The Liquidity Effect in the Federal Funds Market: Evidence at the Monthly Frequency

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Abstract

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1. **Introduction**

Economists often consider the first step in the transmission mechanism of monetary policy to be a shift in the “money supply” that changes interest rates. Some authors (for example, Leeper and Gordon 1992, Reichenstein 1987) have failed to find a negative relationship between some measures of money and some interest rates, dubbing this failure a “liquidity puzzle.” Other researchers (e.g. Bernanke and Mihov 1998a, 1998b, Strongin 1995, Christiano, Eichenbaum, Evans 1996, Leeper, Sims, Zha 1996) document a liquidity effect and argue that the liquidity puzzle is a result of econometric identification problems. In this paper, we show that identification of the liquidity effect can be achieved through a proper understanding of the money and interest rate involved.

The interest rate used as a policy instrument in the United States is the federal funds rate. A major reason for a lack of consensus on the liquidity effect is that the literature’s understanding of the institutional structure of the federal funds market is flawed. The federal funds market is the market for balances held at the Federal Reserve. Some research listed above looked at broad measures of money, M1 or M2, while others looked at narrower measures, such as the monetary base, nonborrowed, borrowed, or total reserves. As we will discuss below, none of these measures is the level of balances at the Federal Reserve and thus none is an appropriate specification. In some cases, the distinction is minor, in others it is significant. As will be clear in the empirical section, prior to the early 1990s the distinction between reserves and balances was not significant, but later became important. In this paper, therefore, we explain the relevant details of the demand for and supply of balances at the Federal Reserve and the consequent determination of the funds rate itself. In so doing, we are able to document a low-frequency liquidity effect that is relevant for the initial stage of the transmission of monetary policy.

With regards to the previous literature, we show that by estimating some of the same models over a recent sample period, we can document a liquidity puzzle and the various econometric "cures" do not resolve the liquidity puzzle over time. Our results are not consistently at odds with the previous literature, however. When the difference between balances and reserves was small, our results are similar to the previous literature. However, we demonstrate that using the balances, the funds that are actually traded in the federal funds market, one can identify a liquidity effect for the recent sample period. The liquidity puzzle is no puzzle at all, merely a misspecification. Previous studies that have focused on reserves instead of balances have excluded a crucial component of the fed funds market. Specifically, we note that Fed balances can be broken down into three categories, required reserve balances, excess balances, and contractual clearing balances, and this last category is not included in measures of reserves. Each component of balances has its own demand relative to the funds rate, which we can estimate separately. This observation helps to define the liquidity effect in this context.

One conception of the effect is that it is the inverse of the elasticity of demand for money with respect to interest rates. That is to say, how much do interest rates move if the money supply is changed. We find this interpretation to be backward, in that the Federal Reserve has an interest rate target that it is consistently able to achieve. In so doing, the Federal Reserve supplies balances perfectly elastically at the target rate. As a result, because the FOMC sets the target rate without concern for reserves market conditions, the appropriate (and analytically equivalent) interpretation of the liquidity effect is the change in balances that result from a change in the target rate.

At a daily frequency, Hamilton (1997) and Carpenter and Demiralp (2006, a) document a liquidity effect in the federal funds market. These results are a product of correctly linking the federal funds rate with Federal Reserve balances. As we discuss below, the daily-frequency estimates of the liquidity effect suggest that a much larger change in balances is needed to change interest rates than suggested by the monthly-frequency estimates. Again, the institutional structure of the market explains why these seemingly contrasting results are in fact consistent. At a daily frequency, the funds rate is in large part determined by expectations about where funds will be trading, typically at the target rate. Larger and unanticipated changes in the level of balances are necessary to cause changes in the funds rate (see Carpenter and Demiralp (2006 a,b)).

At a lower frequency, such as that studied here, the driving variables that affect demand—notably requirements for balances held—adjust, and the result is that changes in the funds rate are associated with smaller changes in balances. In fact, using the estimates from the daily-frequency studies of the liquidity effect to infer the change in balances necessary for even a 25-basis-point change in the funds rate would lead to implausibly large open market operations. Put differently, in the long run, all variables can adjust, so the elasticity of demand for balances with respect to price is smaller. It is precisely this long-run reaction of the level of balances that we are studying here. This elasticity is a reflection of the long-run demand curve for balances with respect to the funds rate.

Some of the previous literature, for example, Bernanke and Mihov (1998a) and Christiano, Eichenbaum, and Evans (1996), has focused on using different interpretations of the policy instrument to identify the liquidity effect. For our sample period of the 1990s, the federal funds rate is the monetary policy instrument.[ii] As a result, the current paper bridges the two literatures. We examine the federal funds market like Hamilton and Carpenter and Demiralp, but do so at a frequency of more relevance for macroeconomic empirical research.

In the next section, we discuss balances of depository institutions at the Federal Reserve and focus on the motivation for holding these balances as a means of describing the demand function, and how that demand relates directly to the federal funds rate. In Section 3, we present simple regression results to document the existence of the liquidity effect for excess and contractual clearing balances at a monthly frequency, but the lack of a clear liquidity effect for required reserve balances. To acknowledge the dynamic aspect of these demand relationships, sections 4 and 5 put our results in the context of a vector autoregression (VAR), highlighting the dependence of required reserves on reservable deposits. We show that previous oversight of the appropriate definition of balances has lead to the observed inconsistent results. Section 6 concludes.

2. Federal Reserve Balances

Figure 1 presents data on the level of Federal Reserve balances from 1989 to 2005. The level of total balances has fluctuated somewhat over the past fifteen years, but there has been an even more dramatic shift in the composition of the total. Balances at the Federal Reserve can be broken down into three components: required reserve balances, contractual clearing balances, and excess balances. We stress that the sum of these components, that is to say total balances, is the measure of money that is relevant for studying the liquidity effect relative to the federal funds rate.

Depository institutions are required by the Federal Reserve to hold in reserve a quantity of funds that is related to the quantity of their customers' deposits.[iii] Currently, only transaction accounts (essentially demand deposits and other checkable deposits) have a required reserve ratio that is greater than zero. Banks' reserve requirements can be fulfilled by holding vault cash, and any level of required reserves that is not met with vault cash must be met with balances on deposit at the Federal Reserve. These balances are referred to as required reserve balances. Required reserves include *both* vault cash used to meet requirements and required reserve balances. Currently, required reserves are a little over $40 billion, with vault cash accounting for a touch over $30 billion. The difference of roughly $10 billion recently is the level of required reserve *balances*. This accounting illustrates the difference between balances—which are traded in the fed funds market—and reserves—which are not.

Banks' reservable deposits are calculated by computing the daily average of customers' checking accounts over a two-week computation period. Based on this two-week average, a formula determines the banks' reserve requirements from the level of checking deposits. A similar two-week average is made for vault cash that is to be applied to reserve requirements. Required reserve balances must be held on a daily-average basis over a two-week maintenance period that begins 17 days after the end of the computation period. Until 1998, however, reserve accounting was contemporaneous, and the computation period overlapped with the maintenance period. Only during the last two days of the maintenance period were reserve requirements known with certainty.

Given the determination of required reserves, the contemporaneous level of interest rates, whether the federal funds rate or some other interest rate, cannot have a direct effect on this magnitude. The level of reserve requirements and the level of vault cash are determined in advance of the maintenance period in which the required reserve balances need to be held. As such, the interest rate in that period cannot change the level of balances. If interest rates were to have an effect on required reserve balances, the mechanism would necessarily have to incorporate a lag and would have to affect banks' reservable deposits first. Consider the following scenario. The FOMC increases the federal funds rate target, and short-term interest rates rise. Demand deposits at commercial banks do not pay interest and interest rates on checkable deposits at thrift institutions follow market rates but tend to adjust slowly. The opportunity cost of holding reservable deposits, therefore, begins to rise as other money market rates adjust more quickly following the new funds rate target. Households economize on their holdings of checking deposits, again, perhaps with some lag. Consequently, reservable deposits fall, but possibly not until the next or subsequent computation period. Two weeks after reservable deposits have fallen, during the corresponding maintenance period, required reserve balances will decline, even if interest rates have stopped rising. In contrast to previous research, where the emphasis is on a short-run or contemporaneous relationship between money and interest rates, this discussion of the determination of required reserve balances points out that the relationship may lag, perhaps even by months.

It is also conceivable that interest rates could affect currency demand and thus the level of cash that banks hold in their vaults. We think that this effect, however, is negligible because banks choose a level of currency based on customer needs, which are rather inelastic with respect to interest rates. Nonetheless, the effect of this change in currency demand would be to partly offset the effect on required reserve balances. As vault cash declines, the amount of reserve requirements that must be satisfied with required reserve balances goes up. Consequently, the net change in required reserve balances resulting from a change in interest rates is indeterminate. To summarize, there ought to be no contemporaneous effect of interest rates on required reserve balances, but a lagged effect is plausible. Even so, it is possible that the lagged effect is muted by the offsetting effects of reservable deposits and vault cash.[iv]

Contractual clearing balances were established in 1980 with the Monetary Control Act as an effort to make Federal Reserve services more available to banks with low or zero reserve requirements and as a way to increase the level of balances in banks' Fed accounts to reduce the likelihood of overdrafts. As can be seen in Figure 1, the level of contractual clearing balances—and its proportion of total balances—has been rising, on average, through time. Unlike other balances on deposit at the Federal Reserve, contractual clearing balances pay implicit interest in the form of earnings credits that can be used to pay for services provided by the Fed—such as check clearing. Few banks held these balances until the early 1990s when reserve requirements for checking accounts were reduced and retail sweep activity began in large amounts. At that point, many banks discovered that the level of balances they wanted to hold were greater than the quantity they were required to hold. Thus, instead of holding excess balances, which pay no interest, banks began to hold contractual clearing balances in significant quantities.

Indeed this shift led the Desk to consider balances instead of reserves as the appropriate measure for targeting the federal funds rate because reserves no longer accurately reflected the demand for funds in the banking sector. The level of contractual clearing balances that a bank must hold is at the bank's discretion, however, the bank may not change the level of contractual clearing balances more than monthly.[v] In deciding on the level of contractual clearing balances to hold, banks consider the amount of Federal Reserve services that they wish to pay for with these earnings credits, the balance they need to hold in their account to clear transactions, and the opportunity cost of these balances relative to other uses of the funds. Each bank strikes its own compromise among these competing influences. Like required reserve balances, contractual clearing balances requirements must be satisfied on a period-average basis.

The interest rate paid on contractual clearing balances was the federal funds rate until January of 2004. At that point, the earnings credit rate was changed to 90 percent of the yield on the three-month Treasury bill, a change that reduced the earnings credit rate slightly. The rate was changed again in January 2005 to 80 percent of the yield on the three-month Treasury bill.[vi] Because the interest generated can only be used to pay for Fed services, changes in short-term interest rates—and it should be noted that the federal funds rate and the yield on the three-month Treasury bill move in virtual lock step—have two distinct effects on demand for contractual clearing balances. First, for a given level of charges for Fed services, a higher interest rate means that a lower level of balances can generate sufficient earnings. Second, rising short-term rates are also linked to rising rates on investments that banks can make. As a result, rising rates imply a rising opportunity cost to banks for holding balances at the Fed. Therefore, both roles of interest rates imply a negative relationship between contractual clearing balances and the funds rate.

