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The Identification of Monetary Policy Disturbances: Explaining the Liquidity Puzzle

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Abstract

This paper examines the recent work on the identification of exogenous monetary policy disturbances by Sims (1992) and Eichenbaum (1992), as well as Sims (1980) and Litterman and Weiss (1985). The main finding is that the anomalies documented by these authors reflect their failure to properly take account of the Federal Reserve's policy of accommodating short run reserve demand disturbances. This, in turn, leads them to misidentify demand shocks as supply shocks. A new method of identifying the supply shocks, which avoids this confusion, is proposed and estimated. Once this is done, a nonborrowed reserves based measure of monetary policy is used to successfully address the difficulties which normally afflict attempts to measure policy innovations, such as the liquidity puzzle and Sims' price puzzle. Specifically, using the proposed specification, a positive innovation in nonborrowed reserves adjusted for the accommodation of reserve demand shocks has a strong and persistent negative effect on interest rates regardless of sub-sample and conditioning variables. Second, contrary to Sims (1992), but in line with Eichenbaum (1992), there is no persistent and significant positive price impact from a contractionary policy disturbance. (There is, however, a positive persistent price effect from the Federal Reserve's accommodation of reserve demand shocks.) Third, using the proposed specification, "money" Granger causes output even in the presence of interest rates and explains approximately 49% of the variance in output over a two year horizon. Fourth, the explanatory power of interest rates for industrial production drops to approximately zero once the proposed policy measure is taken account of. Finally, the paper finds strong evidence that the liquidity effects of policy on interest rates are persistent and that the persistence is directly related to the persistence of nonborrowed reserves' response to an innovation in policy. This suggests that even anticipated accommodative policy actions have a substantial negative impact on interest rates.

I. Introduction

Recently, there has been renewed interest in the identification of exogenous monetary policy disturbances. The recent search for an appropriate way to measure the impact of monetary policy has followed two well-worn paths: interest rates and monetary aggregates. When monetary aggregates are used to measure exogenous policy disturbances, three problems consistently arise. First and most troublesome is that innovations in the standard monetary aggregates seem to be associated with rising rather than falling interest rates. This "liquidity puzzle" has been surveyed by Reichenstein (1987) and was recently re-documented in detail by Leeper and Gordon (1992). The Leeper and Gordon paper shows that what relationship there is between innovations in the monetary base (as well as broader monetary aggregates) and interest rates is highly uncertain, varies across time and usually has the opposite sign than that predicted by the liquidity hypothesis. The second problem is that while monetary aggregates Granger cause output in VAR specifications that exclude interest rates, once interest rates are included in the specification, monetary aggregates no longer Granger cause output (see Sims (1980) and Litterman and Weiss (1985)). A third, (and related puzzle also documented in Sims(1980) and Litterman and Weiss(1985)) is that in VARs which include interest rates and some form of money, innovations in money explain a very small proportion of the variance of output, often 1% or less. In sharp contrast, innovations in interest rates typically explain a very high percentage of the variance of output, often exceeding 40% over a two year horizon, apparently indicating that innovations in policy (as measured by money) have little explanatory power.

These problems with money based measures of monetary policy have led Sims (1992) and Bernanke and Blinder (1992) among others to identify policy directly with innovations in interest rates. This identification scheme is reasonably successful in producing results consistent with a priori expectations about the effects of monetary policy in that both output and money fall in response to a contractionary monetary policy disturbance, e.g. a positive innovation in interest rates. However, a number of conceptual and empirical problems remain. First and most important, without any demonstrated empirical linkage between Federal Reserve actions and interest rate movements, it is unclear how innovations in interest rates can reasonably be attributed to monetary policy. Second, the validity of any such identification hinges critically on the specification's ability encompass all other significant determinants of the interest rate except policy. This suggests that inferences about policy could be very sensitive to specification and omitted variable problems. Only if monetary policy far outweighs all excluded variables in terms of explaining interest rates would inferences be robust, a proposition hard to argue from theory or previous empirical work. Sims (1992) documents just how severe this fragility can be. In specifications that follow Litterman and Wiess (1985) or Sims (1986) a positive innovation in policy, an easing action, is associated with a strong and persistent drop in the price level, exactly the opposite of what would be expected to happen in response to a expansionary monetary policy. Sims is able to reverse this counter-intuitive response by including exchange rates and commodity prices in the specification, variables whose direct explanatory power is fairly small both for interest rates and output. Beyond these problems of fragile inference, this approach suffers from a more general failure in that when policy is identified purely by its consequences, i.e. the residual in an equilibrium condition, rather than directly by Federal Reserve action, there is no way to disentangle the policy response function, thus eliminating a useful diagnostic on the reasonableness of the specification, nor can any questions about policy regimes be meaningfully entertained.

Thus, to this point neither of the aforementioned approaches to identifying monetary policy disturbances seem satisfactory. Eichenbaum (1992) argues that Sims (1992) was rash in rejecting aggregate based measures of monetary policy and suggests that the innovation in nonborrowed reserves is the correct measure of monetary policy. This suggestion is highly successful on a number of dimensions. Positive nonborrowed reserve innovations are associated with increased production and declining interest rates. Eichenbaum's solution, however, is less than fully satisfying. First, nonborrowed reserve innovations produce the same counter-intuitive price response that interest rate innovation do, i.e. contractionary policies generate persistent increases in the price level, although in the case of the nonborrowed reserve innovations the price response is statistically insignificant. Second, the explanatory power for real output is very small; only about 1% of the variance of industrial production can be explained by innovations in nonborrowed reserves. Interest rate innovations still account for the bulk of the explanatory power, nearly 40%. Third, nonborrowed reserves do not Granger cause output in the presence of an interest rate. And finally, Eichenbaum does not explain why his measure of monetary policy disturbances should solve either the liquidity or price puzzle. There is no conceptual explanation for why an innovation in nonborrowed reserves is the right measure of monetary policy, relative to previous attempts. His justification for the use of nonborrowed reserves is much like those normally used for the monetary base (a failed measure by Eichenbaum's analysis), i.e., that the Federal Reserve can control nonborrowed reserves more easily than a broader aggregate.

This paper argues that the main source of the difficulty in identifying monetary policy from the type of reserve data used by Eichenbaum (or any monetary aggregate) is that a significant proportion of the variance in the reserves data is due to the Federal Reserve's accommodation of innovations in the demand for credit and money rather than policy induced supply innovations. This leads to a confounding of supply and demand innovations. This paper utilizes a linear representation of the Federal Reserve's operating procedures, which includes both the level of total reserves and the mix of borrowed and nonborrowed reserves supplied by the Federal Reserve, to identify the exogenous disturbances to monetary policy net of accommodation. By using two measures of reserves with different responses to supply and demand innovations it becomes possible to distinguish between changes in reserves which result from Federal Reserve policy innovations and changes in reserves which result from the Federal Reserve's accommodation of demand innovations. The key assumptions are that the level of total reserves is largely determined by the Federal Reserve's short run accommodation of the demand for reserves[1] and that policy innovations are reflected in the mix of borrowed and nonborrowed reserves used to meet that demand[2]. Specifically, policy innovations are measured by using the innovation in total reserves to extract changes in the reserve mix between borrowed and nonborrowed reserves that are due to the Federal Reserve's accommodation of reserve demand shocks, leaving only those changes in the mix which are true policy innovations. This generates a well identified measure of exogenous monetary policy disturbances which can be used to address the puzzles set forth at the beginning of the paper.

The main empirical results can be summarized as follows. First and most important, in sharp contrast to previous work interest rates fall in response to expansionary monetary policy disturbances. This liquidity effect holds in all sub-periods, is precisely estimated, and its persistence relates directly to the persistence of the own response of the nonborrowed reserve policy measure, indicating that anticipated monetary policy as well as innovations affect interest rates. Second, the proposed measure of monetary policy disturbances has substantially more explanatory power for interest rates and real output than a pure nonborrowed reserves measure or any other single monetary aggregate based measure, accounting for 49% of the variance in output at the end of two years. Third, the marginal explanatory power of interest rates is substantially reduced in the presence of the proposed measure of monetary policy, accounting for less than 2% of the variance of output at the two year horizon. In this specification nonborrowed reserves Granger cause output while interest rates do not. Fourth, unlike interest rate or pure nonborrowed reserves based measures of monetary policy, accommodative policy leads to a permanent and statistically significant increase in the price level. Fifth, these results are largely insensitive to the details of the contemporaneous modeling of the VARs error structure. The key is to fully span the reserve space in term of both level and mix of reserves, thus allowing for the systematic accommodation of demand innovations. This implies that the key point in identifying monetary policy is using the mix between borrowed and nonborrowed reserves and not the details of the contemporaneous adjustment

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[1]This contrasts sharply with earlier work where it was assumed that the Federal Reserve did not accommodate demand shocks and that innovations in the aggregates or the monetary base could be used as a direct measure of monetary policy disturbances. For examples of empirical research which follow this interpretation see Sims (1972), Barro (1978), Mishkin (1981,1982), and Rush (1986).

[2]In the nomenclature used by the Federal Reserve only the part of reserve demand meet by nonborrowed reserves is usually referred to as accommodation.

process.[3]

The core of the paper is in three sections. Section II discusses the relationship between Federal Reserve operating procedures and the identification of monetary policy innovations. It also develops a new identification scheme for identifying monetary policy innovations in the context of a VAR. Section III reviews the history of Federal Reserve operating procedures and, based on this history, predicts what differences in behavior should correspond to different sub-periods of the data. Section IV presents sub-sample and full sample analysis similar in form to Leeper and Gordon (1992), Sims (1992) and Eichenbaum (1992) using the VAR identification scheme developed in Section II on the data sub-samples outlined in Section III. The appendix analyzes a more general model in which less restrictive identification schemes can be discussed.

II. Federal Reserve operating procedures and the identification of policy

The standard assumption[4] in the identification of monetary policy is that the Federal Reserve controls the supply of total reserves[5] and therefore any innovations in total reserves can be thought of as policy innovations. As a matter of actual practice, the Federal Reserve accommodates innovations in the banking system's demand for reserves. Failing to take account of this policy of accommodation can lead to misleading results. As Sims (1986) put it, "we forgo separating bank behavior from Federal Reserve behavior and thereby also forgo properly separating demand from supply behavior." However, once the analysis takes account of the Federal Reserve's operating procedures, policy disturbances can be identified in a fairly simple manner by using two reserve measures which respond to demand and supply innovations differently. The key assumptions are that ***1.) innovations in the level of total reserves are largely the result of the Federal Reserve's accommodation of innovations in the demand for total reserves and 2.) the Federal Reserve exerts its influence on the reserve markets by altering the mix of borrowed and nonborrowed reserves it supplies to meet current reserve demand.***[6]

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[3]The robustness of the qualitative results is not a matter of theory, it is due to the fact that for industrial production virtually all of the explanatory power, not contained in the own shock, is contained in the linear combination of reserves that the paper identifies as the policy shock. As a result, other contemporaneous identification schemes only reallocate the same basic impulse across 1 to 3 shocks without effecting any of the qualitative results.

[4]See footnote 1.

[5]Usually this is applied to even broader aggregates, such as the monetary base, M1 or M2. For a recent and thorough review of empirical results using this approach see Christiano and Eichenbaum (1992a).

[6]In the Federal Open Market Committee's policy directive, this mix is referred to as " the degree of pressure on reserve positions."

