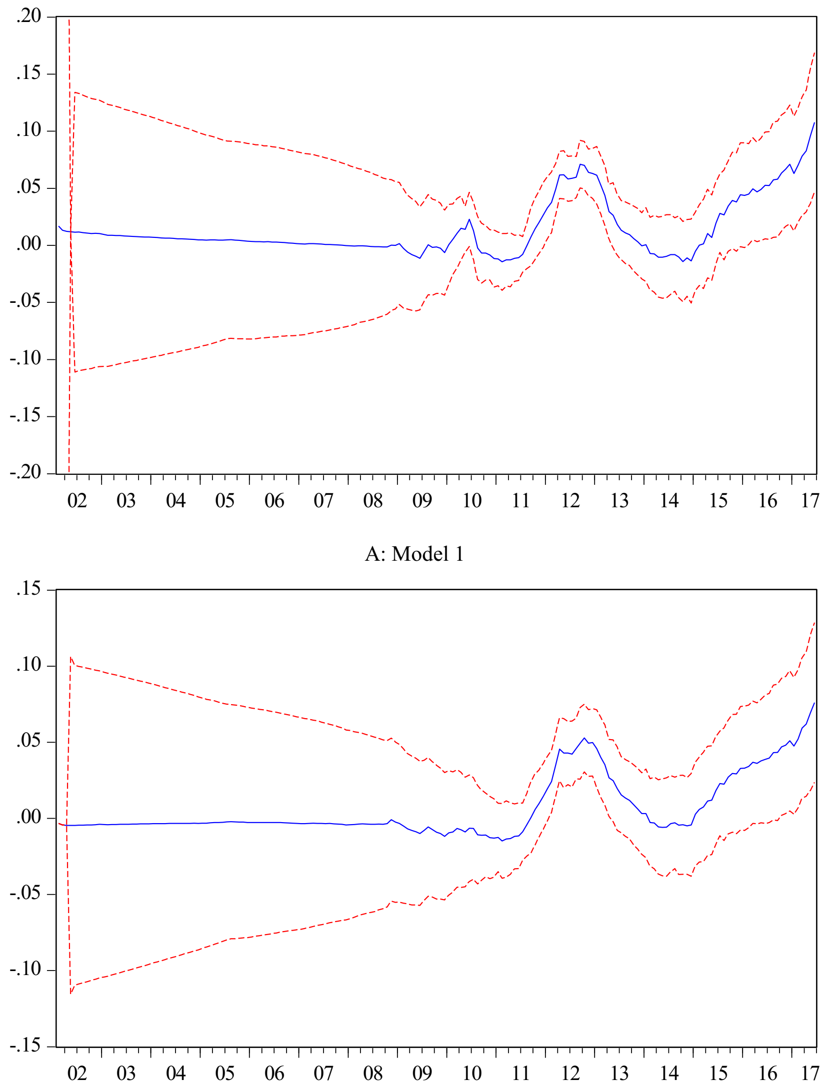
$$\beta_{1t} = \beta_{1t-1} + \beta_2 + \varepsilon_{1t} \qquad \varepsilon_{1t} \sim idd\, N(0, \sigma_1^2) \tag{2}$$

$$\beta_{3t} = \beta_{3t-1} + \varepsilon_{3t} \qquad \varepsilon_{3t} \sim idd\, N(0, \sigma_3^2) \tag{3}$$

$$\beta_{4t} = \beta_{4t-1} + \varepsilon_{4t} \qquad \varepsilon_{4t} \sim idd\, N(0, \sigma_4^2), \tag{4}$$

where subscript t denotes time. In (1)–(4), the monetary base (mb_t) is modelled using a local level model with constant drift. The level is represented by the state variable β_{1t}, which is modelled as a random walk with constant trend β_2 and disturbance ε_{1t}, see (2). The coefficients β_{3t} and β_{4t} serve to capture time-dependent effects of stress indicators si_{1t} and si_{2t} on the monetary base. Both coefficients are modelled as a random walk with disturbances ε_{3t} and ε_{4t}, see (3) and (4). We have experimented with including a temporary disturbance to the level of mb_t and a random walk specification for β_2 (local linear trend model), but in both cases the variance of the disturbances was close to zero and insignificant. For the EA, we estimate the following two specifications. In model 1, si_{1t} is *spread* and si_{2t} is *sovspread*. In model 2, si_{1t} is *fsi* and si_{2t} is again *sovspread*. We estimate the same specifications for the US, except that *sovspread* is replaced by US *bankcds*. This implies that the US estimates use a somewhat shorter sample period, as our *bankcds* series starts in 2004.