Any balances that are held by banks over and above those to satisfy required reserve balances and contractual clearing balances are considered excess balances. Excess balances are costly in that they do not pay interest and are not useful to fulfill requirements. As a result, the federal funds rate represents an opportunity cost of holding these funds. Nevertheless, some banks choose to hold excess balances either because they are small banks and the forgone interest cost is lower than the cost that would be incurred by more closely managing their Fed account, or because banks wish to have a higher level of balances to guard against an accidental overnight overdraft. Overdrafts are penalized severely and as such, banks must weigh the reduction in the expected cost of a potential overdraft against the opportunity cost of holding idle funds. Clouse and Dow (2002) and Carpenter and Demiralp (2006 b) present optimizing models of bank behavior that endogenously generate a demand for excess balances as a buffer against overdrafts. Given the two mentioned motivations for holding excess balances, a liquidity effect is implied. A higher federal funds rate implies a higher opportunity cost to holding excess balances, which should induce banks to economize on these balances. Of course, the impact of excess balances on the total liquidity effect is likely to be small, as excess balances represent only a small fraction of total balances (see Figure 1).

As should be clear from the above description of balances held at the Federal Reserve, there is not a simple demand function. Analyzing just one portion—such as nonborrowed reserves—will only tell a portion of the story, and because nonborrowed reserves are dominated by required reserves—and in particular applied vault cash—it is not clear that there need be a strong contemporaneous relationship between the funds rate and nonborrowed reserves. Contractual clearing balances and excess balances, on the other hand, each have a distinct direct relationship with the funds rate.

The composition of Federal Reserve balances has also changed through time, as can be seen in Figure 1. Early in the sample period, contractual clearing balances were a very small part of total balances, with required reserve balances accounting for the overwhelming majority. Because required reserve balances are part of nonborrowed reserves, the distinction between balances and reserves is not as crucial until the early 1990s. Indeed, as our results will suggest below, our work has similarity to some of the previous research in the area during our early sample period—that is during the period when balances and reserves were not terribly dissimilar concepts. As retail sweep activity increased and banks' use of contractual clearing balances rose to roughly half of total balances, the distinction between balances and reserves became more important. This shift may explain the vanishing liquidity effect for the post 1989 sample when we re-estimated the models that use reserve based measures to estimate the liquidity effect. In the next section, we provide very simple regression results to motivate the differentiation of demand across the three types of balances.

3. Disaggregating Demand for Balances

As a first step, we run a series of regressions of balances on the fed funds rate. We look at the relationship of total balances to the funds rate and compare those results to the relationship of the individual components. Table 1 presents the results. For comparison, all models are run with a common specification, and then additional terms are added to certain models. We include a lagged dependent variable, the lag of the federal funds rate, dummy variables for September 11, 2001 and one lag, and we include dummy variables for April and December, two months in which tax payment flows tend to distort the typical pattern of balances. At a monthly frequency, the deviation of the federal funds rate from the target rate is minimal. Because the target rate is set in response to macroeconomic variables and not conditions in the reserves market, endogeneity is not a significant issue. The only possible endogeneity would arise from higher economic activity leading to higher levels of checking accounts—and therefore required reserves—or higher payment levels—and therefore contractual clearing balances. We find this argument unconvincing, but we account for this type of feedback in our VAR analysis that yields similar results, so we are confident in our results.

Column 1 presents the results for total balances, the sum of required reserve balances, excess balances, and contractual clearing balances. The coefficient of interest is the coefficient on the effective federal funds rate. The coefficient is not statistically significant, and one might consider this a liquidity puzzle. More puzzling would be a positive and statistically significant coefficient; however given that a negative coefficient is theoretically appealing, we will consider this result part of the puzzle to be explained. The fact that the lagged dependent variable is significant and close to unity likely reflects the fact that contractual clearing balance levels are predetermined and adjusted somewhat sluggishly and that checking deposits—which determine required reserves—exhibit a great degree of persistence. We now turn to examine the different components of bank balances held at the Fed.

Column 2 presents the results using required reserve balances instead of total balances. Only the lagged dependent variable and the lagged September 11 dummy variable are significant. Importantly, the coefficient on the federal funds rate is not statistically significant. Again, while this result is not as puzzling as a positive and statistically significant coefficient, it does not fit comfortably with the notion of an easily estimable, downward-sloping demand curve. A straightforward explanation for this fact, as mentioned earlier, is that the level of required reserve balances is dictated by the level of reservable deposits at banks. A subsequent section will address whether these deposits respond to interest rates, and thus, with a lag, would imply a dynamic liquidity effect in required reserve balances.

Column 3 presents the coefficients from the model estimated with excess balances as the dependent variable. The coefficient on the funds rate is negative and statistically significant at the 1 percent level. Looking at column 4, the results change a bit. Controlling for months of high tax payments seems to eliminate the statistical significance. This result presages our later results of a small and inconsistent liquidity effect for excess balances. As will be the case with the contractual clearing balance results, there is a negative coefficient on required reserve balances. Our interpretation is that when banks are forced to hold greater required reserve balance, the probability of an inadvertent overdraft is reduced, and so they decide to hold a lower level of excess balances as a buffer.

Columns 5 and 6 present the results from the model estimated with contractual clearing balances as the dependent variable. The high persistence of contractual clearing balances is evident from the lagged dependent variable. However, like with excess balances, we find some substitutability between contractual clearing balances and required reserve balances. This is because a higher level of required reserve balances provides the banks with more funds for their transactions and the need for additional funds for clearing purposes declines. Note that the liquidity effect, as measured by the negative coefficient associated with the funds rate, is significantly negative for both specifications.

4. Vector Autoregression Results

We think of the results above as akin to stylized facts about the correlations between balances and interest rates but clearly they are not a complete analysis of the data. Indeed, the results are at odds with some of the VAR results in the literature. As VARs have become a fairly standard tool to analyze the effect of monetary policy and investigate the liquidity effect, in order to make a stronger claim about the relationship and to fit our results into the broader literature, we turn to VAR modeling of the liquidity effect.

First, we re-estimate the models of Leeper and Gordon (1992), Christiano, Eichenbaum, and Evans (1996), and Strongin (1995). We are able to document that, even with these alternative methodologies, a liquidity puzzle can exist over our sample period where contractual clearing balances became an important component of total balances. Based on our discussion of the demand for balances, we estimate a VAR in which we include the different components of balances individually to compare the results. In this specification, the liquidity effect is clear and evident for contractual clearing balances and for some specifications, a liquidity effect for excess balances, evidence that the previous literature suffered from a misspecification problem. Lastly, we introduce restrictions onto our system to allow required reserve balances to adjust only through changes in reservable liabilities, consistent with the institutional structure.[vii] Under these restrictions, we confirm a liquidity effect for required reserve balances, underscoring the importance of modeling the institutional structure. Of note, our results on the liquidity effect in some cases include a substantial lag. As we have argued above, this lag is part of the institutional structure of the market and, instead of being evidence against a liquidity effect, highlights the importance of incorporating this type of structure into one's understanding of the market.

For each model, we use a sample period from 1989 to 2005.[viii] As is always the case with estimating VARs, we need to choose a lag length. To be systematic and consistent across models, we calculated both the Schwarz Information Criterion (SIC) and the Akaike Information Criterion (AIC) for each model. Table 2 presents the results. The AIC consistently suggests a longer lag structure than the SIC. However, the vast majority of results for the different models suggests one, two, or three lags. Given that the AIC at times suggests many lags, we settle on using three lags for each model.

Two potentially serious complications remain, however. One of the main reasons for the divergence of balances from reserves is the increased use of sweep activity in the post-1994 period whereby banks move funds from reservable checking accounts of customers into savings accounts that have a reserve requirement of zero. The switch in behavior is linked to the rise in the use of contractual clearing balances. As reserve requirements fell (see figure 1) in the mid-1990s, banks found themselves with insufficient levels of balances to clear transactions through their Federal Reserve accounts. Because excess reserves pay no return, but contractual clearing balances do, banks aggressively stepped up their holdings of these balances.

Second, as mentioned earlier, reserve accounting switched in July 1998 from contemporaneous reserve accounting to lagged reserve accounting (LRA), possibly compromising our results. We partially control for the change in accounting regimes by introducing dummy variables into our estimation of each model to allow for a shift. In section 5, we report results from splitting our sample, first to examine whether our results are different over the period of the increased use of sweeps, and second whether there is a difference under the two accounting regimes. We find that our results are not sensitive to these changes.

Leeper and Gordon (1992) estimate a VAR that includes the monetary base, the federal funds rate, industrial production, and the consumer price index. Figure 2 presents the impulse response functions from estimation over our sample period. As was the case in their results, we find a liquidity puzzle; there is no negative relationship between the monetary base and the federal funds rate. We must remember, however, that the monetary base is defined as required reserves plus excess reserves plus currency. Currency is supplied by the Federal Reserve completely elastically. Estimates such as Porter and Judson (2001) suggest that between one half to two-thirds of U.S. currency is held overseas. Why such demand for currency, then, ought to be linked to the federal funds rate is unclear. The federal funds rate is the interest rate in the market for balances—not the monetary base—and since balances constitute less than 5 percent of the base, we should be unsurprised that there is no statistically significant relationship.

Figures 3 and 4 present results from the modeling of Christiano, Eichenbaum, and Evans (1996). In that paper, a VAR is estimated that includes industrial production, the CPI, a commodity price index, the federal funds rate, nonborrowed reserves, total reserves, and M1. These authors argue that the liquidity puzzle in Leeper and Gordon reflects endogeneity. Specifically, they claim that fluctuations in the monetary base reflect both exogenous supply changes as well as endogenous policy maker responses to demand side disturbances. By focusing on nonborrowed reserves, a narrower definition of money, they try to avoid this identification problem.

Nonborrowed reserves consist of required reserve balances, excess balances, and vault cash used to satisfy reserve requirements. In 2004 for example, nonborrowed reserves were about $45 billion, of which required and excess balances constituted only about $15 billion or one-third of the total. Of that $15 billion, excess balances are roughly one tenth. Contractual clearing balances are excluded from nonborrowed reserves but are roughly equivalent in levels to required reserve balances.

Further blurring the relationship between nonborrowed reserves and the federal funds rate is the way that currency is disbursed to the banking sector. When banks request a shipment of currency, for example to hold as vault cash, balances are drained from the receiving bank’s account. However, the Desk offsets this drain of balances through open market operations in order to target the level of balances consistent with the target rate. All else equal, the drain of balances from currency shipments would lower balances to zero in a couple of weeks. As a result, reserves can change, sometimes greatly, and yet balances can remain constant. Hence, compared to the monetary base, nonborrowed reserves are a much narrower measure of money base, and this measure corresponds much more closely to banks' funding needs, yet, nonborrowed reserves need not be correlated with the federal funds rate itself.