Using assumptions 1 and 2 above, policy innovations can be identified as those changes in the mix of borrowed and nonborrowed reserves which are not the result of the Federal Reserve's accommodation of demand innovations. This can be accomplished by modeling the forecast innovations of both borrowed and nonborrowed reserves as follows. Let ν_s be the policy shock, where an increase in nonborrowed reserves is a positive shock (i.e. an easing action) and where there is an exactly offsetting reduction in borrowed reserves. The assumption that a positive innovation in nonborrowed reserves is exactly offset by a reduction in borrowed reserves guarantees that only innovations in the mix of reserves will be identified as policy innovations.[7] Let ν_d be the reserve demand shock, where ν_s and ν_d are independent. Abstracting from other variables, it follows that the innovation in nonborrowed reserves can be written

$$u_{nbr} = \nu_s + \phi\, \nu_d \ , \tag{1}$$

and that the innovation in borrowed reserves can be written

$$u_{br} = -\nu_s + (1-\phi)\, \nu_d \ , \tag{2}$$

where ϕ is the operating procedure determined split in the accommodation of reserve demand innovations between borrowed reserves and nonborrowed reserves.[8]

Equations 1 and 2 imply that the innovation in total reserves is a pure demand shock. This see this, note that adding equations 1 and 2, produces

$$u_{TR} = \nu_d \ .$$

If this specification is correct, it is easy to see why attempts to use the monetary base or broader aggregates to measure monetary policy might produce misleading results. The monetary base sums the borrowed reserves and nonborrowed reserves shocks as well as the innovation in currency, canceling out ν_s, the policy innovation, while leaving ν_d, the accommodation of the reserve demand shock. The only policy signal

[7]In the appendix a more general model, which encompasses the current specification, is described and analyzed. The general specification allows for feedback both from policy innovations to total reserves and from interest rate innovations to nonborrowed reserves. Thus allowing both for policy to contemporaneously affect total reserves and for the Federal Reserve to follow interest rate smoothing policies. Analysis of the general specification leads back to the specification described below and the key liquidity results are largely invariant to these assumptions, once the reserve mix is identified as the key policy measure.

[8]Of course this is only a linear approximation; operating procedures could specify a non-linear splitting rule. The non-linearities maybe especially important when borrowings levels are very low and the non-negativity constraint on borrowing is binding. This specification also abstracts from the role of the discount rate.

that would be left is determined by how much ν_s affects currency demand contemporaneously.

In this structure interest rates would then be determined by both the supply and demand shocks where

$$u_i = \pi\nu_d + \lambda\nu_s + \nu_{ff}$$

where λ is the liquidity effect of policy actions on interest rates and π is the response of interest rates to reserve demand innovations and ν_{ff} is the interest rate innovation.[9]

To understand why these identifying assumptions described above are reasonable it is helpful to understand some of the perceived rigidities in the process, and also to understand how altering the reserve mix between borrowed and nonborrowed reserves has real effects on interest rates.

First and foremost among these rigidities is the belief that there is very little that either the Federal Reserve or the banks can do to affect the short run level of total reserves. In the most recent Federal Reserve Bank of New York guide to the implementation of monetary policy, U.S. Monetary Policy and Financial Markets, Ann-Marie Meulendyke describes the short run response to a shortfall in reserves that might arise from a contractionary open market operations as follows:

> ...the banks adjustment options to a reserve excess or shortage are in actuality quite limited. Banks confronting a shortage would have several possible options, but most of the options would be impractical to carry out in such a short time period. ... When nonborrowed reserves within a reserve maintenance period are insufficient to meet the demand, the banking system as a whole has no practical alternative to borrowing more reserves at the discount window. ... As banks come to believe that the reduced reserve availability is a deliberate policy move **they will begin** (emphasis added) to make basic adjustments to the pricing of loans and deposits.[10]

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[9] It is useful to note that two different corrections are taking place in this specification. The first is that the specification adjusts for contemporaneous accommodation of total reserve shocks. The second is that this correction shifts the emphasis from the level of total reserves to the mix of nonborrowed to total reserves. While both corrections appear to be useful in identifying monetary policy, it turns out that empirically the shift of focus to the mix of nonborrowed to total reserves dominates the specifics of the contemporaneous identification. How these two effects can be separated will be discussed in detail in the estimation section.

[10] Meulendyke (1989), p.137-138

Meulendyke's assertion that reserve short falls generate increased borrowing from the discount window rather than an actual reduction in the level of total reserves follows from two separate institutional arguments; first, she argues that the demand for required reserves is largely predetermined by current and past deposit levels, and second, she argues that the demand for excess reserves is largely independent of policy. The predetermination of required reserves follows from the belief that banks have extremely limited short run control over the level of deposits held on account and that any operating procedure that attempted to force banks to significantly alter their short run deposit base and hence their short run demand for required reserves would generate unacceptable levels of interest rate volatility. Put in more common terms, the demand for money, which largely determines the demand for reserves, is slow to adjust and has a relatively low short run interest rate elasticity.[11]

The argument that excess reserve demand is largely independent of policy hinges on the nature of excess reserve demand. There is no direct demand for excess reserves only a derived demand due to the costs of managing reserve positions more closely. For large banks the demand for excess reserves is effectively zero. These banks expend considerable resources on managing their reserve accounts and rarely actually hold excess reserves above their carryover allowance[12]. For smaller banks daily reserve flows can be very large relative to the amount of the reserves they actually need to hold for reserve requirements and the costs of closely managing such flows may be deemed excessive relative to the potential gain. Such banks do hold excess reserves and could as a consequence economize on their excess reserves holding in response to a policy action. As noted above, the Federal Reserve views this potential as unimportant empirically. If a bank holds excess reserves only because it is too expensive to control them relative to average interest rates, it is unlikely that is would pay that same bank to manage them in response to 25 basis point policy actions. Further, since the Federal Reserve has purposely attempted to avoid large swings in the Federal Funds market at the end of reserve maintenance periods both by direct accommodation through open market operations and by easier administration of the discount window at the end of reserve maintenance periods, it has minimized any incentives for banks to develop ways of systematically managing excess reserves on a short run basis.

Taken together, the predetermination of required reserve demand and the inelastic demand for excess reserves generate a substantial amount of short run rigidity in the

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[11]See Judd and Scadding (1982) for a survey of money demand articles documenting these phenomena across a wide variety of specifications.

[12]The carry over allowance is the amount of excess reserves banks may carry from one reserve maintenance period to the next, currently 2% of required reserves. Thus, while these reserves appear in the reserve accounts as excess reserves, they are not in fact excess in that they are counted against next period's reserve requirements. There is no direct measure of true excess reserves.

demand for total reserves which should not be underestimated. During the last week of December banks typically do not want to be seen borrowing from the discount window. Discount window borrowings in the final week of the year appear in year-end financial statements and are viewed as signaling financial weakness.[13] This increased reluctance to borrow, in turn, interferes with the normal functioning of the discount window as a safety valve for accommodating unexpected shifts in the demand for reserves. During this week the Federal funds rate has spiked to as high as 100% for individual trades, despite attempts by the Federal Reserve to avoid such spikes. The size of these spikes in interest rates also go a long way toward explaining the Federal Reserve's reluctance to attempt short run control of reserves as well as providing evidence that banks have a very inelastic short run demand for reserves.

Given the perceived inability to control the short run supply of total reserves and the Federal Reserve's "policy" of accommodating reserve shortfalls through the discount window, it is important to understand how altering the mix of reserves between borrowed and nonborrowed reserves has real effects on interest rates. After all, borrowed and nonborrowed reserves both satisfy reserve requirements equally well. The reserve mix matters because banks are reluctant to borrow from the discount window.[14] As a result, if the Federal Reserve fails to provide the necessary reserves to meet reserve demand through open market operations, banks will first try to meet their reserve requirements through the Federal funds markets, thereby bidding up the Federal funds rate. And only when the Federal funds rate has risen sufficiently to overcome banks' reluctance to borrow from the discount window will banks borrow the necessary reserves. This rise in the Federal funds rate will then lead to lower output and to banks and individuals reducing deposit levels in the future. This is sometimes referred to as demand management.

III. A Short History of Federal Reserve Operating Procedures

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[13]This has been especially true in the last few years.

[14]The source of this reluctance to borrow from the discount window is not immediately apparent, especially since reserves acquired through the discount window typically carry a lower explicit interest rate than reserves borrowed through the Federal funds market (i.e. the discount rate is usually below the Federal funds rate). The basic reason for the discrepancy is that individual banks do not have unlimited borrowing privileges and that borrowing through the discount window involves exercising a non-transferable option to borrow again in the near future. Beyond this, the banking system's ability to bypass the restrictions on individual banks' borrowing privileges is severely constrained by the fact that individual banks are not allowed to lend in the Federal funds market and borrow from the discount window at the same time. Thus, a single bank can use the discount window only to make up its own short fall and its gain from doing so is limited the size of its own reserve short-fall times the difference between the current Federal funds rate and the discount rate. See Goodfriend (1983) for a detailed examination of these issues.

Examination of equations 1 and 2 suggests that ϕ should change if the Federal Reserve changes its operating procedures. It should be near 0 under strict nonborrowed reserves targeting regimes and near 1 under strict borrowed reserves targeting regimes. The value of ϕ under mixed regimes will depend on the nature of the mix. In reality, all of the operating procedures covered in the data sample are mixed procedures, though most have been close to strict borrowed reserves targeting. This section describes the history of Federal Reserve operating procedures and develops a set of dates for sub-sample testing in order to examine potential problems with parameter instability in ϕ and other regime shift induced changes. The section also attempts to give the reader a feel for the evolution of the monetary policy process through time and for some of the subtleties of how the procedures were implemented over time. This will provide some useful benchmarks for the interpretations of the sub-sample results presented in Section IV of the paper. For those uninterested in this topic, the last paragraph in this section provides a quick summary.

Broadly speaking, the period from 1959 to the present can be split into five periods. An attempt has been made to define reasonably consistent and homogeneous sub-periods. A lot of judgment is involved in this process. Where dates have attained a place in the literature, such as the "vanishing liquidity" effect that Melvin (1983) suggests began at the end of 1972, the literature date is used, as long as it roughly corresponds to actual operating regime history.[15] A more complete survey of these issues can be found in Meulendyke (1989). The five periods used in this article are as follows:

1959-1966, Free reserves targeting before the modern Federal funds market
1966-1972, Free reserves targeting and the bank credit proviso
1972-1979, Money growth / Federal funds targeting
1979-1982, Nonborrowed reserves targeting
1982-present, Borrowed Reserves/Federal funds targeting

1959-1966

Though the Federal funds market actually dates back to the early 1950s, it was not until the mid-1960s that the Federal funds market and reserve management began to resemble their modern equivalents. Meulendyke (1989) describes this as follows:

> The interbank market was not very broad as the 1960s began, but activity was expanding. Until the mid-

[15]In order to make sure that none of the empirical results presented later are dependent on specific dates, a grid search of 12 months on each side of every proposed date was performed for all dates except the 1979 and 1982 dates. Only dates after October 1979 and before October 1982 were checked. No sensitivity to dates over these ranges was uncovered.

> 1960s, the Federal funds rate never traded above the discount rate. During "tight money periods," when the desk was fostering significant net borrowed reserve positions, funds generally traded at the discount rate, and the funds rate was not considered a useful indicator of money market conditions. ... There was considerable surprise when the funds rate first rose above the discount rate briefly, in October 1964 and more persistently in 1965. As large banks became more active managers of the liability side of their balance sheets, they borrowed funds in the market in a sustained way.[16]

As a result, the pre-1966 period may be different than subsequent periods. The reserves market simply worked in a different fashion than it does today. Basically, this period was characterized by free reserves targeting. Free reserves are the negative of borrowed reserves plus excess reserves (-BR+ER). Free reserves targeting is a variant of borrowed reserves targeting with explicit accommodation of excess reserves (ϕ should be approximately equal to 1). In the modern form of borrowed reserves targeting the accommodation of excess reserves is implicit. The Federal Reserve had no quantitative operating targets during this period and the desk in New York simply sought to stabilize general money market conditions[17], in line with the FOMC's directives.

