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Structural Breaks and Regional Disparities in the Transmission of Monetary Policy[*]

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Abstract: Using a regional VAR, we find large differences in the effects of monetary policy shocks across regions of the United States. We also find that the region-level effects of monetary policy differ a great deal between the pre-Volcker and Volcker-Greenspan periods in terms of their depth and length. The two sample periods also yield very different rankings of the regions in terms of the effects of monetary policy. We find that regional difference in the depths of recession are related to the banking concentration, whereas differences in the total cost of recession are related to industry mix. Finally, we demonstrate that the differences between the two sample periods are due to changes in the mechanism by which monetary policy shocks are propagated. (JEL: E52, R12)

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1. Introduction

The United States has one currency and, correspondingly, one monetary policy for all of its states and regions. The Federal Reserve takes little account of spatial business cycle patterns when it makes monetary policy decisions, despite large differences in regional business cycle fluctuations.[1] Although the Fed collects information at the regional level, this is used primarily to measure aggregate economic conditions, with little regard for the regional distribution of conditions that underlie the aggregate.[2] Presumably, the Fed holds the view that monetary policy cannot and should not be used to affect particular regions or states.[3] While not disagreeing with this view, we demonstrates how an understanding of the regional effects of monetary policy can help policymakers to understand how the aggregate economy responds to monetary shocks.

This paper continues a line of recent research that uses current tools of monetary-policy analysis to estimate the regional effects of monetary policy, a question prominent in the regional science literature in the 1970s and 1980s.[4] Carlino and DeFina (1998, 1999) and Fratantoni and Schuh (2003) estimate region-, state-, and MSA-level effects of monetary policy shocks using vector autoregressions (VARs), the now-standard empirical tool among monetary economists. Carlino and DeFina estimate the impact of permanent changes in the federal funds rate, finding

[1] Owyang, Piger, and Wall (2004), for example, show that there are significant differences in the timing of recessions and expansions across states and regions.
[2] Note, though, that Meade and Sheets (2002) find that the probability of an FOMC member dissenting from the majority is higher the more conditions in the member's region differ from the nation as a whole.
[3] Fratantoni and Schuh (2003, p.7) describe the Fed's view of how to react to region-level events. "This view is illustrated by a video game in the visitors' lobby at the Federal Reserve Board called 'You Are the Chairman,' which asks players to select a monetary policy—tighter, looser, or no change—in response to different scenarios. Most scenarios focus on traditional policy responses to macroeconomic developments in real GDP, inflation, and interest rates. But in one scenario, unemployment begins to rise in several farm-belt states. Players are told the correct answer is no change."

that the decreases in regional income following a contractionary monetary policy shock are larger in regions where manufacturing is relatively more important.[5] In Fratantoni and Schuh, monetary policy shocks are transmitted to the regional and aggregate economies through mortgage rates and the housing market. They find that the aggregate impulse response to a monetary policy contraction exhibits nonlinearities because of aggregation over heterogeneous regions and state-dependence on initial regional incomes.

We bring the literature further in line with current monetary analyses by introducing a structural break into the estimation. Although the preceding papers account for differences in the effects of monetary policy across regions, they do not allow for differences in the effects of monetary policy over time. In large part, the period that these studies analyzed was too short to allow for such considerations.[6] Recently, though, a large literature has examined variation through the post-War era (Clarida, Gali, and Gertler, 2000; and Boivin and Giannoni, 2002). These studies are aimed at finding persistent changes in policy which stem, for example, from changes in central bank leadership or transparency. These changes can have a large effect on the volatility of money, interest rates, and output at the aggregate level. For example, Clarida, Gali, and Gertler argue that a change in the inflation weight in the Fed's post-1982 Taylor rule has resulted in a more stable policy. Boivin and Giannoni consider whether the Fed's effectiveness has evolved during the post-War period. Thus far, however, no studies have considered whether the region-level effects of monetary policy have changed over time.

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[4] Carlino and DeFina (1999) survey this literature, as do Bias (1992) and Dow (1987).

[5] Mihov (2001) performs a similar exercise, but focuses on the comparison between differences in the U.S. and differences in the member countries of the European Monetary Union.

[6] Carlino and DeFina (1998, 1999) use data through 1992. Fratantoni and Schuh (2003) use data through 1996.