Figure 3 presents the results from the Christiano, Eichenbaum, and Evans, model where they assume that the federal funds rate is the appropriate measure of monetary policy, and plots responses of other variables to innovations in the funds rate. We do find some evidence of a liquidity effect, as total reserves, nonborrowed reserves, and M1 all have a negative and statistically significant liquidity effect. In terms of magnitude, however, we will show that liquidity effect measure in this model is only one-tenth the effect we estimate in our model. We take this result as being consistent with the fact that reserves are related to balances, but are not the same thing. As a result, the true liquidity effect, which is the relationship between balances and the funds rate, is masked. We think the fact that a liquidity effect is evident in this model illustrates the similarity of our research to previous work.

From an institutional point of view, however, the quantity of reserves, which is the monetary policy measure in Christiano, Eichenbaum, and Evans is not a useful measure over our sample period. As a matter of practice, the Desk provides balances perfectly elastically at the target rate, and as a result, balances react endogenously *to* the federal funds rate, not the reverse. Nonborrowed reserves, influenced by these changes in balances and banks' demand for vault cash, also react endogenously. Indeed, understanding that nonborrowed reserves includes vault cash—which is a choice variable for banks—and excludes a significant fraction of balances—the variable that the Desk adjusts to maintain the target rate—underscores the inappropriateness of using nonborrowed reserves as a policy measure. Therefore, while the response of funds rate to nonborrowed reserves as the liquidity effect in the exercise shown in Figure 4 may be consistent with a liquidity effect, we do not find it to be compelling evidence of one.

Stongin (1995) generalizes a measure of nonborrowed reserves to nest different policy regimes. He assumes that short-run demand for total reserves is inelastic and the Desk provides sufficient reserves to satisfy this demand. Further, he argues that during a policy tightening, the Desk contracts nonborrowed reserves, resulting in an increase in borrowing. Thus, the ratio of nonborrowed reserves to total reserves ought to fall during a policy tightening. He estimates a model of nonborrowed reserves divided by total reserves and the federal funds rate and analyzes the response of these variables to changes in the nonborrowed reserves variable.[ix] We present the impulse response from that model estimated over our sample period in Figure 5. In contrast to Strongin's original results, we find a liquidity puzzle with no statistically significant response of the federal funds rate to a positive innovation in nonborrowed reserves relative to total reserves.

Both the Christiano, Eichenbaum, and Evans paper and that by Strongin were meant to address the issue of a liquidity puzzle like that found in Leeper and Gordon. Nevertheless, our results above suggest that over a recent sample period, these estimation strategies may still result in a liquidity puzzle, though perhaps a mild one depending on the particular specification. Some researchers have interpreted these types of results as a sign that the liquidity effect is no longer operational in the federal funds market and instead, so-called "open mouth operations" control the fed funds rate (see Thornton (2001)). There is a bit of a tension between our preliminary results and the results we get from replicating others above. We believe that the vanishing liquidity effect is due to a misspecification of the demand function in the fed funds market. To resolve this conflict, we now estimate a model of balances that allows each component of balances to change independently. Importantly, we do not argue that a single component of balances is the appropriate measure of money to study, but that they must be examined together to understand the market.

Our baseline model includes the effective federal funds rate, reservable deposits, required reserve balances, contractual clearing balances, and excess balances. Considering our preliminary results, we infer that the channel for any liquidity effect in required reserve balances is through the response of reservable deposits. Figure 6 presents the impulse response functions from this model in response to a positive shock to the federal funds rate.

The impulse response function for required reserve balances does not show a statistically significant liquidity effect. However, as would be predicted by the structure of reserve requirements, the response of required reserve balances to an innovation in reservable liabilities (not shown) is positive and significant. In contrast, contractual clearing balances and excess balances conform to our previous results. Both of these types of balances show a negative reaction to a positive innovation to the federal funds rate, but only the response of contractual clearing balances is statistically significant. Given the structure of the federal funds market, there is no liquidity puzzle. Instead, the variables for which there is a direct link between the funds rate and balances show a liquidity effect. Moreover, these results are an order of magnitude larger than the effect we estimate using the Christiano, Eichanbaum, and Evans methodology when the federal funds rate is the measure of monetary policy.

The model presented above lacks an interaction between the federal funds market variables in the real economy. Indeed, the goal of research on the liquidity effect is to understand the initiation of the transmission mechanism, making our omission of macroeconomic variables a bit of a problem. Indeed, if demand for balances were a function of economic activity, our results are also subject to an endogeneity bias. Our focus is on the liquidity effect itself, not the transmission mechanism following a change in the funds rate. We feel this latter topic has been well explored, beginning with Bernanke and Blinder (1992) onward. To test the endogeneity, however, we include industrial production, the consumer price index, and the commodity price index. The impulse responses for the balances are no different (not shown), so we continue with our baseline model to maintain our focus on the liquidity effect alone.

The foregoing results are suggestive, but because VARs are very general and we have some institutional restrictions that we can place on the model, we next estimate a "near-VAR" of the following specification[x]:

$$FFR_t = \alpha_j + \sum_{i=1}^{3} \beta_{ij} FFR_{t-i} + \sum_{i=0}^{3} \delta_{ij} D_{t-i} + \varepsilon_t$$

$$RDEP_t = \alpha_j + \sum_{i=0}^{3} \beta_{ij} FFR_{t-i} + \sum_{i=1}^{3} \gamma_{ij} RDEP_{t-i} + \sum_{i=0}^{3} \delta_{ij} D_{t-i} + \varepsilon_t$$

$$RRB_t = \alpha_j + \sum_{i=0}^{3} \gamma_{ij} RDEP_{t-i} + \sum_{i=1}^{3} \eta_{ij} RRB_{t-i} + \sum_{i=0}^{3} \delta_{ij} D_{t-i} + \varepsilon_t$$

$$CCB_t = \alpha_j + \sum_{i=0}^{3} \beta_{ij} FFR_{t-i} + \sum_{i=0}^{3} \gamma_{ij} RDEP_{t-i} + \sum_{i=0}^{3} \eta_{ij} RRB_{t-i} + \sum_{i=1}^{3} \omega_{ij} CCB_{t-i} + \sum_{i=0}^{3} \delta_{ij} D_{t-i} + \varepsilon_t$$

$$ERB_t = \alpha_j + \sum_{i=0}^{3} \beta_{ij} FFR_{t-i} + \sum_{i=0}^{3} \gamma_{ij} RDEP_{t-i} + \sum_{i=0}^{3} \eta_{ij} RRB_{t-i} + \sum_{i=0}^{3} \omega_{ij} CCB_{t-i} + \sum_{i=1}^{3} \xi_{ij} ERB_{t-i} + \sum_{i=0}^{3} \delta_{ij} D_{t-i} + \varepsilon_t$$

for each equation *j*, where:
FFR_t is the effective funds rate
$RDEP_t$ is the reservable deposits
RRB_t is the required reserve balances

CCB_t is the contractual clearing balance
ERB_t is the excess reserve balances
D_t is a dummy variable for September 11

Essentially, we make the federal funds rate exogenous. The funds rate seldom varies significantly from the target rate and these deviations are statistically and economically insignificant at a monthly frequency. Furthermore, the FOMC over our sample period has been targeting the funds rate and not any measure of reserve balances. Therefore, this restriction is valid. We allow reservable deposits to depend exclusively on the fed funds rate. This is, of course, a bit of an approximation, but not a severely limiting one. The level of checking deposits is determined by banks' customers demand for these assets. Presumably, a driving force behind the level is the opportunity cost of holding these deposits which pay little or no interest. As a result, to the extent that the relationship between the fed funds rate and the appropriate opportunity cost is roughly constant, the specification is valid. Given the determination of required reserves, we let required reserve balances depend exclusively on the level of reservable deposits. Because the relationship is essentially an accounting relationship, this restriction is almost non-binding.

Contractual clearing balances and excess balances, by contrast, are allowed to depend on every other variable in the system. Banks have discretion over the level of contractual clearing balances that they set and on the level of excess balances that they hold. As a result, allowing each of these relationships to be completely determined by the data is appropriate. Impulse response functions from this system are presented in Figure 7. In this case, all components have a negative response to innovations in the funds rate, with that of required reserve balances and contractual clearing balances being statistically significant. Indeed, even reservable deposits show a negative response to an increase in the funds rate. This result is consistent with a negative elasticity of money demand with respect to interest rates. This result reflects the institutional fact that required reserve balances can show a liquidity effect only as a result of a change in reservable deposits.

5. Estimation Issues

In 1994, banks began to sweep funds held in customers' checking accounts into special-purpose savings accounts on which the required reserve ratio is zero. This action reduced the level of required reserves, and since banks did not adjust their holdings of vault cash, required reserve balances fell, as can be seen in Figure 1. As a result, one might be concerned that the relationship among our variables changed at that point, leaving our results subject to question. To address this concern, we re-estimated our two models over a shorter sub-sample from 1994 to 2005.[xi]   The impulse response functions from this estimation are shown in figures 8 and 9, for the unrestricted and restricted VAR models, respectively. As can be seen, the results are little changed by restricting our attention to this latter subsample, and so we are confident that our results are not sensitive to this change in banks' behavior.

The change from contemporaneous reserve accounting to lagged reserve accounting that occurred in 1998 is similarly a possible problem for our estimation. To assess whether this change in reserve accounting rules caused a significant change in the impulse response functions estimated from our models, we broke the sample into two parts, one from 1989 through August 1998 that covers the contemporaneous reserve accounting period, and another from 1998 to 2005 that covers the lagged reserve accounting period.

Figures 10 - 13 show the impulse response functions for our models (unrestricted and restricted) from each of these subsamples. As can be seen, qualitatively, the results are unchanged by breaking the sample into the two accounting regimes; we still note a significant liquidity effect in each sample period. Based on the above evidence, we conclude that our results are not sensitive to the two changes in regime during our sample that are represented by the introduction of the use of sweeps and the change from contemporaneous reserve accounting to lagged reserve accounting.

6. Conclusions

The evidence provided above suggests that a liquidity effect in the federal funds market exists at a monthly frequency. We explain how most of the previous literature that find a liquidity puzzle or a liquidity effect that is time sensitive have misspecified the question. The negative relationship between "interest rates" and "money" is, in our view, a reflection of the elasticity of demand for money with respect to an interest rate. As a result, it need only exist when the measures of money and interest rates are tied to each other. For the federal funds rate, the appropriate measure of money is the level of balances at the Federal Reserve, as these are the funds that are actually traded in the market. Of these balances, however, the level of required reserve balances is predetermined because of the method of reserve accounting employed. Consequently, there need be no contemporaneous relationship between required reserve balances and the federal funds rate. Because these balances and vault cash held at banks constitute the lion's share of nonborrowed reserves, this fact helps to explain the puzzle sometimes found by researchers examining nonborrowed reserves. Indeed, as discussed above, the relationship could display a considerable lag between a change in the federal funds rate until there is a change in the level of reservable deposits, which subsequently leads to a change in required reserve balances. This process could take months.