The model in (1)–(4) can be represented in state space form. Combined with Kalman filter estimation, state space modelling offers a convenient tool to work with unobservable variables. The methodology has become widespread in macroeconomics and finance. Harvey (1989), Shumway and Stoffer (2000), among others, offer an introduction to state space modelling. In a survey of potential estimation strategies for time varying parameter models, Neumann (2003) concludes that the state space model with a random walk specification for the time varying parameter generally performs very well. State space models make a distinction between a measurement and a transition equation. The measurement equation describes the observed variable(s) in terms of unobserved state variables, observed explanatory variables and disturbances. In the model above, Eq. (1) represents the measurement equation. The transition equations describe the evolution of the unobserved state variables over time. In our model, Eqs. (2)–(4) are the transition equations. The innovations in the transition equations are independent and identically distributed random variables with respectively variances $\sigma^2_{\varepsilon 1}$, $\sigma^2_{\varepsilon 3}$ and $\sigma^2_{\varepsilon 4}$. Estimation of the parameters is done by maximizing the Likelihood-function using the Broyden–-Fletcher–Goldfarb–Shanno optimization method. The Kalman filter produces smoothed estimates of the state variable β_{1t}, β_{3t} and β_{4t}.



A: Model 1

B: Model 2

Fig. 6. β_4, Euro area.

Our prime interest is in β_{1t}, which captures the development in the monetary base unrelated to financial market stress. We compare the relationship between the growth in β_{1t} and money growth with the relationship between base and money growth. To this end we use the following regression model, which is a first-difference version of a conventional money supply equation (see e.g. McCallum, 1989):

$$dm_{i,t} = b_0 + b_1\, dmb_t + b_2\, d(is)_t + \varepsilon_t \tag{5}$$

$$dm_{i,t} = b_0 + b_1\, d(\beta_{1t}) + b_2\, d(is)_t + \varepsilon_t, \tag{6}$$

where subscript t denotes time and dm_{it} denotes the growth in monetary aggregate i. As in McCallum (1989), we include an interest rate, which is measured by the 3-month interbank rate (*is*). In times of financial stress, base expansion may help to stabilize the banking system as the central bank takes over the function of the money market. But this may not result in higher money growth. If our state space model is able to correct for this effect, we hypothesize that the b_1 coefficient is higher and more significant in (6) than in (5). As Eq. (6) includes a generated regressor, we bootstrap the coefficient standard errors. As a further robustness check, we also estimate the regression models including the lagged dependent variable.

3. Empirical results

Table 4 reports the estimates for the standard deviations of the disturbances in the state space model. For the US, there is no time variation in coefficient β_4. Also, β_4 is insignificant for both US models (with p-values of respectively 0.619 and 0.547), suggesting that US *bankcds* is not a useful variable to explain developments in US base growth. A possible explanation for this is that, while US *bankcds* did react to the European sovereign debt crisis (see Fig. 3), US base growth did not.

Figs. 4–6 plot the smoothed estimates of the EA state variables for models 1 and 2. Combining β_1 and *mb* in Fig. 4 shows that the hump-shaped pattern in *mb* arising from the ECB's LTRO-lending in 2012 is absent from β_1 (for both models). The same holds for the smaller temporary increases in *mb* in the period 2008–2010. This suggests that these increases can be attributed to financial market stress. In contrast, the upsurge in *mb* at the end of the sample period, which is related to start of the ECB's asset purchase program in 2015, is mimicked to a large extent by an increase in β_1 (again for both models). Further evidence on the influence of financial market stress on *mb* in the EA is in Figs. 5 and 6, which plot the time-varying coefficients of the stress indicators together with their 95% confidence intervals. It can be seen that β_3 turns significant mostly during the period 2008–2010, whereas β_4 turns significant in 2012. The graphs for model 1 (Figs. 5A and 6A) and model 2 (Figs. 5B and 6B) are quite similar, suggesting that our finding cannot be attributed to the choice for a specific stress indicator.

Figs. 7 and 8 show the corresponding results for the US. Compared to the EA, the difference between β_1 (for both models) and *mb* is smaller and the time-varying coefficient of the stress indicator (*spread* or *fsi*) turns significant for a shorter duration. These results indicate that our financial stress variables are better able to explain developments in the monetary base in the EA than in the US.