1966-1972

The modern era begins in 1966. The period from 1966 through 1972 was still characterized by a free reserves operating procedure, but the Federal funds market had begun to perform the same function it does today as a major source of bank liquidity. This period was also marked by the introduction of the "proviso" on bank credit into the FOMC's policy directive. The proviso stated that if bank credit growth deviated significantly from target then the desk could adjust the Free Reserve target "modestly." Brimmer (1971) argues that this shift to a quantitative goal for the operation of monetary policy was a major landmark for Federal Reserve operating procedures, which he labels "The Reform of 1966." As mentioned earlier, before this shift, there were no quantitative objectives. Brimmer also argues that this signaled a substantial increase in the role of monetarist thought within the FOMC. This period ended in the early 1970s as monetary aggregates slowly replaced bank credit as the

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[16]Meulendyke (1989), p. 36-36

[17]Money market conditions can be thought of as a very loose combination of interest rates and reserve pressures thought to relate to the general availability of credit.

main focus of long run policy and the Federal funds rate began to replace free reserves as the main operating focus. In general, the Federal Reserve was still stabilizing general money market conditions and was still accommodating reserve demand shocks through nonborrowed reserves. Again, ϕ should be close to 1 during this period.

1972-1979

It is interesting to note that the shift from the free reserves targeting of the previous period to the Federal funds targeting of the 1972-1979 period was not viewed as a major event. Borrowings targets and Federal funds rate targets are quite similar in practice, though the dynamics are not quite identical. Stable borrowing levels usually imply stable interest rates. The difference in procedures only becomes evident when there is a shift in the borrowings function. In a free reserves targeting procedure a shift in the borrowings function will cause interest rates to change. In a Federal funds rate targeting procedure, the reserve mix will be adjusted to exactly offset the shift in the borrowings function and keep the funds rate steady. Thus, ϕ should be less than 1, but closer to 1 than 0 during this period.

This period is dated as beginning at the end of 1972, following Melvin (1983).[18] The Federal funds rate targeting procedure was not actually made public in the FOMC's policy directive until 1974, though it could be argued that the switch occurred earlier. Brimmer (1971), for example, dates the shift to September of 1970. Meulendyke (1989) suggests that while the change began in the early 1970s, its implementation was gradual, lasting until the mid to late 1970s. The ambiguity arises from the fact that the period was characterized by progressively tighter targeting of the Federal funds rate rather than an abrupt shift to strict Federal funds targeting. It was still very much a borrowing reserves targeting type of procedure, except that the operating procedures automatically adjusted for shifts in the borrowings function by stabilizing the Federal funds rates. These operating procedures were in use until 1979 when nonborrowed reserves targeting was introduced. In general, much of the motivation for the 1979 change resulted from a conviction that the preoccupation with keeping interest rates stable that had developed in the 1972-1979 period had created an inflationary bias in the application of policy and that only by allowing substantially more interest volatility could inflation be tamed. Similarly, monetary growth was regularly exceeding target growth ranges due to an unwillingness to raise interest rates enough.

1979-1982

During this period the Federal Reserve adopted a nonborrowed reserves operating

[18]Melvin (1983) actually cites the collapse of Bretton Woods as the precipitating event.

procedure in order to assert greater control over the money stock. Nonborrowed reserves targeting was the most complicated of the reserve operating procedures that the Federal Reserve has ever used and it lasted the shortest length of time. This operating procedure, in fact, targeted neither nonborrowed reserves or any other reserve aggregate in any straight forward way. Considerable debate within the Federal Reserve system about how these procedures actually worked is still going on. Despite the avowed intention of controlling money, the Federal Reserve missed its money targets more in this period than in any other before or since. On the other hand, numerous studies, such as Spindt and Tarhan (1987) and Strongin and Tarhan (1990), show that the desire to control money played a large role in the conduct of policy. Financial deregulation and a general increase in economic volatility make it very difficult to sort out exactly what happened during this period. What is clear is that Federal Reserve operating procedures were quite different during this period than in any other, and that little if any effort went into stabilizing either borrowings or interest rates. Therefore, ϕ should clearly be less than 1 during this period.

The basics of the procedures were quite simple. Short run money growth targets were established at each FOMC meeting. Nonborrowed reserves targets consistent with these money targets were then derived. The nonborrowed reserves targets were then revised each week in order to bring money back to path. If money growth was above target, the nonborrowed reserves path was lowered. This meant that short run fluctuations in money and the resulting total reserves movements were being used by the Federal Reserve to determine future nonborrowed reserves targets (i.e. nonborrowed reserves targets changed each week in response to last week's reserve demand shock) and the market used this same information to forecast future Federal Reserve actions and interest rates [see Strongin and Tarhan (1990)]. Thus, total reserves movements contained information on future Federal Reserve actions that had contemporaneous effects on interest rates due to Federal Reserve actions that had not yet been taken. This interaction between reserve demand shocks and policy could potentially cause the total reserve variable to absorb more of the policy signal over this period than any other. There are a number other potential problems with this period. First, there is very little data; the operating procedures lasted only 3 years. Second, the first six months of this period are suspect, in that it took a while to develop and implement the new operating procedures. And third, the last six months are equally suspect, because dissatisfaction with the procedures led the FOMC to accept larger and larger deviations from its short run money targets during 1982 until borrowed reserves targeting was officially adopted in October of 1982.

1982-present

After October of 1982, the Federal Reserve adopted a borrowed reserves targeting procedure, where the borrowing target changed only by policy action rather than in response to reserve demand shocks. During this period ϕ should be close to 1. The operating procedures in this period are very similar to the procedures in force in the early 1970s, except that the Federal Reserve has shown much more willingness to change the Federal Funds rate.

A note on interest rate volatility

As an additional note, something should be said about the Federal Reserve's attitudes toward interest rate volatility across these periods. This is not an easy task in the sense that the Federal Reserve typically does not have a specific policy toward interest rate volatility per se. Nevertheless, the Federal Reserve's attitudes toward interest rate volatility have undergone some large shifts over the years. Beginning in the early 1970s, the Federal Reserve began to look upon interest rate stabilization as an end in itself, and the target ranges for the Federal funds rate became progressively smaller. Earlier periods had emphasized the stability of overall money market conditions. The 1979 shift was in large part a rejection of the interest rate smoothing goal and interest rate volatility was no longer avoided. As the monetary control experiment ended in 1982, dissatisfaction with the large amount of interest rate volatility that nonborrowed reserves targeting had created was one of the strongest factors in the rejection of continued nonborrowed reserves targeting. The 1982-1991 period has once again seen increasingly narrow ranges for Federal funds rates, though the target ranges are moved more often than in the 1972-1979 period. Thus, 1972-1979 and 1982-1991 periods stand out as having interest rate smoothing as a relatively important Federal Reserve operating goal, especially the 1972-1979 period. The 1979-1982 period stands out as being by far the least concerned with interest rate smoothing. The implications of these changes in attitude are not obvious for reserve management, but it is likely that if a significant percentage of reserve actions were aimed at stabilizing interest rates, it might dampen observed interest rate effects of policy.

By and large one would expect to see differences between periods, but only the 1979-1982 period represents a major shift in operating procedures. All of the other operating regimes are variants of borrowed reserves targeting and Federal funds rate targeting, which in the course of Federal Reserve history have tended to blur into each other and are both characterized by ϕs much closer to 1 than 0, though 1972 to 1979 should have the lowest ϕ of these periods due the heavy emphasis on interest rate targeting. Within the literature, Melvin (1983) suggests that 1973-1979 has a diminished liquidity effect, and Cochrane (1989) finds it reappeared in 1979. However, most work finds little or no liquidity effect in any of these periods [see Reichenstein (1987) for a survey of this work]. Further, it is also clear the 1972-1979 is characterized by the greatest desire to smooth interest rates, while 1979-1982 is characterized by the least desire to smooth interest rates.

IV. Estimation and results

Estimating the specification outlined in Section II is actually very easy. Noting that the forecast innovation in total reserves is v_d, v_s can be identified simply by having total reserves immediately precede nonborrowed reserves in a standard Choleski decomposition. Once this is done v_s can be identified as the orthogonalized error in the nonborrowed reserves equation.[19] Normalizing total reserves and nonborrowed raises a question since the normal method of using log levels would violate the linear identification developed in Section II. In the results that follow total reserves and nonborrowed reserves are both normalized by the level of total reserves in the prior month, i.e. both are divided by the lag of total reserves. This preserves the strict linear identification formulated in Section II. Also, by explicitly including a reserve mix variable (i.e. nonborrowed reserves divided by the lag of total reserves) in the specification, it is easier to examine issues involving the persistence of policy shocks and the effects of anticipated policy actions.[20] **More importantly by explicitly using a measure of the mix of nonborrowed to total reserves (NBRX) it is possible to separate the contemporaneous modeling of reserve accommodation from the observation that the Federal Reserve influences interest rates through controlling the mix rather than the level of reserves.** This turns out to be important in analyzing the impact of policy innovations on output since the results presented hinge critically on the reserve mix, but are fairly robust to specification of the contemporaneous error structure. In fact, as we will see, eliminating the total reserve shock entirely has only a second order impact on the system as long as the nonborrowed to total reserve mix is used to identify policy rather than rather than a variable which relates to the level of reserves. A direct implementation of the specification from Section II in levels would simultaneously implement both aspects of the identification scheme making it impossible to assess which was more important. The proposed specification has the addition technical benefits of allowing easier analysis of policy persistence.

The results are presented in two subsections, Sub-sample analysis and Full sample analysis. The Sub-sample analysis section analyzes the liquidity effect in each of the sub-samples enumerated earlier. Two sets of VARs are presented for each sub-sample. The first are three variable VARs containing TR (total reserves), NBRX (the nonborrowed reserves mix)[21] and FF (the level of the Federal funds rate) in that

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[19]The essential point is that by projecting nonborrowed reserves on total reserves, the policy disturbances can be extracted from the Federal Reserve's accommodation of reserve demand shocks. This is easily done in the context of sequential OLS estimations or structural VARs.

[20]A number of other normalizations and linear approximations were also examined, including simply using logs for both reserve series and a variety of demand and mix variables, where a mix variable is some variable that measures the mix of reserves as opposed to the demand for total reserves. The general notion is that a reserve demand proxy must precede a reserve mix variable. Variable choice made very little difference on the qualitative results analyzing the impact of the decomposed errors.

[21]The nonborrowed reserve series is adjusted for extended credit and so-called special borrowing. These are borrowing programs which supply reserves to banks on an extended basis and do not involve the using up the borrowing privilege discussed earlier. These reserves are implicitly treated by the open

order. Data for TR and NBRX are seasonally adjusted and adjusted for reserve requirement changes. TR and NBRX as noted above are divided by the level of total reserves in the prior month. The data is all monthly and the data sample begins in January 1959 and ends in February of 1992. The second group of monthly VARs presented are 5 variable VARs. These VARs contain IP (the log of industrial production) and CPI (the log of the consumer price index) preceding TR, NBRX and the Federal funds rate in the Wold causal ordering.[22] The ordering of TR, NBRX, and the Federal funds rate is dictated by the identification scheme developed in Section II. IP and CPI are placed first, so that policy can respond to on going events.[23] This ordering is also consistent with Sims (1992), Eichenbaum (1992) and Christiano and Eichenbaum (1992a and 1992b). All sub-sample VARs were run with 6 lags of data. (Longer lags were also estimated in those cases where there was a sufficient number of observation to perform a reasonable estimation with little difference in results.) All innovations discussed are the orthogonalized innovations from the ordering described above. The first set of VARs correspond most closely to the liquidity puzzle literature and most of the important results about the liquidity effect can be seen in this first set of VARs. The second set is presented to demonstrate the robustness of the results to more complicated systems and to provide a bridge to the third set of VARs presented in the Full sample subsection. The Full sample analysis subsection uses the same data as the 5 variable VARs, but uses 12 lags of data. This subsection emphasizes the identification of monetary policy and the assessment of its impact on the economy.

Sub-sample analysis

Figures 1 and 2 show the impulse responses of TR, NBRX, and FF to TR and NBRX innovations. The error bands are plus and minus 2 sigma bands and are generated by Monte Carlo techniques. Each column shows one impulse response function for each of the five time periods. Figure 1 contains the responses to TR innovations and Figure 2 the responses to NBRX innovations, the proposed policy measure. The reserve to reserve impulse response functions are the response to a one percent innovation in reserves. This is done so that initial values are interpretable as ϕ. All other impulse response functions are the response to a one standard deviation shock. Table 1 shows the estimates of ϕ and its standard error and the concurrent period

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market desk as nonborrowed reserves. This has no impact prior to the 1980s and has only marginal impact since. The adjustments simply eliminate outliers that result from episodes such as the failure of Continental Bank.