We allow each region's response to a monetary shock to differ between the pre-Volcker and Volcker-Greenspan eras and address at the regional level two issues: the cost of disinflation and the timing and pattern of monetary-policy-induced recessions. Further, we consider whether the regional differences in the effects of monetary policy are related to measures of various channels of monetary policy: the money channel, the broad credit channel, and the bank lending channel.

The paper proceeds as follows: Section 2 reviews the structural VAR of monetary policy and presents the estimation of a benchmark aggregate VAR in three sample periods: the full sample, the pre-Volcker period, and the Volcker-Greenspan period. Section 3 describes and estimates our regional VAR, and compares the timing, depth, and lengths of regional responses to a monetary tightening across the three sample periods. In section 4, we examine the possibility that a monetary VAR that includes a regional dimension can partially address the so-called duration puzzle. In section 5, we use the results of our regional VAR to estimate the importance of different channels of monetary policy, and in section 6 we determine that the changes over time are due to changes in the monetary-policy-propagation mechanism. Section 7 concludes.

2. Monetary VARs

Innovations to monetary policy can occur in two forms: changes in the implementation of policy and changes in the objectives of policy. We focus on the former, which is typically modeled as vector innovations to a system of equations (e.g., a VAR) in which monetary policy has been identified by structural restrictions on either the contemporaneous impacts of the variables (e.g., Christiano, Eichenbaum, and Evans, 1999; and Bernanke and Mihov, 1998) or the long-run effects on the system of variables (e.g., Blanchard and Quah, 1989; and Shapiro and Watson, 1988). This structural VAR literature has identified a number of stylized facts about the effects of a contractionary monetary shock: a U-shaped output response, a permanent decrease in the price level, and a temporary rise in interest rates.

A structural economic system can be written as

$$A_0 y_t = \sum_{j=1}^{k} A_j y_{t-j} + B w_t + \nu_t, \qquad (1)$$

where y_t is the period t vector of n variables in log levels,[7] w_t is a vector of exogenous variables, k is the number of lags, and $\nu_t \sim N(0,\Omega)$ assumes that the system's primitive shocks are uncorrelated with each shock j having variance ω_j^2. The vector of endogenous variables, y_t, can be partitioned as follows: $y_t = [x_t, r_t, z_t]'$, where x_t are variables that respond to policy with a lag, z_t are variables that respond contemporaneously, and r_t are the policy instruments.

We estimate two versions of the VAR: a benchmark VAR that uses aggregate data and another that uses regional data. In the benchmark aggregate VAR, x_t includes the log CPI price level and the log level of real aggregate personal income (PI). In the regional VAR, aggregate PI is replaced by the PIs of the eight BEA regions.[8,9]

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[7] The exceptions are interest rates, which are expressed as percentages.

[8] The composition of the BEA regions is given in the Appendix.

[9] Although GDP, industrial production, and coincident indicators are the aggregate income variables of choice in the literature, we use PI because none of the aforementioned variables are available at the regional level on a quarterly basis. To ensure that our results are not specific to our use of PI, we have also estimated our benchmark aggregate VAR with GDP data, finding very little difference in the shape and magnitude of the resulting impulse responses.

In both versions of the VAR, z_t contains both the 10-year Treasury rate and a commodity price index.[10] Also, the only policy instrument in r_t is the federal funds rate (FFR). This abstracts from Bernanke and Mihov (1998), who argue that the instrument changes from the federal funds rate to reserves during the so-called monetarist experiment period of 1979-82. We control for energy prices by including w_t, which are exogenous oil dummies corresponding to the Hoover and Perez (1994) oil dates.[11]

To provide a benchmark to compare to our regional VAR results, we construct a fairly standard aggregate VAR. Rewrite (1) as a three-lag, reduced-form VAR:

$$y_t = \sum_{j=1}^{3} \beta_j y_{t-j} + \delta w_t + \varepsilon_t, \tag{2}$$

where $\varepsilon_t \sim \mathrm{N}(0,\Sigma)$ and $\Sigma = A_0^{-1} \Omega A_o^{-1}{'}$.