While our results demonstrate that a liquidity effect exists, they also indicate the importance of understanding institutional arrangements of markets before being able to draw valid inferences about that market. The relationship between reserves—a commonly examined monetary aggregate—and balances is not one-for-one. Understanding the difference is crucial to understanding the actual mechanisms through which the federal funds market works and thus the way monetary policy is implemented in the United States. Previous studies that focused on reserves, whether nonborrowed, borrowed, or total, are no longer valid. The federal funds market is the market for balances, not reserves, and that distinction should be incorporated into economists' understanding of the transmission of monetary policy. Despite our protestations about the misspecification of previous research, our results hold great similarities to that research. One key insight is that during the period when reserves and balances were roughly equivalent, the distinction is immaterial. Following institutional changes in the early 1990s, however, the conceptual differences between the two measures emerged and the estimation result diverge. Consistently studying balances avoids this sample specificity.

Our results also inform the debate between whether a negative liquidity effect or a direct Fisher effect is the appropriate model of interest rate response to changes in open market operations. In the federal funds market at least, and therefore, likely other short-term interest rates, there exists a clear and statistically significant negative liquidity effect.

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Table 1. The liquidity effect for various measures of balances. Regression results, 1989:2 to 2005:06

	Total Balances	Required Reserve Balances	Excess Balances	Excess Balances	Contractual Clearing Balances	Contractual Clearing Balances
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	634.33	250.82	1504.74**	1499.07**	494.76**	1222.65**
	(444.85)	(248.41)	(212.87)	(510.34)	(90.98)	(215.12)
y_{t-1}	0.98**	0.99**	0.38**	0.26**	0.96**	0.91**
	(0.02)	(0.01)	(0.08)	(0.09)	(0.01)	(0.03)
Funds rate	-41.66	-35.29	-72.63**	-24.29	-45.91**	-79.79**
	(50.84)	(46.68)	(19.17)	(23.09)	(8.82)	(15.03)
9/11	18631.56**	196.36	18155.15**	17970.32**	195.51	87.25
	(154.57)	(114.61)	(55.04)	(61.76)	(19.55)	(36.88)
9/11 lagged	-13497.80**	4068.83*	-6893.58**	-4955.12**	104.07	50.43
	(246.97)	(126.25)	(1544.14)	(1611.45)	(21.77)	(35.85)
December	599.36	10.89	445.78**	419.39**	83.43	87.41*
	(294.41)	(310.30)	(141.27)	(134.08)	(56.66)	(49.56)
April				-269.27*		35.64
				(144.64)		(51.02)
Trend				2.27		-0.51
				(2.05)		(0.73)
RRB				-0.01		-0.01**
				(0.01)		(0.00)
R-squared	0.96	0.98	0.86	0.87	0.996	0.996
D-W	2.18	1.98	2.19	2.13	1.31	1.40

Standard errors are in parentheses

*,** denote statistical significance at the 5, and 1 percent levels, respectively

Table 2: Lag Order Selection Criteria
1989-2005

	AIC	SIC
Leeper and Gordon	5	2
CEE	12	1
Strongin	3	2
Carpenter and Demiralp	2	1

Notes:

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[i] The views expressed are those of the authors and do not necessarily reflect those of the Board of Governors or the Federal Reserve System. We thank Oscar Jorda and an anonymous referee for helpful comments. Shawn Liu and Brianna Wilcox provided excellent research assistance. Any errors, however, are solely those of the authors. Carpenter: Section Chief, Division of Monetary Affairs, Board of Governors of the Federal Reserve System, Mail Stop 59, 20th and C Street, NW Washington, DC 20551 scarpenter@frb.gov Demiralp: Assistant Professor, Department of Economics, Koç University, Istanbul, Turkey 34450 sdemiralp@ku.edu.tr.

[ii] The Federal Reserve did not begin to announce changes in the target for the federal funds rate until 1994, however the targeting itself began in the late 1980s, see Meulendyke (1998).

[iii] We will use the term “depository institution” and “bank” interchangeably, but in reality mean any depository institution, including commercial banks, thrifts, and the like.

[iv] During the period of contemporaneous reserve accounting, for the funds rate to have a contemporaneous effect on required reserve balances, there must be an instantaneous effect of the federal funds rate on the level of checking account balances desired by the public that happens within 12 days. Based on the historical relationship between checking account balances and interest rates, we consider this possibility to be unlikely.

[v] In January 2004, banks were permitted to change their contracted level of clearing balances every maintenance period.

[vi] Slightly more precisely, the earnings credit rate was changed to be a fraction of the 13-week moving average of the yield on the three-month Treasury bill.

[vii] The utility used to estimate the near VARs in this paper is provided at http://www.dnanalytics.net/nvar/

[viii] We also include dummy variables for September 11, 2001.

[ix] To be specific, Strongin normalizes the reserves measures with the level of total reserves from the previous month.

[x] As mentioned earlier in the text, we also include an interactive dummy variable for the post LRA period in each equation.

[xi] To preserve more degrees of freedom, the estimations for the sub sample analysis do not incorporate dummy variables for the post LRA period.

Figure 1: Total Federal Reserve Balances (1989-2005)