[22]There are a number of structural VARs that could easily be estimated, based on Sims (1986). Such models were estimated and provide very similar results. The Wold ordering results are presented for simplicity and for comparability to previous results. Differencing IP and CPI also generates similar results. The general question of identification is addressed in the appendix.

[23]The placement of CPI and IP in the Wold ordering is not important.

estimate of the liquidity effect for a one standard deviation shock in NBRX on the FF and its standard error for each sub-period. Table 2 shows the decompositions of variance for the effect of NBRX innovations on TR and the Federal funds rate and the decomposition of variance of TR innovations on the Federal funds rate for the end of year 1 and 2 (standard errors are in parentheses).

The key results are that for each and every sub-sample there is a clear liquidity effect and it is always negative and highly significant. Further, the persistence of NBRX shocks varies considerably across sub-samples and so does the persistence of the liquidity effect on interest rates (more on this later). The TR or reserve demand shock has the opposite sign on interest rates and thus reflects the "normal" perverse result in the literature, suggesting that previous specifications have often confused reserve demand shocks with policy disturbances. It also shows why the use of broader aggregates often leads to the absence of an estimated liquidity effect.

Also of interest is the response of TR to NBRX innovations and of NBRX to TR innovations. First, there is a strong contemporaneous impact of total reserves on NBRX implying that ϕ is clearly not zero and that the reserve demand correction is statistically and quantitatively important. Second, other than this contemporaneous effect, NBRX and TR are not strongly related. This suggests that the ability to pick up policy innovations from TR or the monetary base (to say nothing of the broad aggregates) is likely to prove extremely difficult. In addition, it is likely that even for relatively long sampling periods, such as quarterly or annually, NBRX is likely to remain a significantly better measure of monetary policy than a broad aggregate, even when used in isolation.[24]

Another very important implication of these impulse response functions taken as a group concerns how the persistence in NBRX's response to policy disturbances relates to persistence in the estimated liquidity effect. The more persistent NBRX's response is, the more persistent the liquidity effect is, suggesting that anticipated movements in NBRX are quite important. In fact, careful examination of the "Effect of NBRX on NBRX" graphs in comparison with the "Effect of NBRX on FF" graphs shows a remarkable similarity, sub-period by sub-period. If NBRX's response to an NBRX innovation damps, FF's response to an innovation in NBRX damps. If NBRX's response to an innovation in NBRX changes sign n periods in the future, FF's response also changes sign approximately n periods in the future. This is true for every sub-period with shapes matching in each case. This suggests that Federal Reserve actions have significant effects on interest rates, regardless of the policy regime and the degree to which Federal Reserve actions are anticipated.

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[24]In alternate specifications which include money it is clear that total reserve shocks are largely technical arising from instabilities in the reserve multiplier. This follows from the fact that while NBRX is useful for forecasting money, TR has only limited ability to forecast future money growth. Impulse response functions for a typical six variable VAR with money are included in the appendix.

Table 1 indicates that ϕ varies across time in line with the expectations outlined in Section III. For the borrowed reserves targeting periods, 1959-1966, 1966-1972 and 1982-1991 the values are in the .95 range and are statistically indistinguishable from 1. In the Federal funds targeting period, 1972-1979, and in the NBRX targeting period, 1979-1982, ϕ is .656 (.167) and .546 (.296), respectively, indicating much more mixed operating procedures, though in no case would the hypothesis of a pure borrowed reserves targeting operating procedure be rejected. Table 1 also shows that in sharp contrast to Leeper and Gordon (1992) and most of the previous literature there is a strong negative impact on FF from a positive innovation in monetary policy as measured by the innovation in NBRX in each and every sub-period. This estimated liquidity effect is strong, immediate and statistically significant in all sub-periods. Consistent with previous findings[25], the liquidity effect is especially strong in the 1979-1982 sub-period, nearly 5 times greater than for any other sub-period; however, given the very short sample period, one should not be make too much of this result.

Table 2 provides some evidence that the Federal Reserve's attitude toward interest rate smoothing is important. Specifically, Table 2 shows that in the two periods where interest rate smoothing was of the greatest interest -- 1972-1979 and 1982-1991 -- NBRX innovations had the least impact on interest rates. Similarly, the largest explanatory power was in the 1979-1982 period, when the least attention is being paid to interest rate smoothing. Overall these results show a very strong correspondence to the history of operating procedures covered in Section III.

Table 3 shows the estimate for ϕ and its standard error and the concurrent period estimate of the liquidity effect for the NBRX innovations on the Federal funds rate and its standard error for each sub-period for the five variable system. The estimates of ϕ are similar to those shown in Table 1 and are still within 2 standard deviations of 1. The estimated liquidity effects are slightly smaller in magnitude in all 5 cases, only in the 1979-1982 period is the change significant. Nevertheless, the estimated liquidity effects are still negative and highly significant in all sub-periods.

Table 4 shows for the five variable VARs the decompositions of variances reported in Table 2. These results are generally consistent with the results shown in Table 2, though in most cases the explanatory power is lower. The greater uncertainty associated with point estimates of the decompositions of variance suggest that none of these differences are significant. Figure 3 shows the impact of TR and NBRX innovations on the Federal funds rate for all the sub-periods as well as the NBRX own effect, so that we can examine the persistence result shown in the three variable case. Once again it is clear that the persistence of NBRX's response to a policy shock is directly related to the persistence of the liquidity effect, indicating that expected

[25]Cochrane (1989) and Strongin and Tarhan (1990)

policy actions matter.

The Full sample analysis

The full sample five variable VAR reinforces these general results. Figure 4 shows the complete impulse response functions to one standard deviation shocks for the five variable system estimated over the full sample in line with Sims (1992) and Eichenbaum (1992). The overall results in Figure 4 are consistent with the previous sub-sample analysis. They also meet Sims' and Eichenbaum's criteria for a good measure of monetary policy. Real output effects are positive, statistically significant and persistent in levels, but not in changes. Total reserves rise in response to an easing action. Early price effects are highly uncertain and near 0, though the point estimates are negative; however, the long run price effect are positive and significant.[26] TR innovations have a strong positive and persistent impact on the price level indicating that to the extent that money is allowed to grow, inflation rises. This suggests that passive behavior on the part of the Federal Reserve may have important implications for long run inflation, which is quite consistent with the monetarist position that inflation is not the result of transient policy actions, but the result of persistent biases in the application of the efforts to smooth interest rates and output. Again, it should be noted that TR innovations have positive, but imprecise effects on the Federal funds rate. These effects are consistent, not with supply innovations, but with reserve demand shocks.

The decompositions of variance for the full sample VAR are presented in Table 5. NBRX innovations, the proposed monetary policy measure, account for 49% (std. dev. 10.04) of the variance of IP at the end of two years. This compares with only 0.4% using Eichenbaum's (1992) specification that uses only the log of NBRX without the reserve demand correction (The main results for Eichenbaum's specification are shown in Table 6. DNBR is the log level of nonborrowed reserves with the extended credit and special borrowings corrections.) NBRX innovations also account for 26% (std. dev. 6.76) of the variation in the Federal funds rate at the end of 1 year, as opposed to Eichenbaum's 11% (std. dev. 5.63). More importantly, the residual explanatory power of interest rates to explain IP variance at the end of two years falls from 36% (std. dev. 11.8) in Eichenbaum's specification to only 0.23% (std. dev. 1.91) in the proposed specification.

On the other hand, NBRX has virtually no explanatory power for either TR or CPI, which as stated before is consistent either with the notion that most policy actions at the monthly frequency do not represent innovations in long run policy goals for either prices or the monetary aggregates or that the impact of policy on inflation has long

[26]The graphs do not show enough time span for the price effects to become significantly positive, which happens around a 5 year horizon.

lags. However, positive innovations in TR generate a significant and persistent positive impact on the price level, suggesting that the Federal Reserve's passive accommodation of reserve demand has a more immediate impact on inflation, although the decompositions of variance suggest that this has not been a very important factor, only explaining about 11.76% (std. dev. 8.15) of the variance of CPI at the two year horizon. Perhaps what is most striking about the results in Table 5 is the general lack of explanatory power in interest rates innovations once TR and NBRX are taken account of.

There is an additional important point about alternative identification schemes that is evident in Table 5, but is even more clear in Table 6. Many questions about the very strong assumptions made in the identification scheme proposed in this paper can be reduced down to a very simple question with careful examination of the decomposition of variance. The three variables in this system that can be reasonably assumed to have some explanatory power for output based on monetary policy are TR, NBRX and FF. In fact, as noted earlier, each of these variables has been suggested as the one true measure of policy. If the question of VAR identification was redefined along the line of canonical correlations, we could ask what linear combination of these variables has the most explanatory power for industrial production. In general such a combination would not have any economic interpretation. In the present case, examination of either Table 5 or 6 shows that this best linear combination would be the NBRX-ϕTR, the exact combination suggested as a measure of policy. This correspondence follows from the fact that the explanatory power of the FF and TR shocks are effectively 0. The very low explanatory power of TR and FF (always less than 2% regardless of horizon) also indicates that there is only one shock of any significance for IP contained in the linear space defined by TR, NBRX and FF. The clear implication of this is that all any of various possible alternate identification schemes can do is redistribute the explanatory power of this one shock. Thus, the only real identification question is what should NBRX-ϕTR be called. Any other shock constructed from these innovations would either be uncorrelated with output or just relabeled NBRX-ϕTR. As the earlier part of the paper argues, there are strong institutional reasons to argue that monetary policy is the correct label for NBRX-ϕTR.

Table 6 shows the way explanatory power for IP can be reassigned by various Wold orderings. It also shows two alternate 4 variable VAR systems. Alternate model 3 which shows a NBRX specification without TR and Alternate model 4 which shows Eichenbaum's suggested specification. As can be seen there is only a small loss in explanatory power from dropping TR. However, there is a much larger loss when the change in nonborrowed reserves (DNBR) is used. Clearly the mix is the key concept.

As a point of comparison to previous work, Granger F-tests show that NBRX Granger causes output (F-statistic=2.73, P-value=.001), while interest rates do not (F-statistic=.95, P-value=.49).[27] This is in contrast to Eichenbaum (1992) or Litterman and Weiss (1985), where interest rates Granger cause output, but an uncorrected NBRX measure or any other aggregate does not. For instance, in the Eichenbaum specification, which uses the log of nonborrowed reserves and does not include total reserves, the F-test for nonborrowed reserves is 1.45 (P-value=.14) and the F-test for interest rates is 2.90 (P-value=.009).

V. Conclusion

This paper examined recent work on the identification of exogenous monetary policy disturbances by Sims (1992) and Eichenbaum (1992), as well as Sims (1980) and Litterman and Weiss (1985). The main finding is that the anomalies documented by these authors reflected their failure to properly take account of the Federal Reserve's policy of accommodating short run reserve demand disturbances. This, in turn, leads them to misidentify demand shocks as supply shocks. A new method of identifying the actual supply shocks is proposed and estimated. The new measure of monetary policy disturbances is used to successfully address all of the difficulties normally encountered in attempts to measure policy disturbances that were listed in the introduction. Specifically, a positive innovation in nonborrowed reserves adjusted for reserve demand shocks has a strong and persistent negative effect on interest rates regardless of sub-sample and conditioning variables. Second, unlike Sims (1992) but in line with Eichenbaum (1992), there is no persistent and significant positive price impact from a contractionary policy disturbance. There is, however, a positive persistent price effect from the Federal Reserve's accommodation of reserve demand shocks. Third, using the proposed specification, NBRX Granger causes output even in the presence of interest rates and innovations in NBRX explain approximately 49% of the variance in output over a 2 year horizon. Fourth, the proposed measure of policy contains all of the explanatory power for industrial production contained in total reserves nonborrowed reserves and interest rates. Finally, the paper finds strong evidence that the liquidity effects are persistent and that the persistence is directly related to the persistence of nonborrowed reserves' response to an innovation in policy. This suggests that even anticipated accommodative policy actions have a substantial negative impact on interest rates.