We estimate the preceding five-variable aggregate VAR with OLS equation-by-equation using quarterly data. Our full-sample estimation uses data for 1960:I - 2002:IV, our pre-Volcker estimation uses data for 1960:I - 1978:IV, and our Volcker-Greenspan estimation uses data for 1983:I - 2002:IV. Unfortunately, because the so-called monetarist experiment period of 1979-1982 offers too few observations, we cannot examine that subperiod separately.[12] Data are seasonally adjusted and are taken from the Federal Reserve Board (FFR, 10-year Treasury), the

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[10] As in Bagliano and Favero (1998), the 10-year Treasury rate is included to separate the effects of monetary policy shocks from independent disturbances to long-term rates. As in Sims (1986), commodity prices are included to mitigate the effects of the price puzzle.

[11] VARs sometimes include energy prices for this purpose. Hamilton (2003), however, has argued that incorporating oil or energy price data directly into the regression is inappropriate. Oil price shocks affect the economy asymmetrically: A decrease or a small increase in the price of oil tends to have a small effect on the larger economy while larger increases—particularly those that are viewed to be permanent—can have large and persistent effects. This asymmetry might lead to a mis-specification of the response of other variables.

[12] An alternative to excluding the monetarist experiment period altogether is to dummy out its effects. Doing so provides qualitatively similar results to our full-sample estimation.

Bureau of Economic Analysis (PI, CPI), and the FIBER industrial materials price index (commodity prices). We employ a standard lower-block recursive identification of monetary policy with three blocks: the policy block and the non-policy variables that are and are not contemporaneously affected by monetary policy shock.[13]

We should note that our estimation differs from Carlino and DeFina (1998, 1999) in that we consider the effects of a one-time shock to the federal funds rate, rather than the permanent shock that they considered. In their estimation, because the shock to the federal funds rate is permanent, so is the monetary-policy-induced recession. Because we consider a one-time shock, as is standard in the monetary economics literature, we can analyze the dynamics of recovery from a monetary-policy-induced recession.

Figure 1 illustrates the impulse responses—along with their 90-percent bootstrapped confidence bands—to a one-hundred-basis-point shock to the FFR. In addition, Table 1 presents four key measures (in central tendency) of the effect on PI: the number of quarters after the shock that the region's PI reached its trough, the magnitude of the PI decrease at the trough, the number of quarters it took for the region's PI to recover its pre-shock level, and the total PI loss over the 20 quarters. Qualitatively, the responses are roughly representative of the results found in the monetary VAR literature (for example, Boivin and Giannoni, 2003).

For the full sample, aggregate PI declines subsequent to the contractionary monetary shock, reaching its trough—a 0.25 percent decrease—in the seventh quarter. PI begins reverting back to the initial level following a recessionary period, although it does not quite reach it within

[13] We also assume that the policymaker does not react to long-term interest rates.

the 20 quarters depicted. Combining the depth and length of the recession, the total PI loss over the 20 quarters is just over 3 percent. The CPI increases for a short period (the price-puzzle effect) but, after two years, is lower than in the initial period. Similarly, the contractionary shock to the funds rate is reversed after about ten quarters, while the 10-year Treasury rate and the commodity price index return to their initial levels after three and five years, respectively.

The results for the two split samples reveal that the full-sample results mask significant changes over time in the effects of monetary policy. Most importantly, a monetary shock induces a deeper and more-persistent recession during the pre-Volcker period than during the Volcker-Greenspan period. In the earlier period, PI at the trough is about 0.6 percent lower than its initial level, while in the later period it is only about 0.1 percent lower. The trough of the Volcker-Greenspan period occurs three quarters later than in the pre-Volcker period, although recovery does not occur by the 20th quarter for either period. The starkness of the differences between the samples is highlighted by the result that a FFR shock in the pre-Volcker period results in a total PI loss after 20 quarters that is almost 10 times as high as in the Volcker-Greenspan period, and more than three times as high as indicated by the full sample.

There also appears to be an inflation-expectations response during the Volcker-Greenspan period: PI rises in the first year following the shock while the 10-year bond rate remains at or near its initial level. Note also that, for the Volcker-Greenspan period, PI is not statistically different from the initial level for any quarter following the shock. Another important difference across the three samples is in the response of the CPI. Whereas there is significant CPI deflation over the 20 quarters in the full sample, the shock in the pre-Volcker period yields a long price-puzzle effect, whereas there is little-to-no CPI response in the Volcker-Greenspan period. This is consistent with Hanson (2004).

3. A Regional Monetary VAR

Our intent is to investigate the nature of the responses of real regional PI levels to a monetary policy shock. To do this, we modify the aggregate VAR above to account for regional differences. Thus, in the non-policy block x_t we replace aggregate PI with its eight regional counterparts.