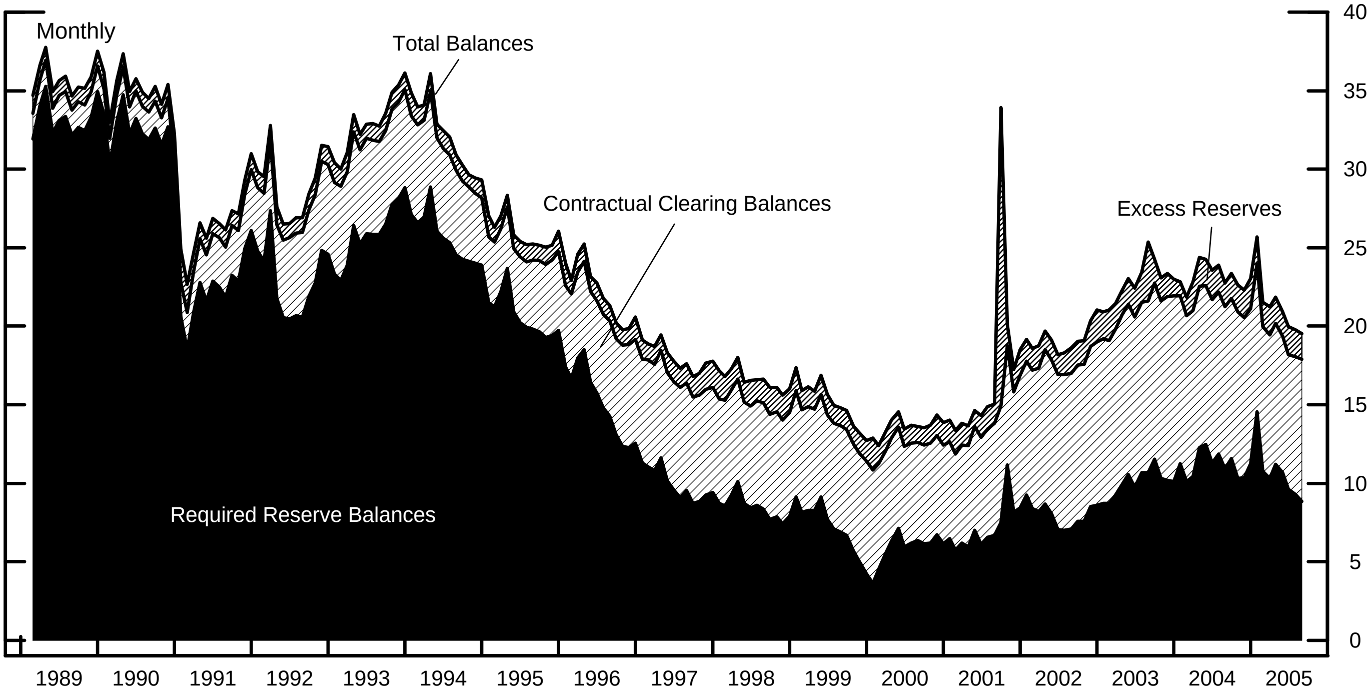

Figure 2: Leeper and Gordon (1989-2005)
{MB, FFR, IP, CPI}

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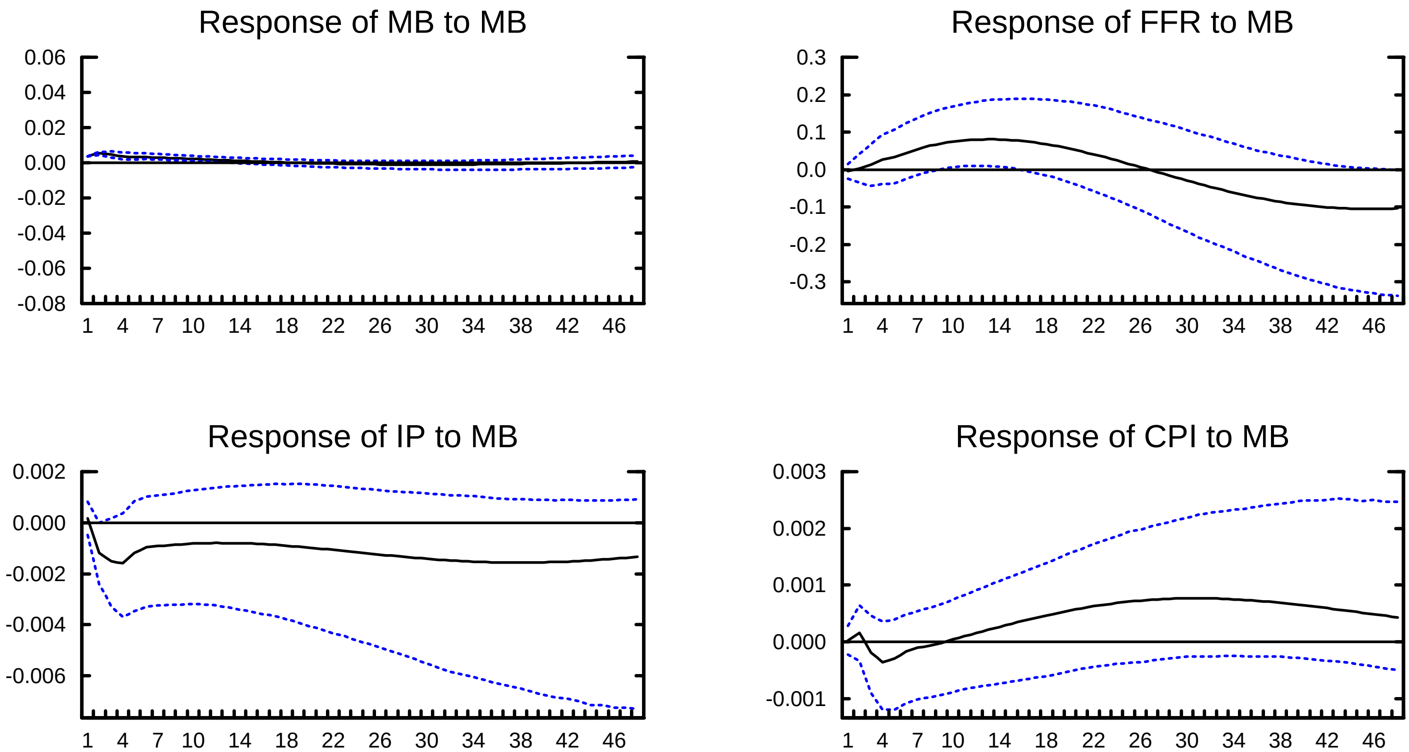
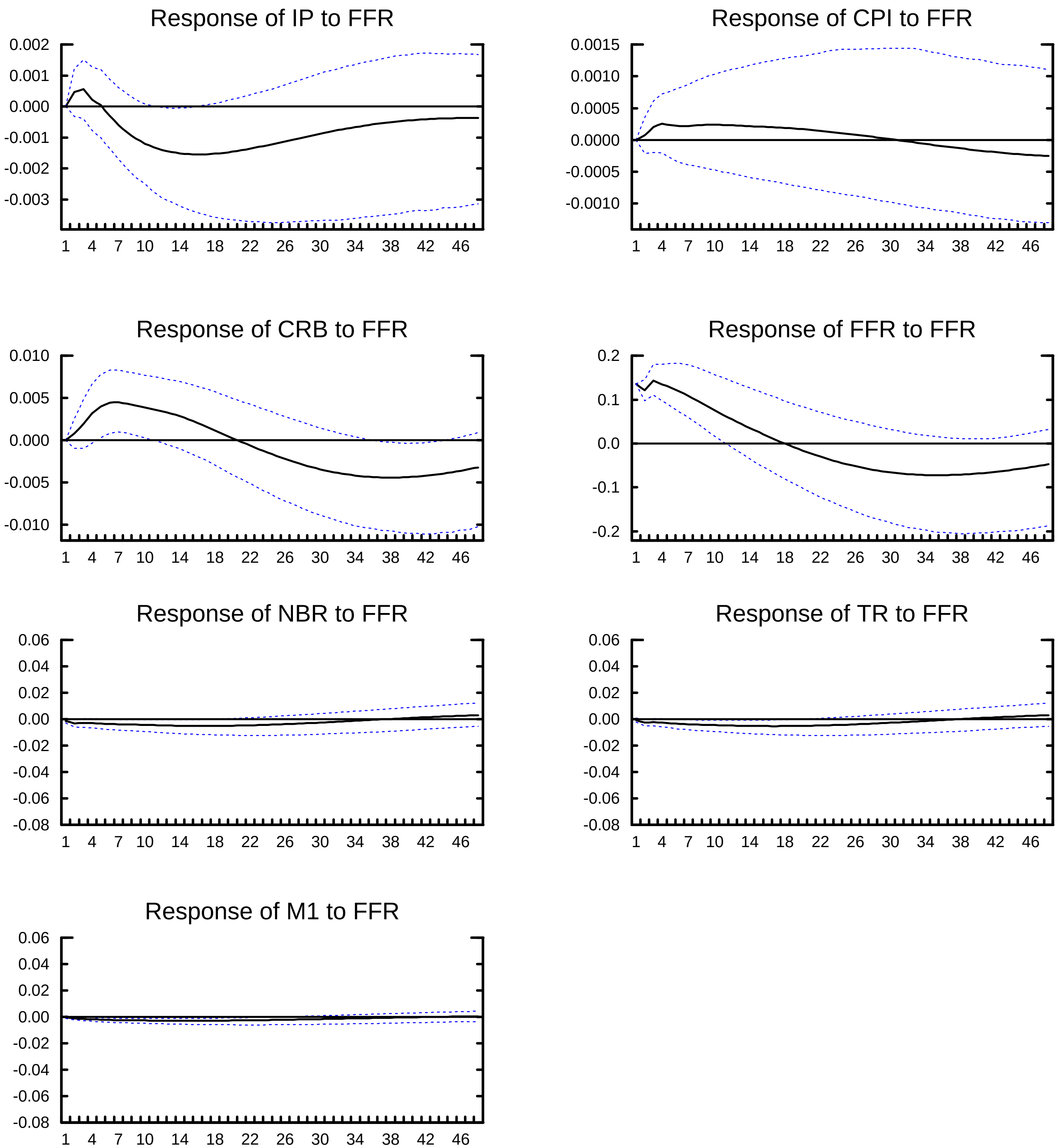


Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 3: Christiano, Eichenbaum, and Evans (1989-2005)
{IP, CPI, CRB, FFR, NBR, TR, M1}

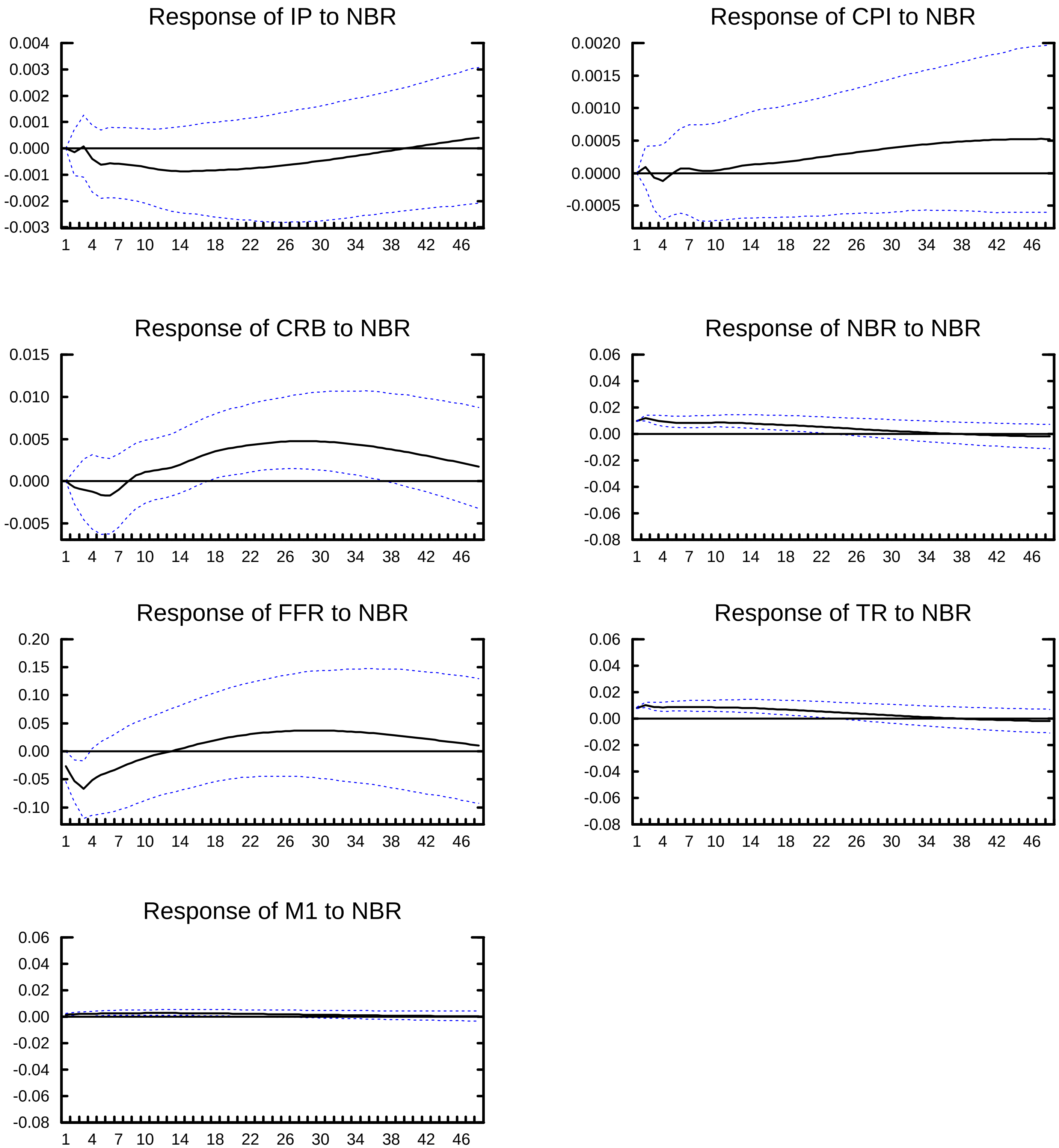
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 4: Christiano, Eichenbaum, and Evans (1989-2005)
{IP, CPI, CRB, NBR, FFR, TR, M1}

Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 5: Strongin (1989-2005)