Finally, Table 5 reports the results of the regression model in (5) and (6). These show that the interaction between base expansion and financial market stress has a marked effect on the relationship between the monetary base and monetary aggregates in the EA, but not in the US. For *dm1* in the EA, the estimate of b_1 is small (0.004) and insignificant, but rises to 0.1118 (significant at a 5% level)

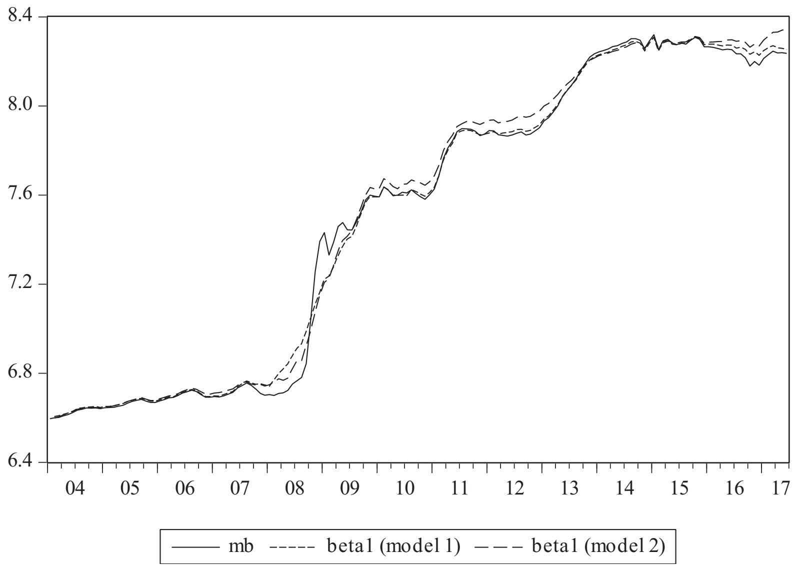


Fig. 7. β_1 versus *mb*, United States.

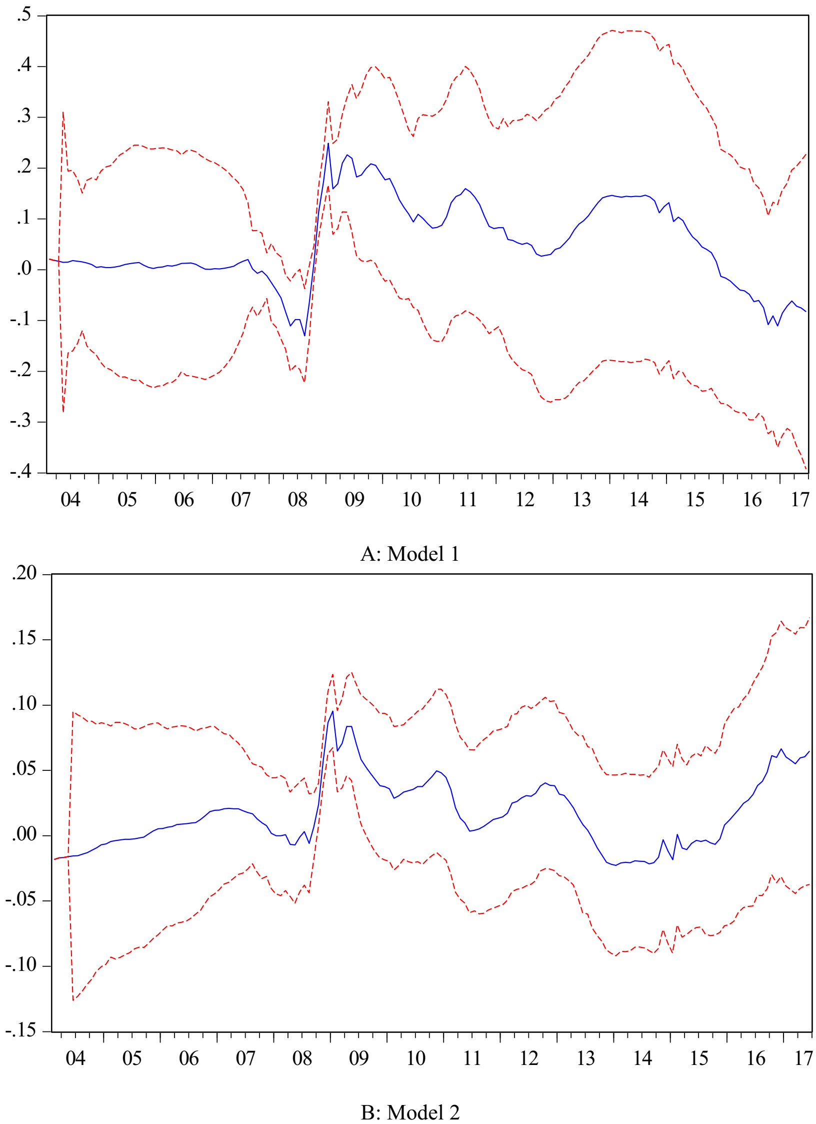


Fig. 8. β_3, United States.