In addition to the standard assumptions about the contemporaneous effect of policy, we make assumptions regarding the propagation of regional income shocks. As in Carlino and DeFina (1998, 1999) and Fratantoni and Schuh (2003), we assume that the idiosyncratic regional income shock does not affect other regions contemporaneously, although it is allowed to affect other regions in subsequent quarters.[14]

Figure 2 provides the impulse responses to a one-time, one-hundred-basis-point shock to the FFR in this 12-variable VAR using the three samples.[15] For each of the three samples, the impulse responses from the regional VAR are qualitatively similar to their respective counterparts from the aggregate VAR illustrated by Figure 1. More interesting, though, are the large cross-regional differences within each sample, and the large cross-sample differences for individual regions.

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[14] While these assumptions will aid us in comparing the relative effects of the monetary shock against other shocks, we need not specify the propagation mechanism for the regional income shocks to identify the monetary shock alone. In principle, we could restrict our attention to the monetary shock and achieve identification without restrictions on contemporaneous cross-regional impacts in the matrix a_x.

[15] Presented along with the impulse responses are 90-percent bootstrapped confidence intervals.

3.1 Full-Sample Results

The cross-regional differences in the impulse responses using the full sample are illustrated by Figure 2, and the measures of the magnitudes of the regional monetary-policy-induced recessions are summarized in Table 2. All regions reach their trough in the sixth or seventh quarter, roughly in line with the aggregate economy. The regional differences in the magnitudes of the income losses at the troughs are prominent, though, and vary a good deal around the 0.25 percent PI loss indicated by the aggregate VAR. The Great Lakes has, by far, the deepest trough, seeing a 0.31 percent lower PI, while, at the other end, the Mideast, Southwest, and New England regions have the shallowest troughs of 0.131, 0.139, and 0.141 percent reductions in PI, respectively.

Recovery from the recession occurs at very different times across the regions. Whereas the aggregate VAR indicates that the aggregate economy does not return to its initial PI by the 20th quarter, our regional VAR indicates that recovery occurs in the 18th quarter or earlier in five regions. In contrast, the Southwest, Rocky Mountain, and Far West regions are still in recession after the 20th quarter.

As is clear from our results, there are large regional differences in both the depths and lengths of monetary-policy-induced recessions. The final column of Table 2 takes into account both the depth and length, providing calculations of the total losses to regional PI over 20 quarters. The Great Lakes region has the largest total PI loss. At the opposite end, three regions—New England, the Plains, and the Mideast—had total PI losses much smaller that of the Great Lakes. For the Mideast and New England, this is because their monetary-policy-induced recessions are both shallow and brief, while for the Plains it is because its rather deep recession is followed by a rapid recovery.

For the full sample, our regional results bear some resemblance to those of Carlino and DeFina (1998). But because their monetary policy shock is a permanent increase in the FFR—thereby inducing a permanent change in the growth rate of PI—the two sets of results are not entirely comparable. In particular, because recovery never occurs following their monetary shock, they cannot compare regions on the basis of the length of time it takes to recover from the monetary-policy-induced recession.

3.2. Pre-Volcker Period

As is clear from Table 2 and Figure 2, the results using only the pre-Volcker sample indicate much deeper and more costly regional recessions following a monetary policy tightening than do the results using the full sample. This is consistent with the differences between the two samples in the aggregate VAR. In addition, though, the two samples provide different results about the regional effects of the monetary policy shock. All regions see deeper troughs and all but the Rocky Mountain region see higher total PI losses. As in the full sample, the Great Lakes has the deepest trough. The difference between the Great Lakes and other regions in this regard, however, is not as large as the full-sample results suggest: The Plains and the Southeast have troughs that are nearly as deep as the Great Lakes. Also, in contrast with the full-sample results, the shallowest troughs are in the Rocky Mountain, Far West, and Southwest regions, rather than in the Mideast, New England, and the Southwest.

The recession lengths are also affected by the splitting of the sample. Four regions see recovery arriving at least two quarters earlier than in the full sample, while two see recovery arriving at least two quarters later. Also, compared with the full sample, the pre-Volcker sub-sample suggests somewhat smaller relative differences in the total PI losses of a monetary-policy-induced recession. Only the Rocky Mountain region stands out as having much lower total PI losses than the other regions.