{TRX, NBRX, FFR}

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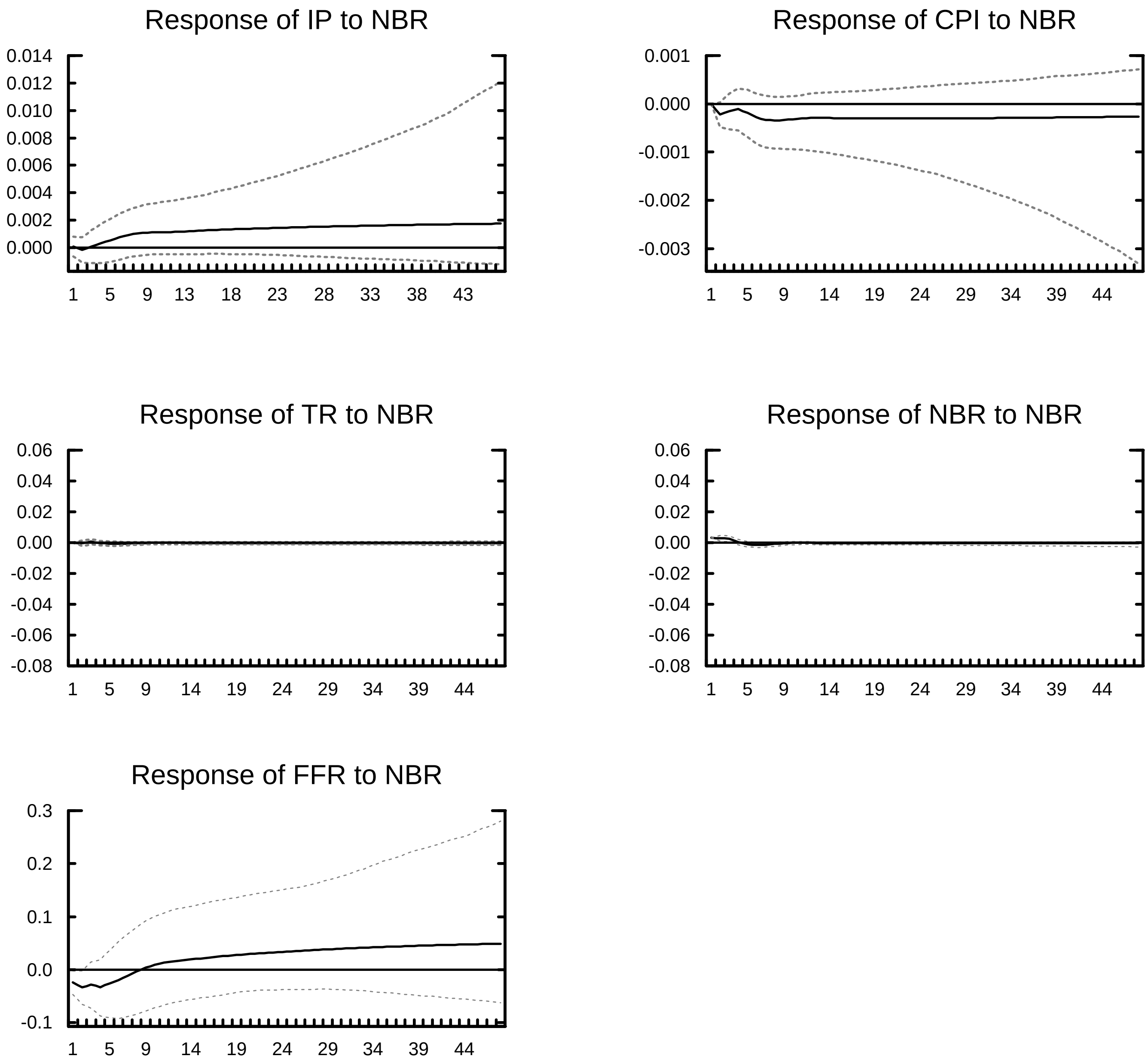
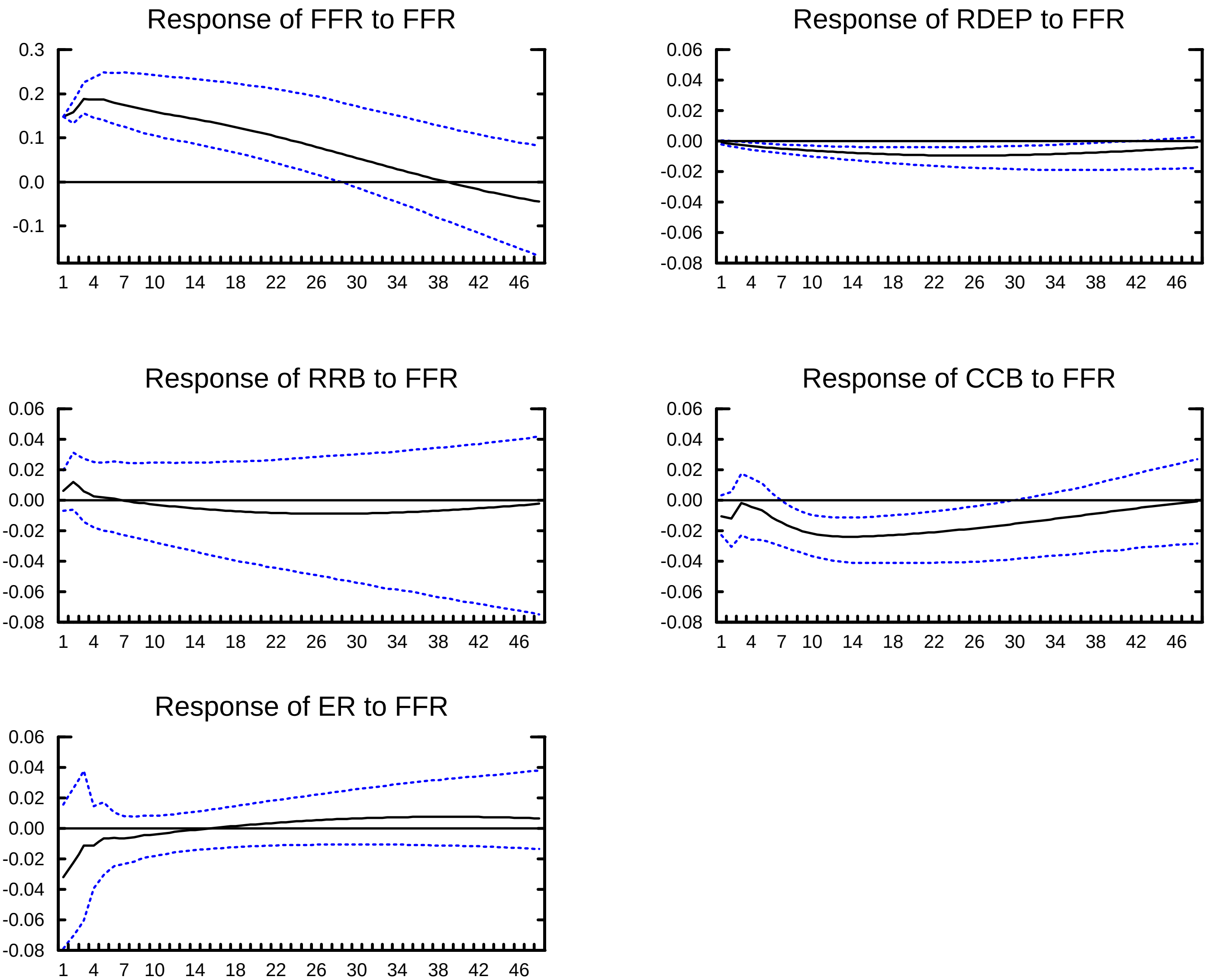


Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 6: Carpenter and Demiralp (1989-2005), Unrestricted VAR
{FFR, RDEP, RRB, CCB, ERB}

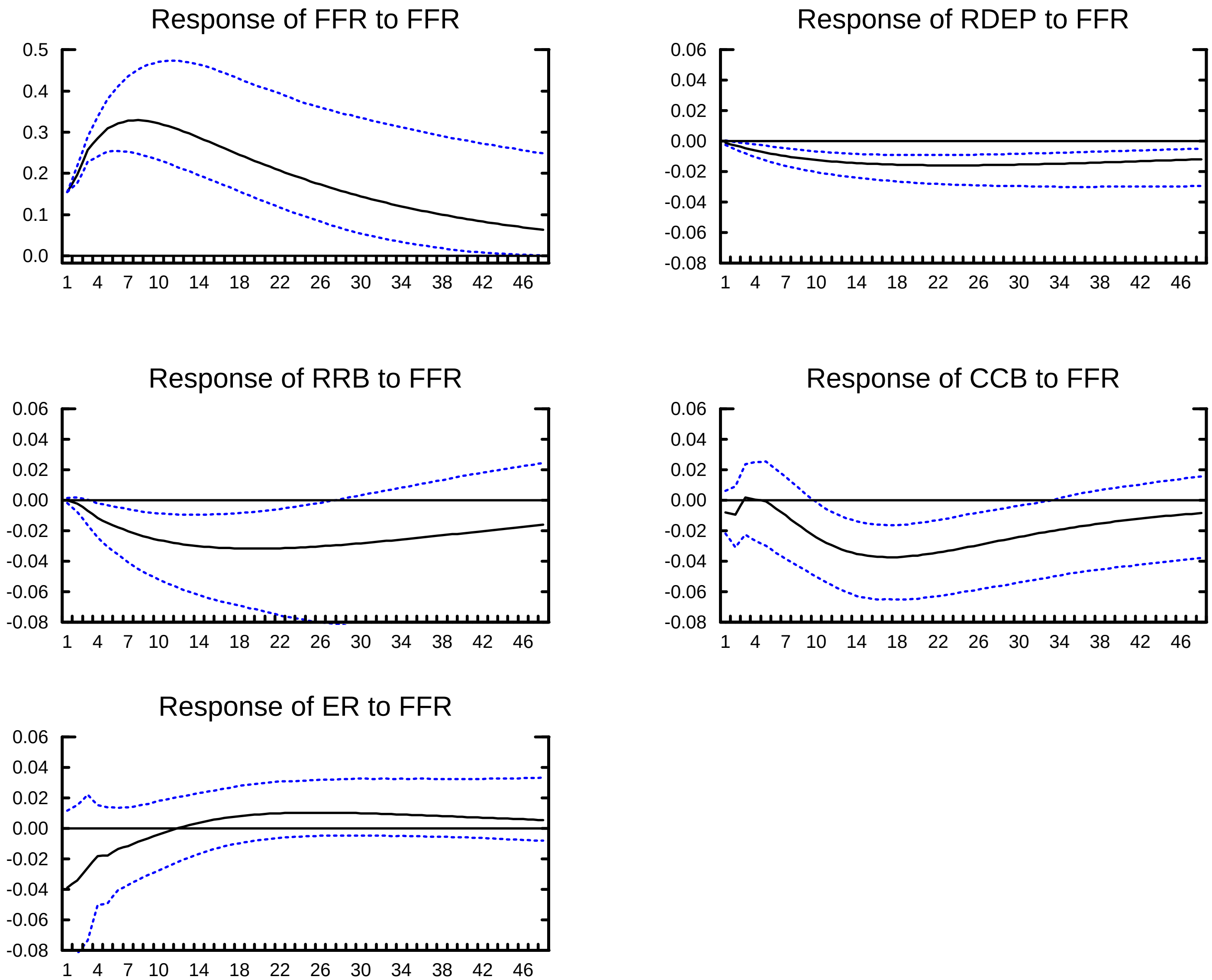
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 7: Carpenter and Demiralp (1989-2005), Restricted VAR {FFR, RDEP, RRB, CCB, ERB}