once we replace *dmb* with $d(\beta_1)$ from model 1. The b_1 estimate using $d(\beta_1)$ from model 2 is very similar (0.1183). The adjusted R-squared increases from 0.4–1.4% to 2.5–5.3%, indicating that filtering out the effect of financial stress on the monetary base helps to repair the relationship between base and money growth in the EA. In contrast, for the US the coefficients of *dmb* and $d(\beta_1)$ are of a similar magnitude and the use of the adjusted base does little to increase the explanatory power of the model. The b_1 coefficient is more significant when we use *dmb* instead of $d(\beta_1)$ (this applies to both models). In general, the b_1 estimates are higher for narrow than for broad monetary aggregates, confirming that in a fractional reserve banking system, *M1* is most closely related to the monetary base and base expansion has a more limited effect on broad aggregates (Van den End, 2014). Nevertheless, the b_1 estimates are still low compared to the one-to-one relationship between base and monetary growth that one would expect with a stable money multiplier. In all regressions, the change in the interest rate is insignificant at a 5% level. Finally, compared to the narrow monetary aggregates, the regressions involving the broad monetary aggregates report much lower Durbin-Watson statistics.

As a robustness check, Table 6 reports estimates including the lagged dependent variable. This leads to an improvement in the Durbin-Watson statistics for the regressions using the broad monetary aggregates. For the narrow monetary aggregates, the lagged dependent variable is always insignificant at a 5% level and the conclusions from Table 5 do not change. For the broad monetary aggregates, the lagged dependent variable is highly significant in the EA but less so in the US. Compared to Table 5, the *b1* coefficient for EA model 1 now turns insignificant, but not for model 2. The US results remain similar. Overall, the explanatory power of the regression models remain low, indicating that the relationship between base growth and money growth is weak at best.

Table 5
First differences regressions.

	Dependent variable: *dm1*						Dependent variable: *dm3* (EA) / *dm2* (US)					
	Base growth		model 1		model 2		Base growth		model 1		model 2	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Euro area												
intercept	0.0064	0.0005***	0.0054	0.0006***	0.0053	0.0006***	0.0041	0.0003***	0.0037	0.0004***	0.0032	0.0004***
dmb	0.0040	0.0169					0.0127	0.0102				
d(β_1)			0.1118	0.0343***	0.1183	0.0451***			0.0533	0.0286*	0.1073	0.0339***
d(is)	−0.0055	0.0036	−0.0049	0.0048	−0.0048	0.0051	0.0043	0.0022**	0.0040	0.0022*	0.0044	0.0021**
Adj. R2	0.0037		0.0301		0.0247		0.0135		0.0219		0.0532	
DW	1.90		1.96		1.97		1.52		1.55		1.61	
N	186		186		186		186		186		186	
United States												
intercept	0.0050	0.0007***	0.0051	0.0009***	0.0046	0.0009***	0.0047	0.0003***	0.0047	0.0000***	0.0047	0.0003***
dmb	0.0872	0.2380***					0.0251	0.0085***				
d(β_1)			0.0994	0.0547*	0.1409	0.0601**			0.0249	0.0180	0.0321	0.0213
d(is)	−0.0040	0.0035	−0.0052	0.0052	−0.0040	0.0048	−0.0006	0.0012	−0.0007	0.0020	−0.0005	0.0020
Adj. R2	0.0767		0.0443		0.0769		0.0425		0.0130		0.0251	
DW	2.34		2.24		2.25		1.54		1.52		1.51	
N	186		160		160		186		160		160	

Note: due to the limited availability of bank CDS data, the US sample involving $d(\beta_1)$ starts in 2004 instead of 2002. Significance levels are indicated as follows: 0.10 (*), 0.05 (**), 0.01 (***).

4. Conclusions

Since the start of the global financial crisis, policymakers have been concerned that the monetary base expansion resulting from the implementation of unconventional monetary policy measures would insufficiently spill over into the wider economy. In the EA, these concerns seem to be validated by the complete absence of a bivariate relationship between base and money growth. But also in the US, the relationship has been weak at best, as the huge surges in base money during the crisis seem to have had just a modest effect on monetary aggregates. Some authors regard the missing spillover of base expansion into money as a puzzle.