3.3. Volcker-Greenspan Period

As with the aggregate VAR, monetary policy shocks have much smaller recessionary effects during the Volcker-Greenspan period than in the pre-Volcker period or the full sample. In addition, estimates for the Volcker-Greenspan period yield quite different comparisons among the regions in the timing, depth, and costs of monetary-policy-induced recessions. For four regions—Plains, Southwest, Rocky Mountain, and Far West—the recession is extremely shallow to the extent that the trough is an order of magnitude smaller than in either of the other two samples. The other five regions, on the other hand, have troughs that are in line with those from the full sample. The Great Lakes, though, is the only region whose PI level is below its initial level to a statistically significant extent for at least one quarter.

This sub-sample's results highlight also the varying lengths of regional recessions. The recovery quarters tend to come much earlier than in the other samples, and the ranking across the regions differs a great deal. In particular, note that the earliest recoveries occur for the Mideast, Southwest, Rocky Mountain, and Far West regions. In contrast, the full-sample results indicate that the last three of these do not see recovery until beyond the 20 quarters that we examine.

The differences between the Volcker-Greenspan sample and the other two samples are illustrated most clearly by the differences in the region's total PI loss following a monetary policy shock. Because of shallower recessions, quick recovery, and the inflation-expectations response, the total PI losses are much smaller, and five regions actually see total PI gains over the period.

4. Duration Puzzle

Recall that, for all three sample periods, our aggregate VAR indicates that personal income does not return to its original level even five years after a monetary policy shock. This "duration puzzle" is the norm in the literature, which tends to find implausibly long monetary-policy-induced recessions (e.g., Christiano, Eichenbaum, and Evans, 1999; Bernanke and Mihov, 1998; Clarida, Gali, and Gertler, 2000; and Hanson, 2004). In contrast, for all three sample periods, our regional VAR indicates that a majority of regions see their personal incomes return to their initial level well before what is suggested by our aggregate VAR. In fact, for the Volcker-Greenspan period, the regional VAR indicates that all regions have recovered by the 13th quarter, whereas the aggregate VAR indicates that recovery does not occur even by the 20th quarter.

One explanation for the duration puzzle might, therefore, be that aggregate VARs suffer from aggregation bias because of nonlinearities in the relationship between the FFR and PI. This is consistent with Lütkepohl (1984), who demonstrates how the persistence of an aggregate series reflects the most persistent of the disaggregated series. Figure 3 compares the impulse response from the aggregate VAR (from Table 1 and Figure 1) to the weighted sum of the regional PI responses from Figure 2. Key aggregate measures of the monetary-policy-induced recession from the regional VAR are included in Table 2.

In the full and pre-Volcker samples, the regional VAR suggests a shallower and shorter recession than does the aggregate VAR. This difference is especially stark for the pre-Volcker sample, in which the regional VAR suggests a trough of 0.375 rather than the trough of 0.595 suggested by the aggregate VAR. Also for this period, the regional VAR suggests that the recession ends by the sixteenth quarter and has a total PI loss of less than 4 percent. For the aggregate VAR, however, after 20 quarters PI growth is barely above its trough and total PI is 9 percent lower.

The impulse responses of aggregate PI from the aggregate VAR and the regional VAR also differ for the Volcker-Greenspan period. The aggregate VAR indicates that, following a monetary policy shock, aggregate PI growth will remain negative for at least 20 quarters and result in a total PI loss of 0.971 percent. In contrast, the regional VAR indicates that aggregate PI will suffer a short recession that reaches its trough quickly, ends by the 11th quarter, and results in a total PI loss of only 0.098 percent. Thus, the sum of the disaggregated responses from the regional VAR revert back to trend more rapidly than the aggregate response produced by the aggregate VAR.

5. Channels of Monetary Policy

The finding that a monetary shock has very different effects across regions is interesting on its own, but perhaps of more interest to monetary economists is that these findings might allow greater insight into the transmission of monetary shocks. As in Carlino and DeFina (1998, 1999), multiple observations of the effects of monetary-policy shocks can be used to estimate the role of a list of monetary-transmission mechanisms. Our eight regional impulse responses, however, are inadequate for the job and more disaggregation is necessary. We need not restrict our analysis to the eight BEA regions, and, depending on data and tractability restrictions, it is possible to disaggregate further to obtain sub-regional impulse responses.