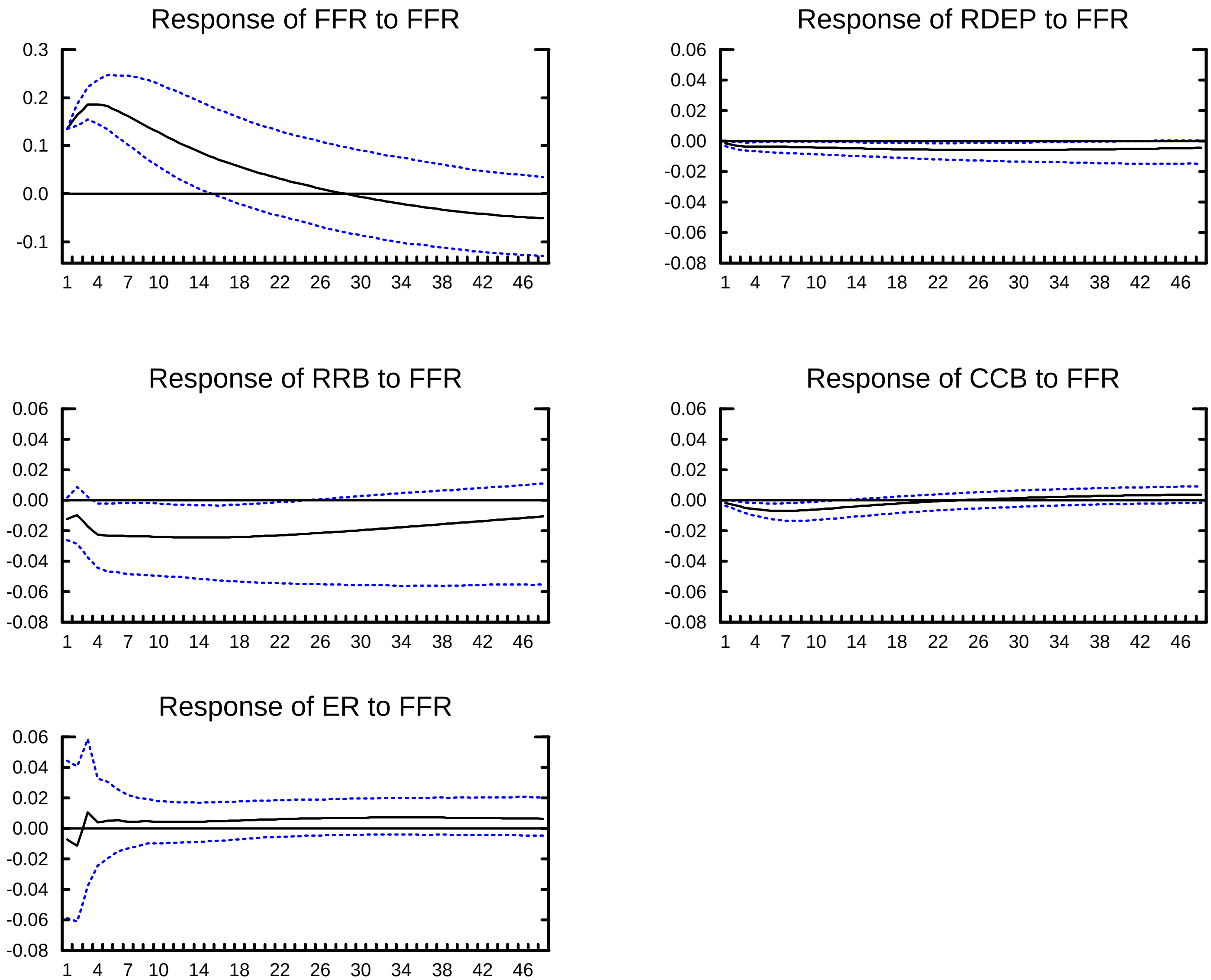
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 8: Carpenter and Demiralp (1994-2005), Unrestricted VAR
{FFR, RDEP, RRB, CCB, ERB}

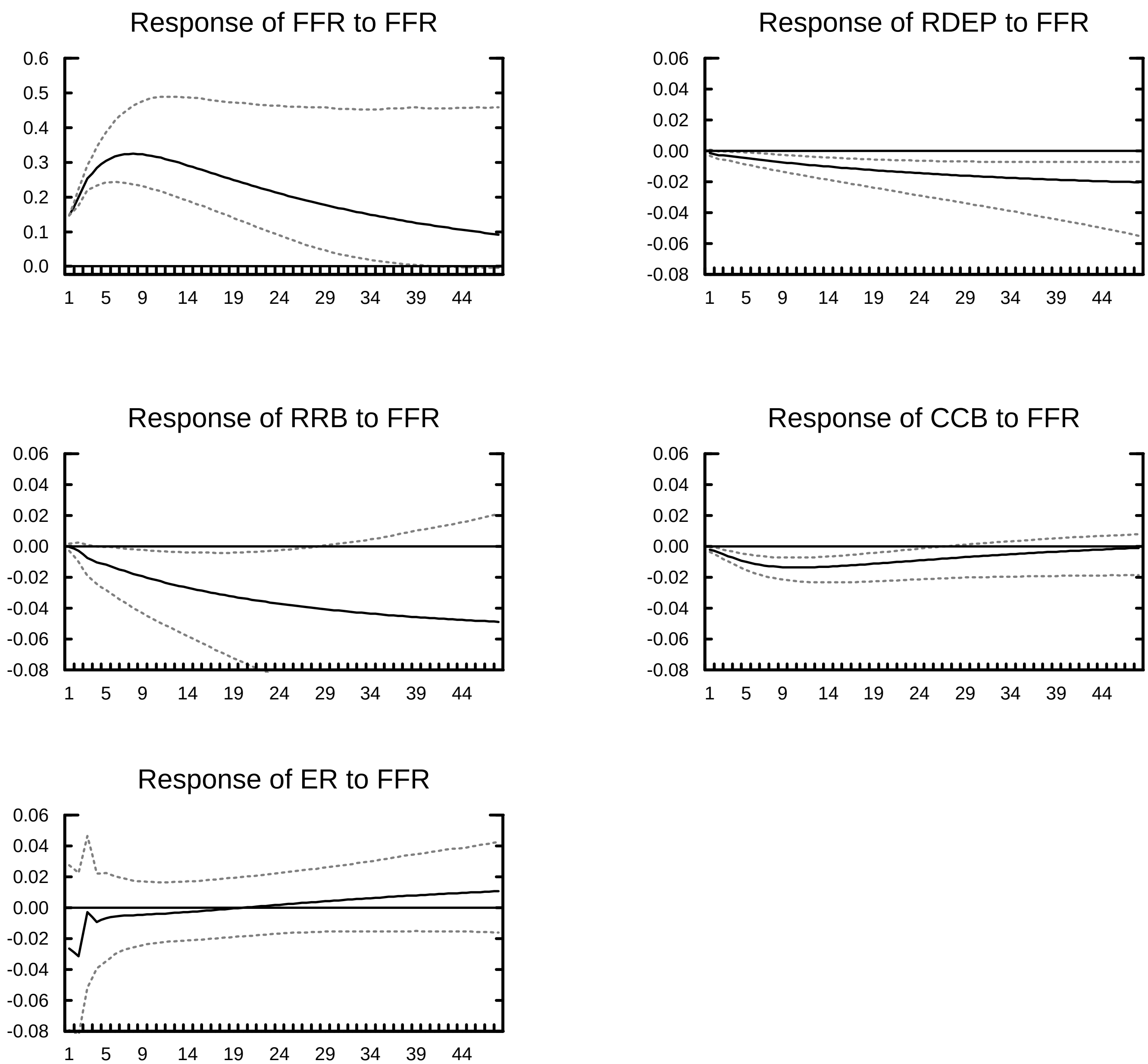
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 9: Carpenter and Demiralp (1994-2005), Restricted VAR
{FFR, RDEP, RRB, CCB, ERB}

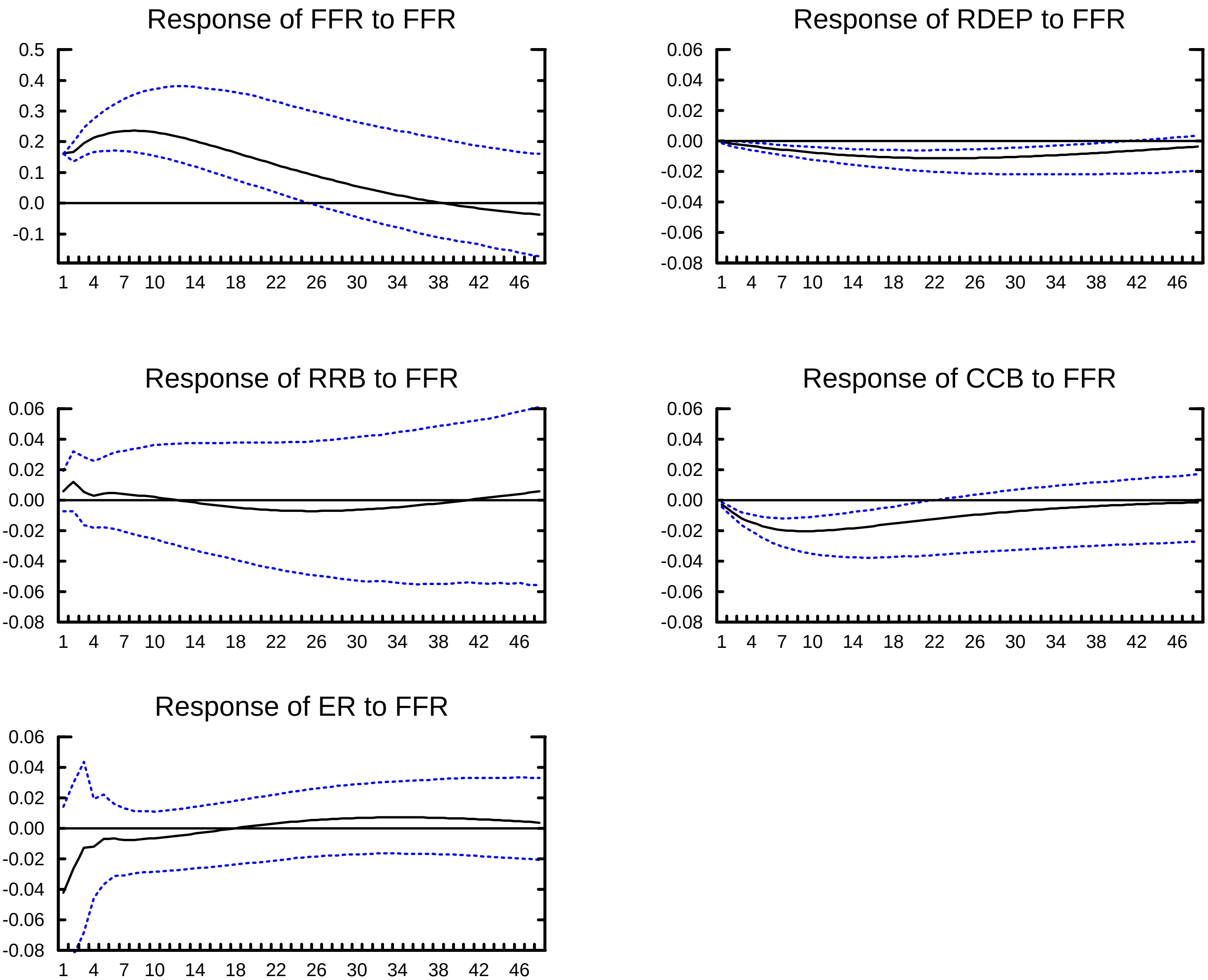
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 10: Carpenter and Demiralp (1989-1998), Unrestricted VAR {FFR, RDEP, RRB, CCB, ERB}