[27]Using the levels specification can cause problems in Granger causality tests; however, if IP and CPI are differenced the results are even stronger. The F-statistic for NBRX Granger causing output is 3.45 with a P-value of .017, while the F-statistic for FF Granger causing output is 1.48 with a P-value of .22. Sub-sample results are inconclusive due to a lack of precision, but they maintain the qualitative result that NBRX is more important than FF.

Appendix

The key identifying assumption used in the paper is that policy innovations in nonborrowed reserves are exactly offset by changes in borrowed reserves. This is equivalent to assuming that policy has no short run effects on the supply of total reserves. To more fully understand what happens if this assumption is relaxed, we need a more general form of the specification in the paper. Also it is generally argued that the Federal Reserve seeks to smooth interest rates in the short run. To incorporate these two features, let the forecast innovation in total reserves be represented as

$$u_{tr} = \nu_d + \gamma \nu_s \,,$$

and the forecast innovation in nonborrowed reserves be represented as

$$u_{nbr} = \phi \, \nu_d + \nu_s + \theta \nu_{ff} \,,$$

where γ is the degree to which policy actions in nonborrowed reserves are reflected contemporaneously in total reserves, θ is the interest rate smoothing parameter and ϕ is the operating procedure determined split in the accommodation between borrowed reserves and nonborrowed reserves in response to a reserve demand shock. The relevant range for γ is from 0 to 1. As long as γ is greater than 0, a reserve drain (a negative policy impulse) will cause total reserves to fall contemporaneously. Negative values would indicate that reserve drains lead to increases in the supply of reserves. Values above 1 would indicate that reserve injections cause banks to borrow more. Neither of these possibilities are sensible. Setting γ and θ to 0 reproduces the model used in the paper. Setting $\gamma >> 0$ would recreate the normal model in the literature where innovations in supply are fully reflected in total reserves. Interest rate smoothing requires that θ, the interest rate smoothing parameter, be positive. A negative value for this coefficient would imply that the Federal Reserve was seeking to generate volatility in interest rates.

Clearly, this more general model is under-identified. Nevertheless, there is a reasonable estimation strategy, at least with respect to γ. If we take as given the notion that we are identifying supply and demand shocks and that positive demand shocks cause interest rates to rise and positive supply shock cause rates to fall, then we can set γ such that the contemporaneous effect of an innovation in supply has as the maximum negative impact on FF. This adds an identifying assumption of a type not normally useable in a VAR context. If the specification suggested in the paper is correct then within the constrained space the minimum should occur at $\gamma=0$. If, as is normally assumed, total reserves are exogenous then the minimum should occur for γ significantly greater than 0. The interest rate smoothing parameter, on the other hand, is not subject to a similar method of identification and must be treated as a conditioning parameter, though as it turns out results are not particularly sensitive to reasonable choices for this parameter.

Figure 5 shows the result of parameterizing γ and θ over the relevant ranges specified above for the key liquidity effect parameter, λ[28]. This was accomplished by solving the quadratic form linking the sample covariance and the structural system. This is substantively different than the standard structural VAR approach in which the restrictions are placed on the relationship of forecast errors to each other. Here, the restrictions are on the parameters which link structural errors to the forecast errors (i.e. restrictions on A_0^{-1} in the standard nomenclature rather than on A_0). As can be seen λ is everywhere negative, ranging from a value of -15 to -35. It can also be seen that λ is minimized when γ equals 0[29], as predicted by the model. It can also be seen that assuming moderate amounts of interest rate smoothing would only increase the impact of policy on interest rates. Thus, unless interest rate smoothing were to be viewed as the major focus of Federal Reserve policy the presented results would hold up almost exactly as stated, perhaps with a slight increase in the estimated liquidity effects. Further, we can infer from the canonical correlation interpretation of NBRX-ϕTR that interest rate smoothing cannot be a first order issue; however, to fully explore this issue it is useful to take a look at a model which takes interest smoothing as the key goal of monetary policy. This would be similar in spirit to Bernanke and Blinder(1992).

Specifically, "Alternate Model 2" from Table 6, where FF precedes the reserve series, can be viewed as the extreme interest rate smoothing model. In such a system the innovation in FF would be policy (as in Bernanke and Blinder (1992)) and the innovation in NBRX would due to shifts in the borrowings function. Such a model runs into serious contradictions seeking to explain why the remaining innovation in NBRX still has such large explanatory power for IP, 35% at a two year horizon, which strongly exceeds FF at 11.5%. Further, it is difficult to understand why shifts in the borrowings function would produce impulse response functions of the type shown in Figure 7, which look just like the original NBRX impulse response functions, especially the interest rate response which still shows lagged effects on interest rates. This, as stated above, is not at all surprising given the canonical correlation interpretation of NBRX-ϕTR, which strongly indicates that interest rate smoothing can only be of second order importance.

A final point on the impact of alternate specification on impulse response functions

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[28]Figure 5 shows the entire constrained manifold in which the original specification is embedded. Values outside of this range are either rejected by theory as specified or cannot produce the sample covariance regardless of how the other coefficients are set. The solution method used is based on ongoing work with Tom Gittings and Mark Watson. At the fringes of the manifold, parameter values become complex.

[29]The global minimum for λ occurs when $\gamma = -.0883$ and $\theta=.003$ in which case $\lambda=-39.2$.

is in order. As would be suspected from the analysis of decomposition of variances in the paper, alternate specifications do not have much impact on the NBRX impulse response functions, they simply transfer approximately proportional variants of NBRX's impulse response functions to FF and TR and add noise to the NBRX shock. This is, in fact, the case, as can be seen in Figures 6-8 which show the impulse response functions for the alternate NBRX models in Table 6, in order. Figure 9 shows a slightly larger system in which M1 is included. The only point to this expanded system is to show how little impact the inclusion of money has, the lack of a strong short run relationship with TR, and that NBRX innovations generate permanent increases in the money supply.

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TABLE 1

3-VARIABLE VARS BY PERIOD

	ϕ	Contemporaneous Effect of NBR on FF
1959-1966	0.920	-0.073
	(0.103)	(0.027)
1966-1972	0.951	-0.143
	(0.108)	(0.033)
1972-1979	0.656	-0.180
	(0.167)	(0.043)
1979-1982	0.546	-0.590
	(0.296)	(0.097)
1982-1991	0.909	-0.090
	(0.054)	(0.041)

NOTE: Numbers in parenthesis are standard errors.

TABLE 2

DECOMPOSITION OF VARIANCE USING 3-VARIABLE VARS

1959-1966	NBR→TR	TR→FF	NBR→FF
End of year 1	12.59	1.79	37.22
	(6.20)	(5.62)	(14.22)
End of year 2	12.47	1.50	31.35
	(6.46)	(5.68)	(15.13)
1966-1972			
End of year 1	6.42	3.79	48.51
	(4.86)	(6.92)	(18.07)
End of year 2	6.69	3.91	46.26
	(5.64)	(7.38)	(17.41)
1972-1979			
End of year 1	7.62	29.33	27.32
	(5.43)	(15.16)	(15.12)
End of year 2	7.96	30.42	18.19
	(6.22)	(16.32)	(16.97)
1979-1982			
End of year 1	22.91	33.32	54.17
	(10.55)	(12.72)	(13.17)
End of year 2	27.49	34.13	53.50
	(12.84)	(13.31)	(13.30)
1982-1991			
End of year 1	6.65	0.57	25.88
	(5.52)	(6.27)	(16.76)
End of year 2	6.64	0.40	22.10
	(6.74)	(9.72)	(18.81)

NOTE: Numbers in parenthesis are standard errors.

TABLE 3

5-VARIABLE VARS BY PERIOD

	ϕ	Contemporaneous Effect of NBR on FF
1959-1966	0.922	-0.072
	(0.094)	(0.021)
1966-1972	1.113	-0.082
	(0.132)	(0.024)
1972-1979	0.714	-0.129
	(0.140)	(0.031)
1979-1982	0.671	-0.343
	(0.184)	(0.046)
1982-1991	0.888	-0.051
	(0.065)	(0.025)

NOTE: Numbers in parenthesis are standard errors.

TABLE 4

DECOMPOSITION OF VARIANCE USING 5-VARIABLE VARS

1959-1966	NBR→TR	TR→FF	NBR→FF
End of year 1	17.25 (5.39)	3.06 (4.63)	43.20 (11.77)
End of year 2	17.33 (5.54)	2.67 (4.64)	46.18 (12.16)
1966-1972			
End of year 1	4.79 (4.53)	2.67 (5.95)	19.06 (11.28)
End of year 2	5.09 (5.63)	2.60 (6.45)	26.63 (13.85)
1972-1979			
End of year 1	6.01 (4.60)	13.20 (11.82)	7.92 (6.64)
End of year 2	6.15 (5.12)	10.89 (10.99)	8.09 (6.72)
1979-1982			
End of year 1	8.98 (4.02)	60.68 (13.68)	15.11 (6.48)
End of year 2	8.65 (4.39)	52.54 (14.70)	9.89 (5.12)
1982-1991			
End of year 1	5.49 (4.06)	6.17 (8.69)	4.96 (4.95)
End of year 2	7.57 (5.81)	12.51 (12.72)	11.58 (8.66)

NOTE: Numbers in parenthesis are standard errors.

TABLE 5

DECOMPOSITION OF VARIANCE FOR ALL VARIABLES
USING 5-VARIABLE VAR (1959-1991)

Variance explained by	End of year 1		End of year 2	
Equation IP				
IP	83.84	(6.66)	48.96	(10.04)
CPI	0.30	(1.28)	3.81	(4.15)
TR	0.87	(2.35)	0.64	(2.89)
NBR	14.77	(5.96)	46.36	(10.03)
FF	0.22	(1.36)	0.23	(1.91)
Equation CPI				
IP	18.98	(7.44)	25.87	(10.28)
CPI	65.26	(8.89)	59.42	(11.57)
TR	8.87	(5.40)	11.76	(8.15)
NBR	4.06	(3.94)	1.87	(3.28)
FF	2.83	(2.83)	1.08	(2.64)
Equation TR				
IP	2.91	(1.67)	3.21	(1.75)
CPI	5.02	(2.25)	6.28	(2.58)
TR	83.58	(3.45)	80.60	(3.96)
NBR	2.54	(1.58)	3.23	(1.76)
FF	5.95	(2.23)	6.68	(2.46)
Equation NBR				
IP	27.44	(7.31)	31.26	(7.66)
CPI	4.37	(3.20)	4.22	(3.13)
TR	12.69	(3.91)	12.65	(4.75)
NBR	53.77	(6.89)	49.75	(7.05)
FF	1.73	(1.61)	2.13	(2.56)
Equation FF				
IP	40.29	(8.36)	45.73	(9.40)
CPI	2.50	(2.82)	4.48	(4.91)
TR	8.48	(5.72)	11.66	(8.44)
NBR	25.95	(6.76)	18.24	(5.91)
FF	22.78	(5.69)	19.90	(6.90)