Because quarterly PI data are available at the state level, it is, in principle, possible to estimate 50 different responses to a monetary shock. Unfortunately, though, the estimation of a 54-variable model with our identification is intractable.[16] As an alternative, we divided the eight BEA regions into 20 sub-regions, each with between two and four states from the same BEA region. The criteria for splitting the regions into sub-regions were contiguity and business cycle similarity, as measured by the simple correlation of states' quarterly PI growth rates.[17] We eliminated the Detached Far West sub region, whose two members are Alaska and Hawaii. With 19 sub-regions, we have enough observations to estimate the roles of different monetary channels, while still requiring only one VAR and a single contemporaneous impact matrix.

Table 3 presents the results of the sub-regional VAR for the full sample and the Volcker-Greenspan period. The effects of the monetary-policy-induced recession are summarized by the PI loss at the trough and the total PI loss over 20 quarters. For the most part, the results echo those for the regional VAR. The most notable new result is the large difference for both samples

[16] Note that Carlino and DeFina (1998, 1999) obtain impulse responses for each of the 50 states by estimating 50 different VARs, each with nine regions. For state *i*'s VAR, the nine regions are: state *i*, state *i*'s BEA region excluding state *i*, and the other seven BEA regions. Because the definition of regions differs across VARs, each VAR has its own contemporaneous impact matrix.
[17] The list of sub-regions and their states is provided in the appendix along with the correlations of quarterly PI growth rates within BEA regions.

between the East Great Lakes and West Great Lakes sub-regions. For our purposes, though, these 19 impulse responses allow us to test various channels of monetary policy.

Textbook explanations of the impact of monetary policy typically show that a monetary contraction reduces the demand for capital and durables, thereby reducing aggregate demand. Cecchetti (1995) has termed this the *money channel*. Because manufacturing industries (particularly capital- and durable-goods industries) are the most sensitive to interest rates, the importance of the money channel would be indicated by a positive relationship between the loss of PI following a monetary policy shock and the size of the manufacturing sector. To proxy for the interest sensitivity of the region's industrial mix, we use the sub-regions' shares of total non-farm employment in the manufacturing sector.[18]

If the differences between sub-regions in the effects of monetary policy are due to differences in the ability of their banking sectors to provide loans, then monetary policy can be said to work through *credit channels* (Gertler and Gilchrist, 1994). Small firms are thought to have higher information and transaction costs when dealing with banks, thereby making it more costly for them to obtain financing (Bernanke and Blinder, 1988; Bernanke, 1993). To proxy for this *broad credit channel*, we use two separate measures: the share of total employment that is in firms with fewer than 100 employees, and the average number of employees per firm.[19] If the broad credit channel is important, regions with a high share of small firms should see larger PI losses following a monetary tightening; as would regions with a low average firm size.

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[18] These data are from the BLS and are available at the state level for 1969-2001. For the full sample period, we used the yearly manufacturing share averaged over 1969-2001. For the Volcker-Greenspan period, we used the same measure averaged over 1983-2001.

[19] These data are from the Statistics of U.S. Business data set produced by the Census Bureau. Because the data are available starting in 1988, we use the same measures for the full sample and the Volcker-Greenspan period.

In addition to the broad credit channel, empirical studies have identified a *bank lending* or *narrow credit channel*: Small banks are more limited than large banks in their ability to find alternative funding sources when monetary policy is tight and are, therefore, less able to make loans (Kashyap and Stein, 1995, 2000). If the bank lending channel is important, regions in which large banks are relatively more important should experience smaller decreases in PI following a tightening of monetary policy. To proxy for the bank lending channel we use the average deposit share of the largest three and the largest five banks.[20]

Summary statistics for all the variables are presented in Table 4. The results of our OLS estimation using recession costs for the full-sample results and the Volcker-Greenspan results are presented in Tables 5 and 6, respectively. Unfortunately, there are insufficient data to perform this exercise for the pre-Volcker period. Thus, we are comparing estimates obtained using the methodology in the existing literature—which considered the full sample only—with estimates obtained using our methodology—which allows for a structural break. For each of the two periods, we estimated the effects of the channels of monetary policy on the PI loss at the trough and on the total PI loss. By alternating the two measures for each of the broad credit channel and the bank lending channel, we used four combinations of independent variables for each dependent variable.