In this paper we argue that any analysis of the link between money and the monetary base should take into account the multiple objectives of central banks' policies during the crisis. The unprecedented expansion of their balance sheets was not only aimed at stimulating economic growth and/or inflation, but also at stabilizing a weak financial system. Liquidity provision that was geared towards the latter objective may have prevented an implosion of the money supply, similar to the one that the US witnessed during the Great Depression. When dysfunctional financial markets lead to a substitution of interbank transactions by central bank intermediation, the monetary base may expand without a corresponding surge in monetary or credit aggregates.

To our knowledge, this paper provides the first attempt to disentangle the response of base money to the financial crisis from monetary policy actions aimed at stimulating economic growth. To this end, we employ a state space model for the monetary base that incorporates time-varying coefficients. This feature allows the model to identify when financial market stress has spilled over into the monetary base. After extracting the part of the monetary base that is unrelated to financial market stress, we estimate the relationship with narrow and broad monetary aggregates using regression analysis. Our main finding is that financial market stress, measured by a variety of stress indicators, has significantly distorted the relationship between base and money growth in the EA. This conclusion holds for both *M1* and *M3*. In contrast, we find no evidence for a similar effect in the US. These findings lend empirical support to the observation by Cukierman (2014), that changes in the balance sheet of the ECB in the period 2008–2014 have been determined predominantly by the liquidity needs of banks, whereas the strong growth in the Federal Reserve's balance sheet seems to result from Federal Reserve policy aimed at stimulating the macro-economy. This difference has disappeared with the advent of the ECB's asset purchase program in 2015 aimed at reflating the EA economy. This led to an upsurge in the EA monetary base unrelated to financial market stress. The strong effect of financial stress on EA base growth can thus be understood as arising from the EA banking system's exposure to both the global financial crisis and the sovereign debt crisis and the ECB's overriding priority to maintain the stability of the financial system during a multi-year period (Reichlin, 2014). This contrasts with the Fed's relatively early switch from its financial stability objective to its macroeconomic objective, which may explain why adjusting the monetary base for financial stress has no effect in the US.

Our findings imply that we are partly able to solve the puzzle of the missing spillover. For the EA, we have shown that movements in the monetary base were not just a monetary phenomenon, but also strongly related to financial market stress. Adjusting the EA monetary base restores the relationship with monetary aggregates and thus solves the puzzle of the complete absence of a link between base money and monetary aggregates. However, as the explanatory power of the money supply regressions remains low, we also have to conclude that the effect of US base growth and EA adjusted base growth on monetary aggregates remains modest.

Table 6
First differences regressions, including lagged dependent variable.

	Dependent variable: *dm1*						Dependent variable: *dm3* (EA) / *dm2* (US)					
	Base growth		model 1		model 2		Base growth		model 1		model 2	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Euro area												
intercept	0.0061	0.0007***	0.0053	0.0007***	0.0052	0.0007***	0.0031	0.0004***	0.0029	0.0004***	0.0025	0.0004***
dmb	0.0026	0.0170					0.0027	0.0103				
d(β_1)			0.1085	0.0352***	0.1139	0.0460**			0.0313	0.0264	0.0780	0.0325**
dm(-1)	0.0563	0.0744	0.0320	0.0808	0.0267	0.0817	0.2693	0.0733***	0.2606	0.0709***	0.2360	0.0719***
d(is)	−0.0052	0.0036	−0.0047	0.0050	0.0267	0.0817	0.0034	0.0021	0.0035	0.0021	0.0039	0.0020*
Adjusted R-squared	0.0014		0.0257		0.0199		0.0765		0.0826		0.1009	
DW	2.01		2.02		2.02		2.17		2.18		2.17	
N	186		186		186		186		186		186	
United States												
intercept	0.0056	0.0008***	0.0056	0.0010***	0.0051	0.0010***	0.0034	0.0004***	0.0034	0.0007***	0.0033	0.0007***
dmb	0.0961	0.0242***					0.0235	0.0082***				
d(β_1)			0.1062	0.0533**	0.1502	0.0578**			0.0243	0.0176	0.0319	0.0208
dm(-1)	−0.1281	0.0720*	−0.0940	0.1110	−0.1100	0.1077	0.2552	0.0704***	0.2641	0.1394*	0.2649	0.1383*
d(is)	−0.0041	0.0035	−0.0053	0.0047	−0.0041	0.0042	0.0000	0.0012	0.0000	0.0020	0.0001	0.0019
Adjusted R-squared	0.0876		0.0470		0.0830		0.1020		0.0759		0.0886	
DW	2.07		2.04		2.02		2.07		2.07		2.05	
N	186		160		160		186		160		160	

Note: due to the limited availability of bank CDS data, the US sample involving *d*(β_1) starts in 2004 instead of 2002. Significance levels are indicated as follows: 0.10 (*), 0.05 (**), 0.01 (***).

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