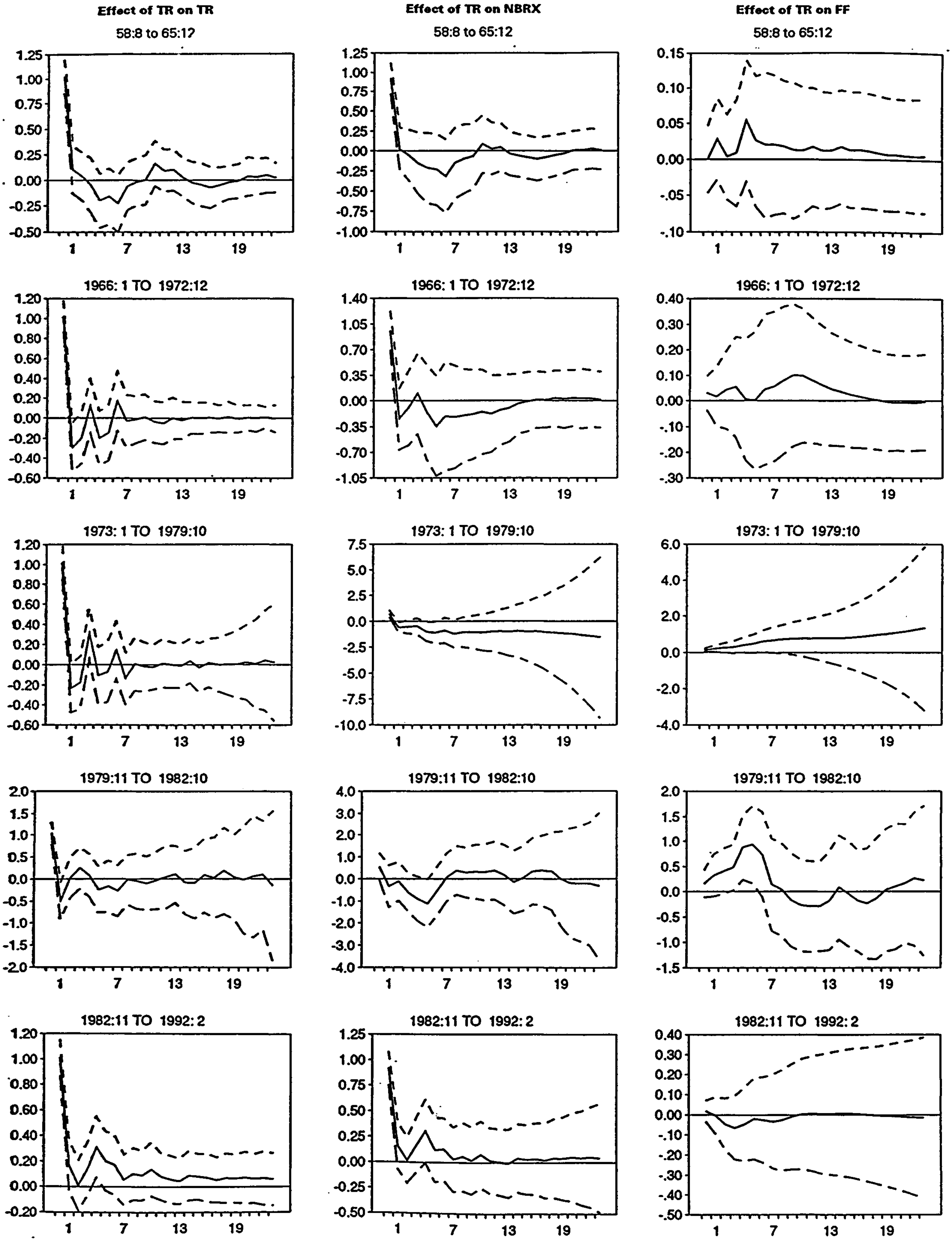
NOTE: Numbers in parenthesis are standard errors.

TABLE 6

Variables listed in Wold causal order	Decomposition of Variance at End of Year 1	End of Year 2	End of Year 3
Proposed 5 Variable VAR			
IP	83.8(6.7)	49.0(10.0)	34.4(9.3)
CPI	0.3(1.3)	3.8(4.2)	5.6(6.3)
TR	0.9(2.3)	0.6(2.9)	1.2(3.9)
NBRX	14.8(6.0)	46.4(10.0)	58.6(10.4)
FF	0.2(1.3)	0.2(1.9)	0.2(2.4)
Alternative Model 1			
IP	83.8(6.4)	49.0(9.6)	34.4(8.6)
CPI	0.3(1.3)	3.8(4.7)	5.6(6.7)
NBRX	12.7(6.0)	30.3(10.6)	33.3(11.5)
TR	3.0(3.7)	16.7(8.9)	26.5(11.5)
FF	0.2(1.1)	0.3(1.9)	0.2(2.5)
Alternative Model 2			
IP	83.8(6.6)	49.0(9.6)	34.4(8.9)
CPI	0.3(1.3)	3.8(4.5)	5.6(6.6)
FF	3.8(3.5)	11.5(7.1)	16.3(9.2)
TR	1.5(2.3)	1.1(3.0)	1.1(3.1)
NBRX	10.6(5.4)	34.5(9.6)	42.6(10.5)
Alternative Model 3			
IP	83.6(6.6)	48.4(10.1)	34.2(9.3)
CPI	0.5(1.3)	6.2(5.6)	9.5(8.8)
NBRX	15.3(6.3)	42.9(9.9)	51.2(10.7)
FF	0.7(1.6)	2.5(3.4)	5.1(5.3)
Alternative Model 4			
IP	90.4(5.6)	70.8(10.8)	54.8(12.9)
CPI	0.3(1.4)	6.3(6.1)	15.5(10.3)
DNBR	3.8(3.8)	9.1(7.7)	8.2(7.8)
FF	5.5(4.1)	13.8(8.1)	21.4(10.9)

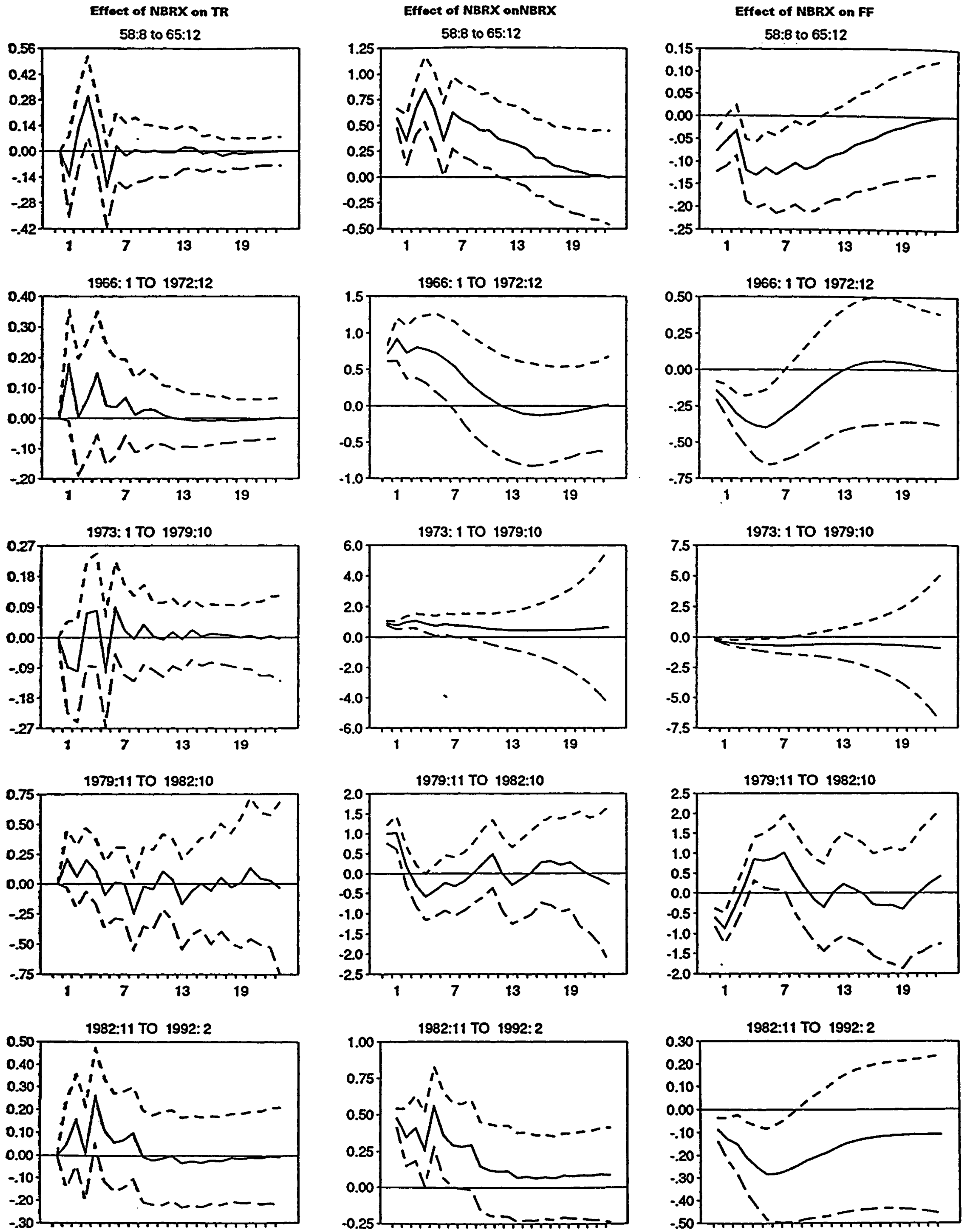
NOTE: Numbers in parenthesis are standard errors.

FIGURE 1.



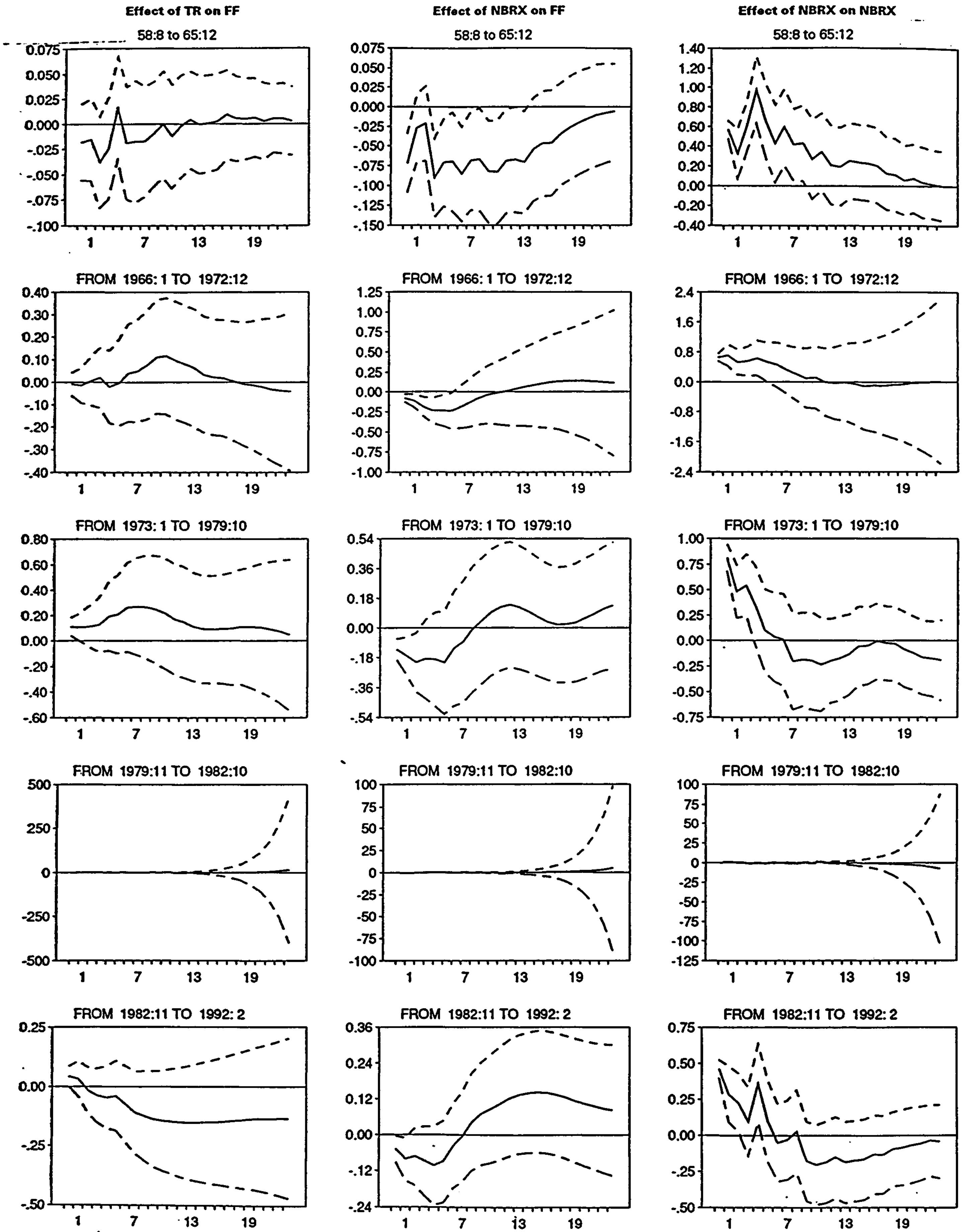
NOTE: Error bands are ± 2 sigma.