For the impulse responses obtained using the full sample, there is no evidence that any of the channels are important for explaining the depth of the trough of a recession. None of the estimated coefficients on the monetary-channel variables are statistically different from zero, and

[20] For each region, we use the weighted average of the state deposit shares. These data are State and Metropolitan Area Data Book (1986, 1991) produced by the Census Bureau. Because the earliest data are for 1983, we use the same measures for the full sample and the Volcker-Greenspan period.

the empirical specifications have little explanatory power. There is abundant evidence, however, that all three channels are important for explaining the total costs of a monetary-policy-induced recession, as the estimated coefficients are typically statistically different from zero. Although the signs are as expected for the money channel and the broad credit channel, the results are not as expected for the bank lending channel. They suggest that monetary-policy-induced recessions tend to be more costly in regions where large banks have higher shares of deposits.

Recall, though, that the costs of a monetary-policy-induced recession differ a great deal according to whether the VAR uses data for the Volcker-Greenspan period or the full sample. Correspondingly, the conclusions about the importance of the various channels of monetary policy also depend on the sample period used to generate the regional impulse responses. In fact, the distinction is crucial to the results regarding the importance of the three channels.

As summarized by Table 6, for the Volcker-Greenspan period, only the bank lending channel is important in determining the depths of monetary-policy-induced recessions, and in the expected way: Regions in which large banks are more important tend to have shallower recessions. Recall that the full-sample results did not provide evidence that any of the channels were important in determining the depths of the recessions. On the other hand, the results for the Volcker-Greenspan period suggest that only the money channel is important for determining the total PI costs of the recessions: Monetary-policy-induced recessions tend to be more costly for sub-regions with large manufacturing sectors.

Our results are in contrast with Carlino and DeFina (1998, 1999), who find that all three channels have some role in explaining regional difference in the effects of monetary policy, although the effect of the bank lending channel is opposite of what is expected. Recall, though, that because they look at the effects of a permanent tightening of monetary policy, their estimation does not provide separate results for the depth and total costs of recessions. According to our results, however, this distinction is important.

6. Counterfactuals

We have identified marked variation in the reaction of personal income across regions, and have attributed some of the regional differences to local attributes. We have shown also that every region of the United States has been decidedly less responsive to monetary policy during the Volcker-Greenspan era than during the pre-Volcker era. In this section, we conduct a series of counterfactual experiments to determine whether changes in volatility and responsiveness across time can be attributed either to changes in the contemporaneous impact of monetary policy or to the propagation mechanism. To do so, we create a counterfactual for each period by combining its contemporaneous impact matrix with the other period's propagation mechanism. We then compare the resulting impulse responses to a 100-basis-point shock to the true one for the period.

Figure 4 illustrates the results of these experiments, which demonstrate that, for every region and each subperiod, you can obtain something very close to the other period's impulse response function by swapping propagation mechanisms. We conclude, then, that the cross-period differences in the true impulse response functions depend more on the nature of the transmission mechanism than on the contemporaneous impacts of the shocks.

7. Conclusions

As with the previous literature, we have shown that there are large regional differences in the effects of monetary policy shocks. The primary contribution of our analysis is to show that the choice of sample period matters a great deal in estimating the depths, lengths, and total costs of regional monetary-policy-induced recessions. Moreover, the ranking of the regions in terms of these recession measures is also sensitive to the sample period. For the Volcker-Greenspan period, recessions are deepest in New England and the Great Lakes region, and end the earliest in the Southwest and Far West. Over 20 quarters, the total costs of the monetary policy shock is positive only for three regions: the Southeast, Great Lakes, and New England. Our regional VAR also suggests that an aggregate VAR suffers from aggregation bias, suggestion a partial solution to the duration puzzle. Specifically, the aggregate of our regional impulse responses indicates a shorter monetary-policy-induced recession and lower total PI losses than does our aggregate VAR.

To test for the importance of various channels of monetary policy, we also estimate a sub-regional VAR. As with the regional VAR, the period examined matters. For the Volcker-Greenspan period, we find evidence that the depth of recession is related to the bank lending channel, and that the total cost of recession is related to the money channel. Finally, we perform counterfactual experiments to determine that the changes in the regional effects of monetary policy over time are due to changes in the monetary-policy-propagation mechanism, rather than to change in the contemporaneous effects of a monetary-policy shock.