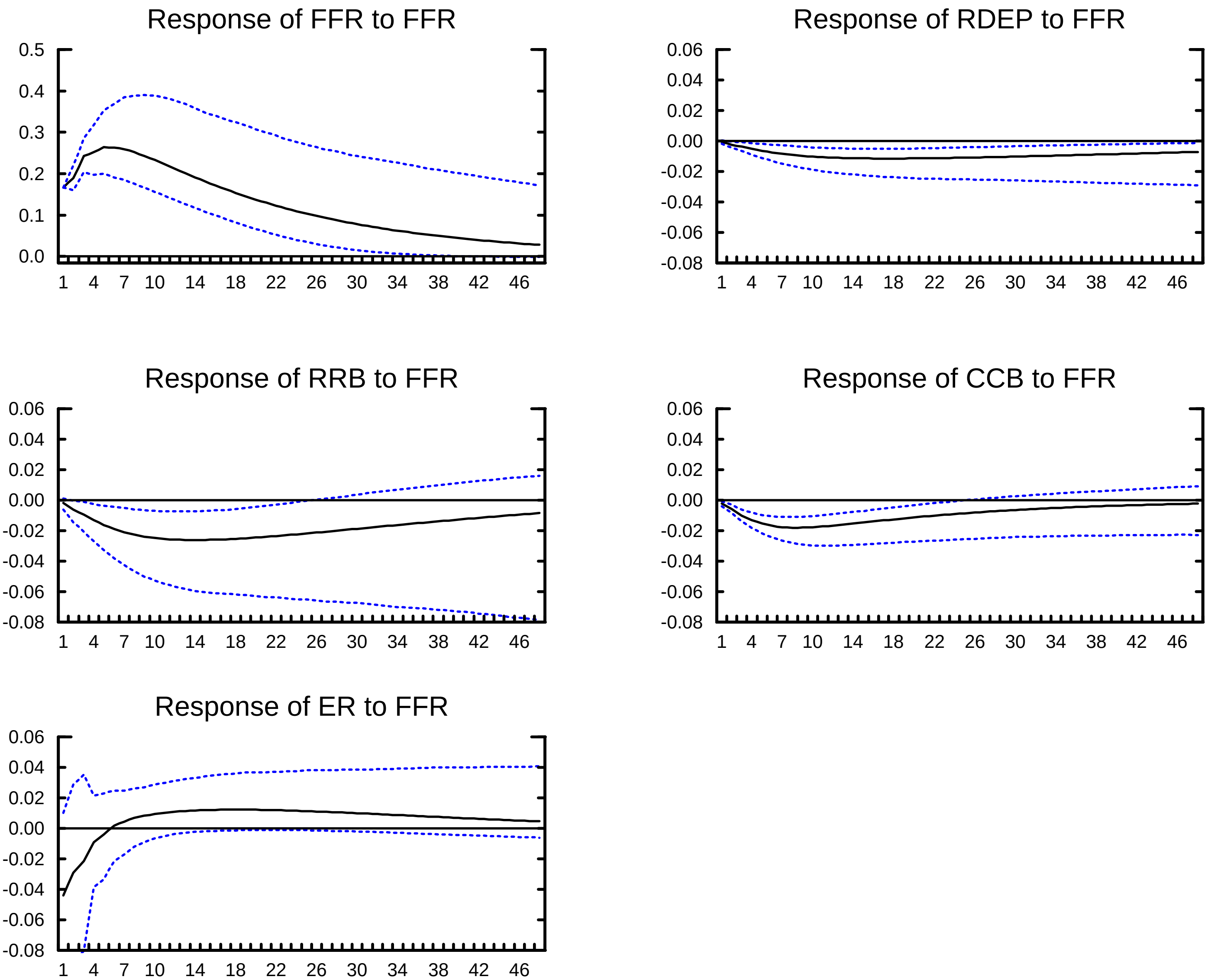
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 11: Carpenter and Demiralp (1989-1998), Restricted VAR
{FFR, RDEP, RRB, CCB, ERB}

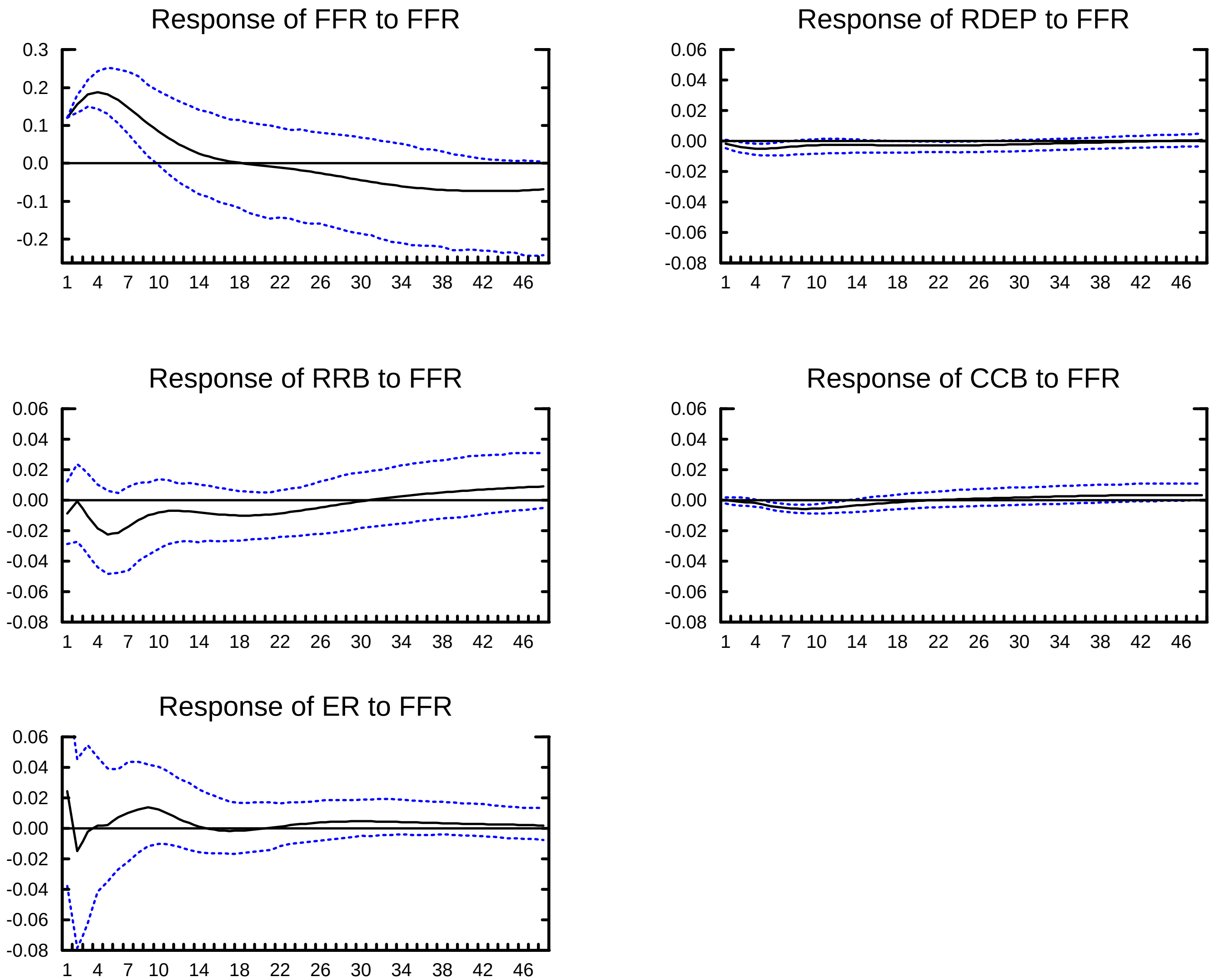
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 12: Carpenter and Demiralp (1998-2005), Unrestricted VAR
{FFR, RDEP, RRB, CCB, ERB}

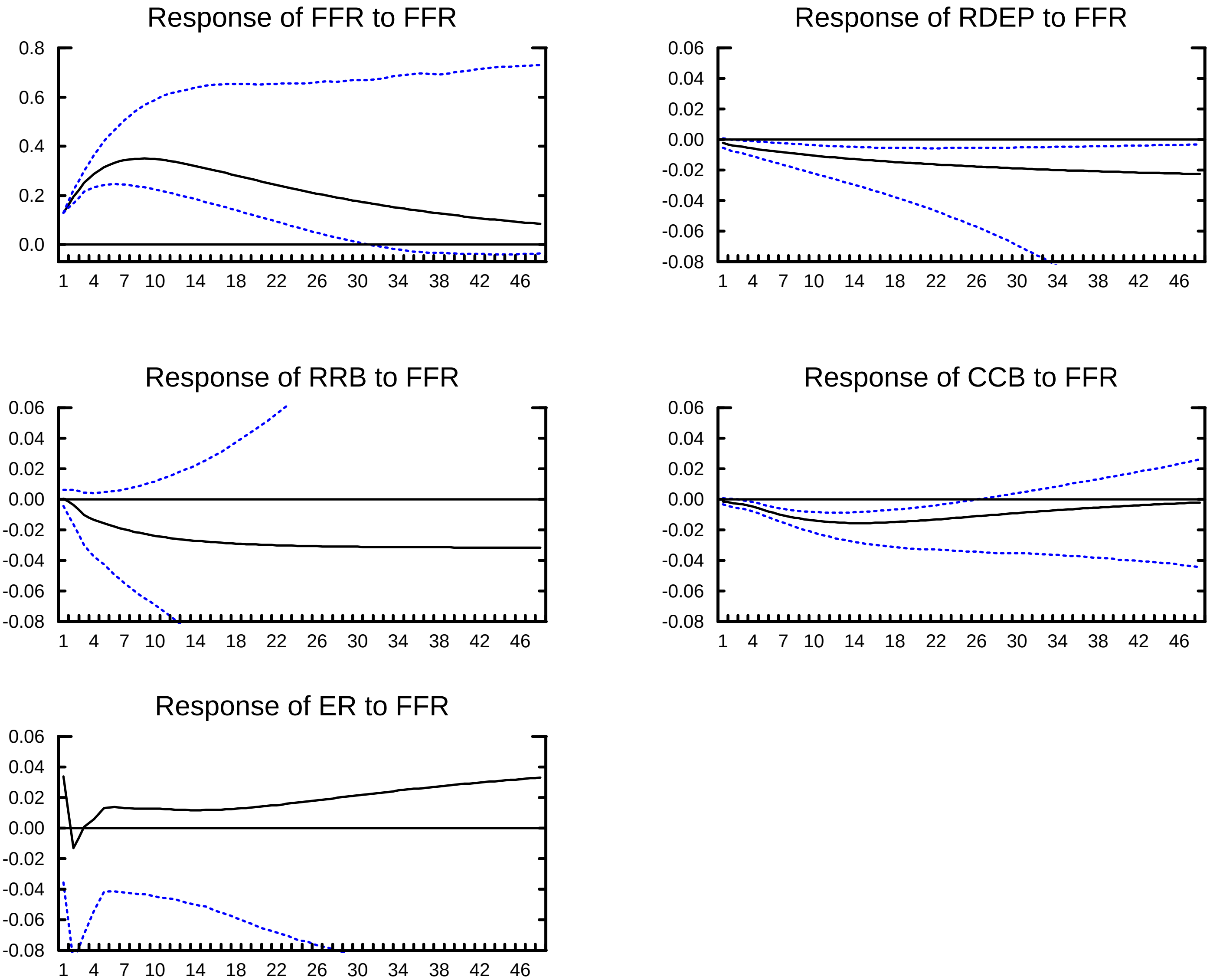
Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.

Figure 13: Carpenter and Demiralp (1998-2005), Restricted VAR
{FFR, RDEP, RRB, CCB, ERB}

Response to One S.D. Innovations



Note: The dashed lines represent 95 percent confidence intervals computed by bootstrap method.