FIGURE 2.



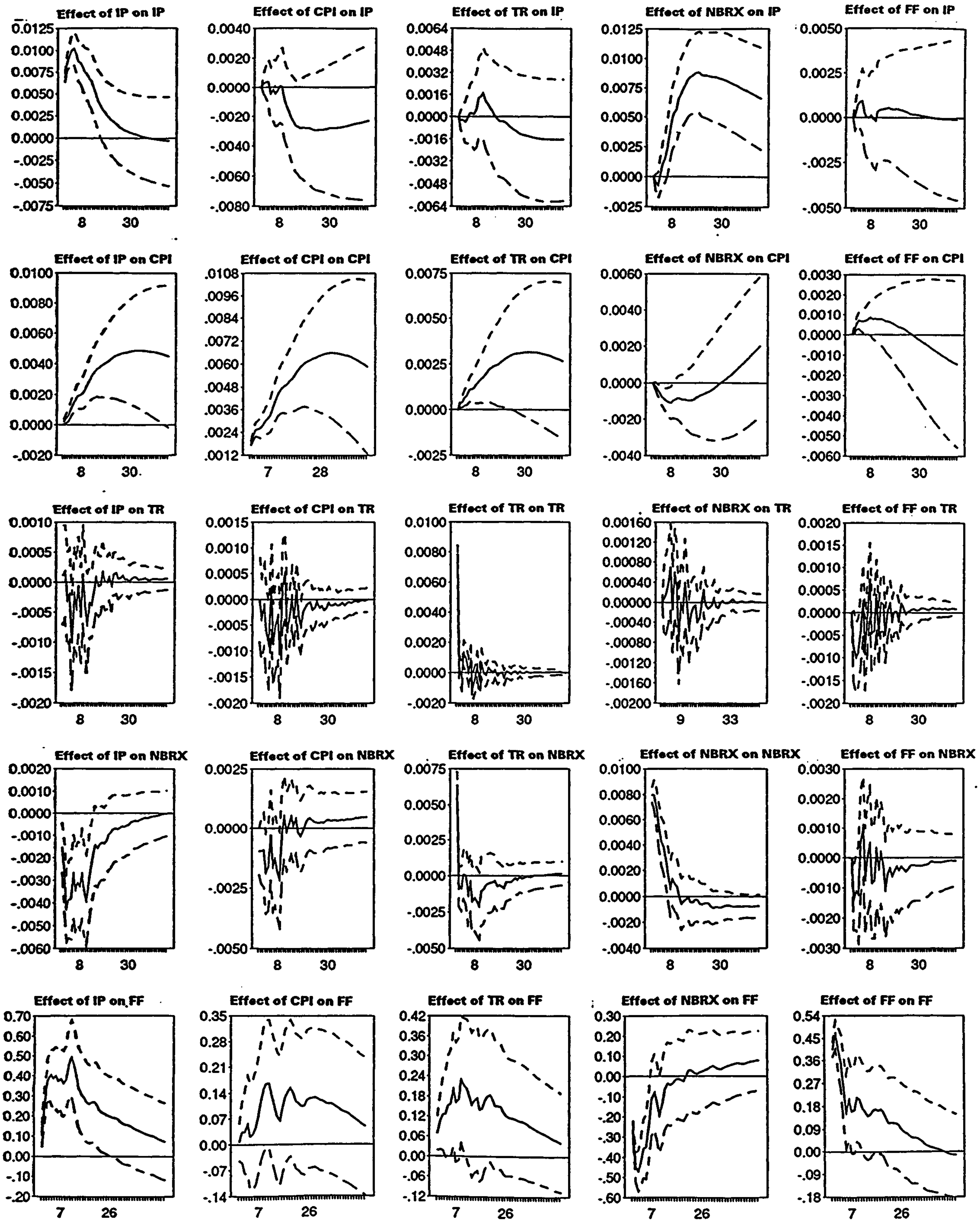
NOTE: *Error bands are* ± 2 sigma.

FIGURE 3.



NOTE: Error bands are ± 2 sigma.

FIGURE 4.



NOTE: Error bands are ± 2 sigma.

FIGURE 5.

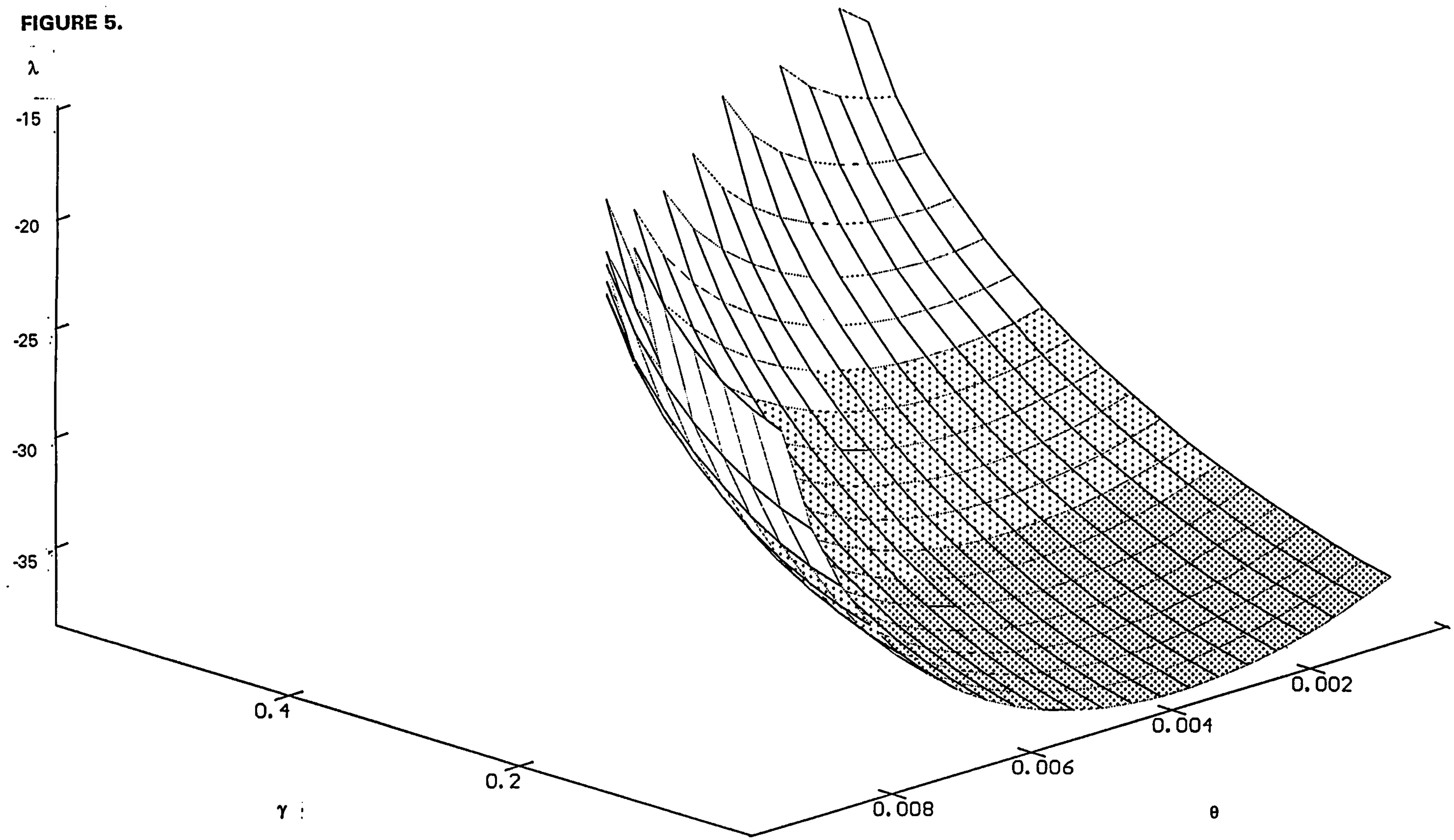
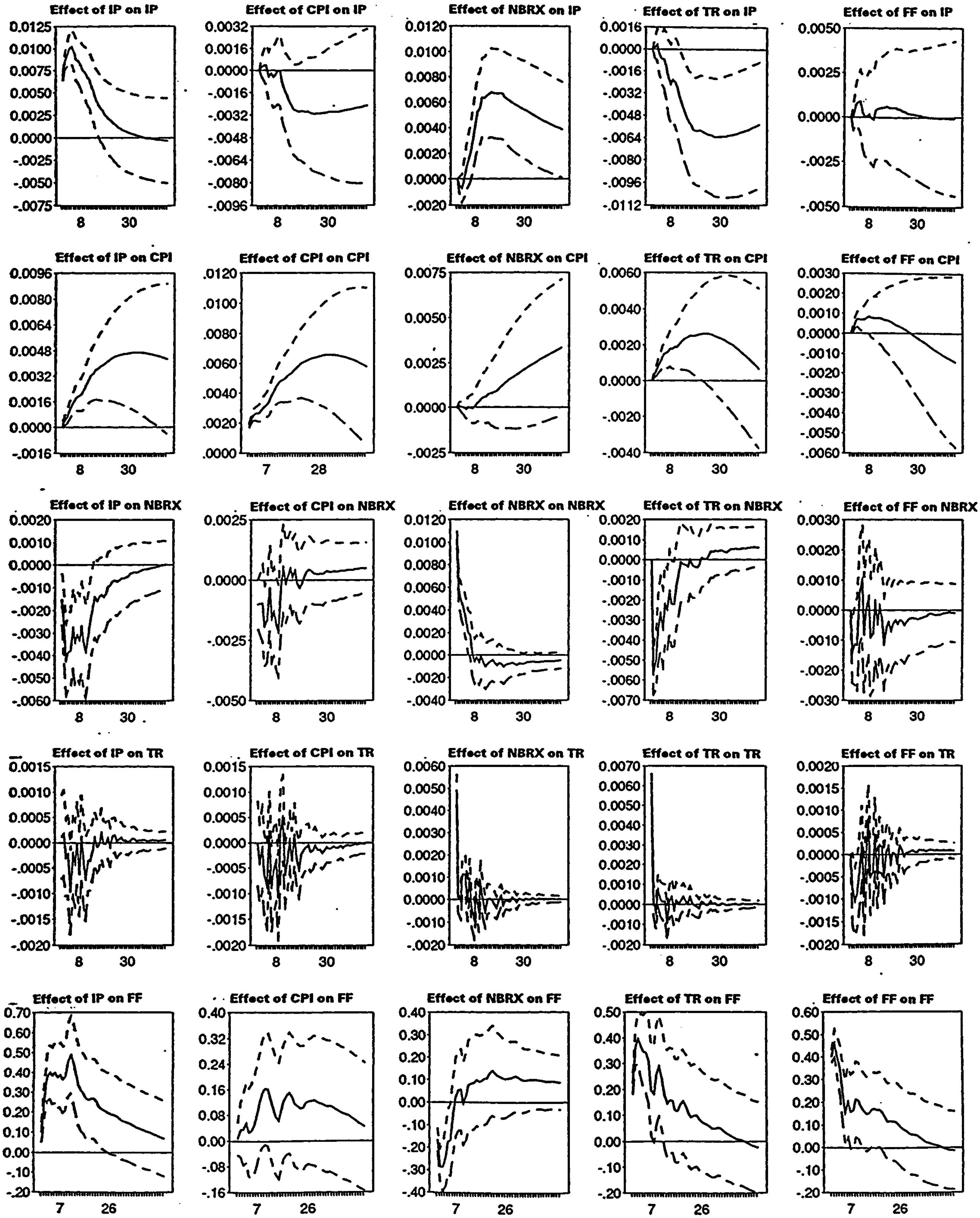
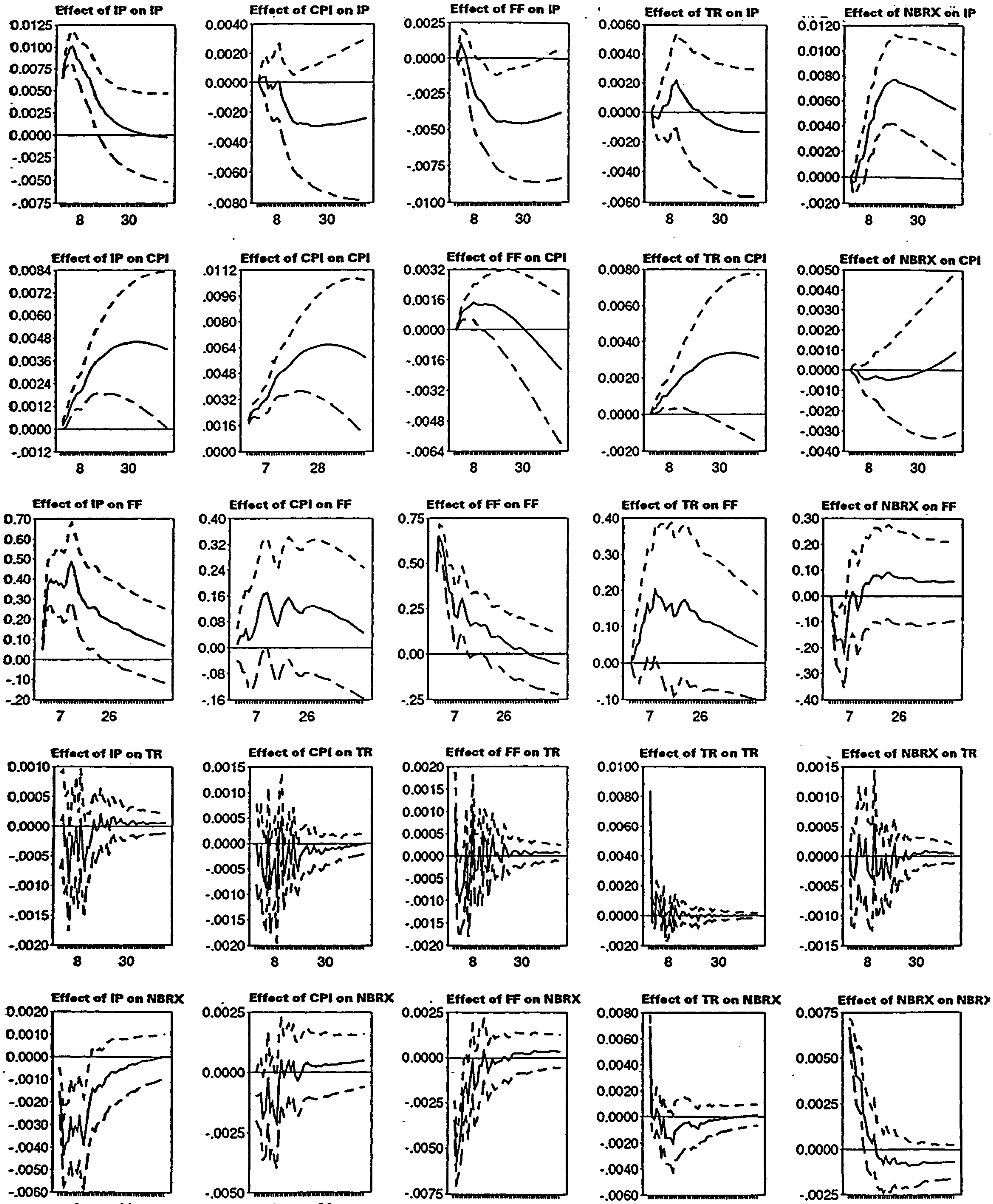


FIGURE 6.



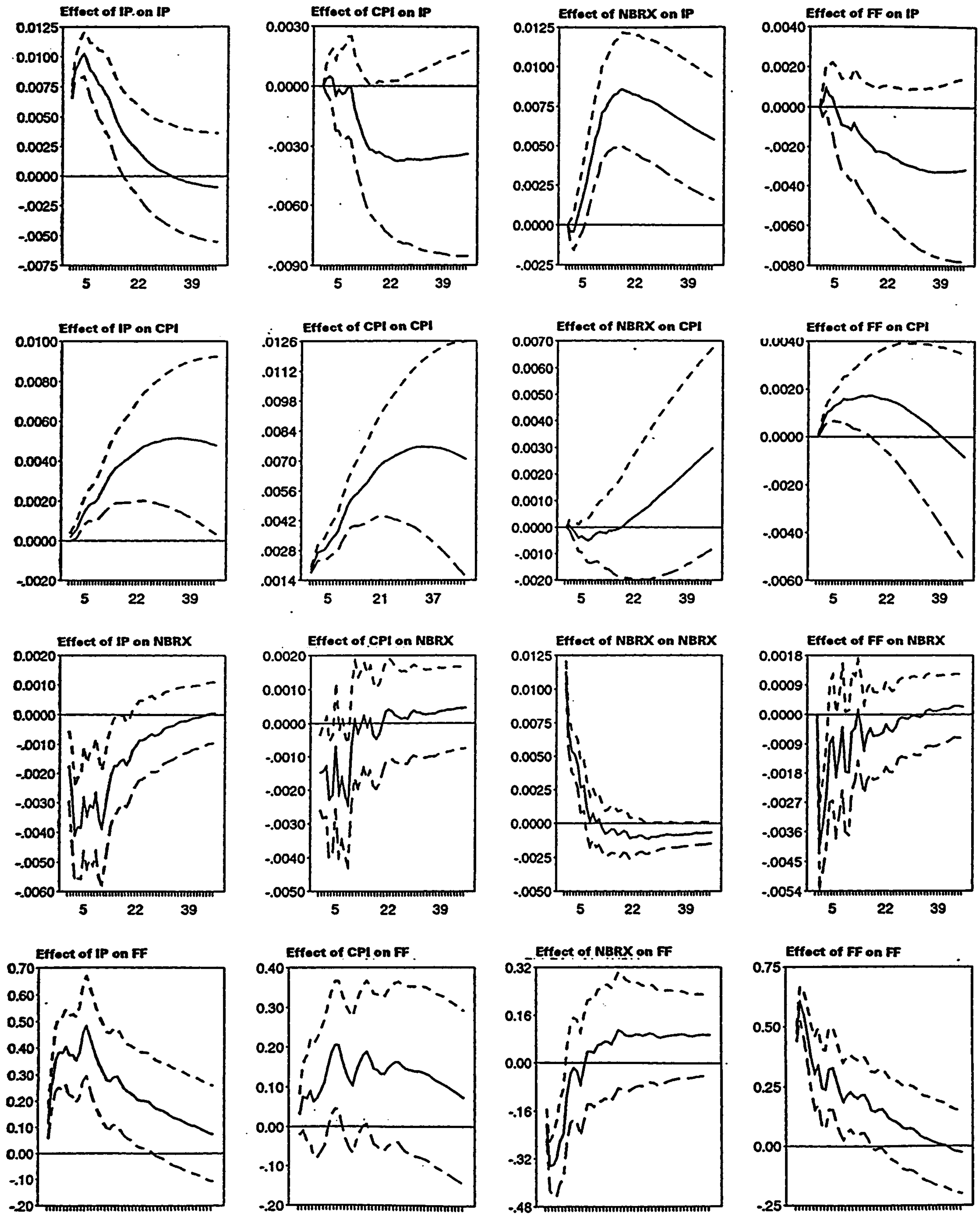
NOTE: Error bands are ± 2 sigma.

FIGURE 7.



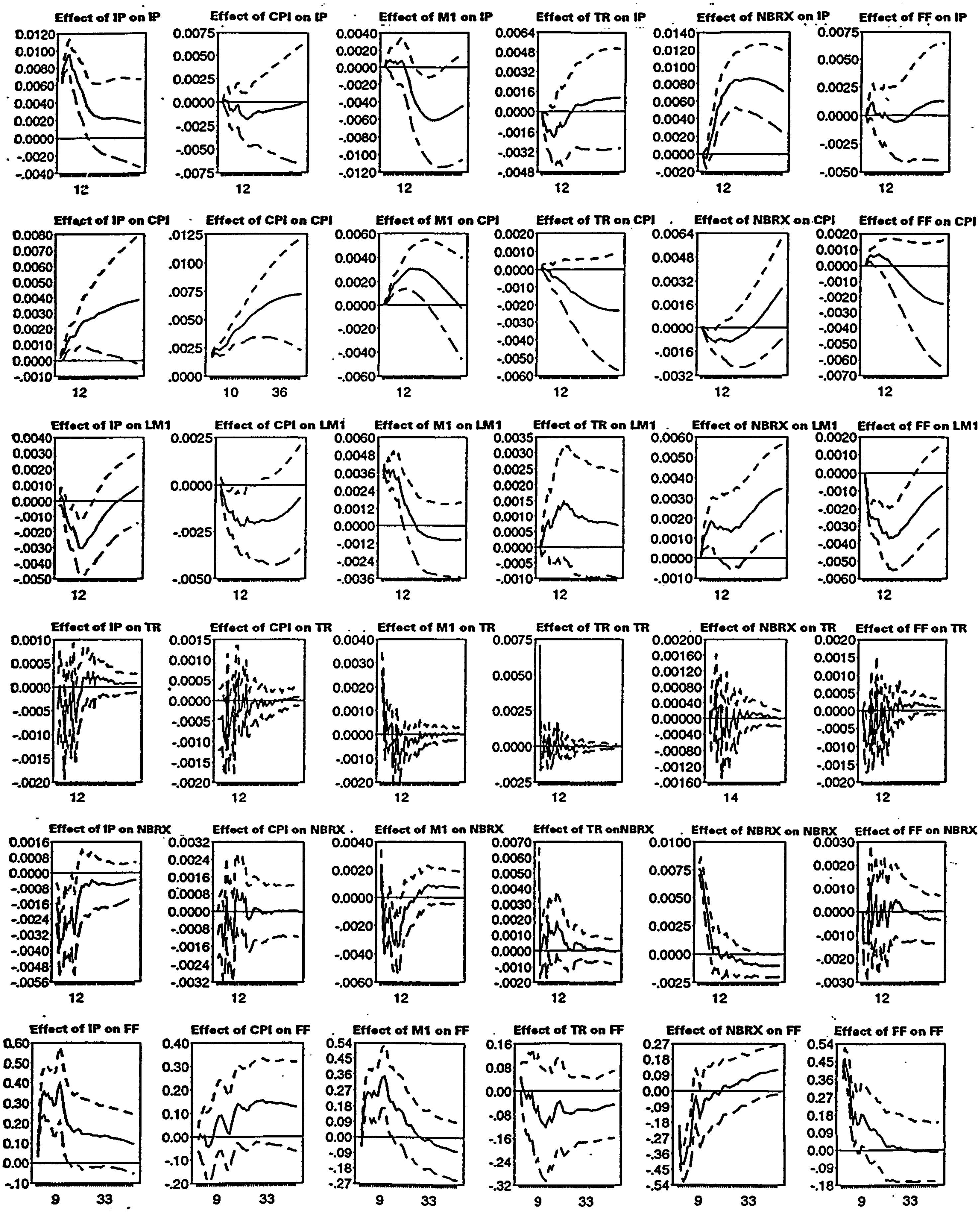
NOTE: Error bands are ± 2 sigma.

FIGURE 8.



NOTE: Error bands are ± 2 sigma.

FIGURE 9.



NOTE: Error bands are + 2 sigma.