Appendix: Allocation of States to Regions

BEA Regions	Sub-Regions	States
New England	North	Maine, New Hampshire, Vermont
	South	Connecticut, Massachusetts, Rhode Island
Mideast	North	New Jersey, New York
	South	Delaware, Dist. of Columbia, Maryland, Pennsylvania
Great Lakes	East	Indiana, Michigan, Ohio
	West	Illinois, Wisconsin
Plains	Northeast	Iowa, Minnesota
	Northwest	Nebraska, North Dakota, South Dakota
	South	Kansas, Missouri
Southeast	Central	Alabama, Kentucky, Tennessee
	East	Florida, Georgia, North Carolina, South Carolina
	North	Virginia, West Virginia
	West	Arkansas, Louisiana, Mississippi
Southwest	East	Oklahoma, Texas
	West	Arizona, New Mexico
Rocky Mountain	North	Idaho, Montana, Wyoming
	South	Colorado, Utah
Far West	North	Oregon, Washington
	South	California, Nevada
	Detached	Alaska, Hawaii

The division of BEA regions into sub-regions is as determined by the authors.

Appendix: Simple Correlations of Quarterly Growth in Personal Income within BEA Regions (1960.I – 2003.III)
Shaded areas indicate subregions listed in table

New England

	ME	*NH*	*VT*	*CT*	*MA*	*RI*
ME	1.00					
NH	0.84	1.00				
VT	0.68	0.81	1.00			
CT	0.73	0.63	0.49	1.00		
MA	0.71	0.68	0.63	0.72	1.00	
RI	0.71	0.75	0.68	0.62	0.69	1.00

Mideast

	NJ	*NY*	*DC*	*DE*	*MD*	*PA*
NJ	1.00					
NY	0.55	1.00				
DC	0.82	0.60	1.00			
DE	0.83	0.56	0.71	1.00		
MD	0.74	0.51	0.56	0.74	1.00	
PA	0.34	0.30	0.40	0.32	0.27	1.00

Great Lakes

	IN	*MI*	*OH*	*IL*	*WI*
IN	1.00				
MI	0.66	1.00			
OH	0.74	0.62	1.00		
IL	0.45	0.21	0.34	1.00	
WI	0.67	0.46	0.61	0.58	1.00

Plains

	IA	*MN*	*NE*	*ND*	*SD*	*KS*	*MO*
IA	1.00						
MN	0.66	1.00					
NE	0.74	0.74	1.00				
ND	0.74	0.57	0.75	1.00			
SD	0.71	0.58	0.71	0.74	1.00		
KS	0.77	0.73	0.74	0.75	0.73	1.00	
MO	0.59	0.55	0.65	0.59	0.57	0.55	1.00

Southeast

	AL	*KY*	*TN*	*FL*	*GA*	*NC*	*SC*	*VA*	*WV*	*AR*	*LA*	*MS*
AL	1.00											
KY	0.41	1.00										
TN	0.67	0.43	1.00									
FL	0.82	0.43	0.58	1.00								
GA	0.68	0.35	0.44	0.68	1.00							
NC	0.73	0.41	0.50	0.73	0.81	1.00						
SC	0.51	0.32	0.23	0.40	0.48	0.55	1.00					
VA	0.66	0.30	0.53	0.57	0.48	0.51	0.47	1.00				
WV	0.70	0.34	0.63	0.62	0.42	0.50	0.38	0.60	1.00			
AR	0.66	0.35	0.48	0.69	0.67	0.66	0.39	0.58	0.46	1.00		
LA	0.73	0.41	0.44	0.74	0.65	0.65	0.40	0.45	0.45	0.59	1.00	
MS	0.63	0.36	0.44	0.68	0.58	0.58	0.36	0.49	0.49	0.51	0.75	1.00

Southwest

	OK	*TX*	*AZ*	*NM*
OK	1.00			
TX	0.62	1.00		
AZ	0.47	0.60	1.00	
NM	0.67	0.73	0.74	1.00

Rocky Mountain

	ID	*MT*	*WY*	*CO*	*UT*
ID	1.00				
MT	0.32	1.00			
WY	0.39	0.59	1.00		
CO	0.38	0.58	0.51	1.00	
UT	0.44	0.67	0.73	0.60	1.00

Far West

	OR	*WA*	**CA**	*NV*	*AK*	*HI*
OR	1.00					
WA	0.25	1.00				
CA	0.21	0.41	1.00			
NV	0.09	0.37	0.53	1.00		
AK	0.15	0.40	0.61	0.53	1.00	
HI	0.22	0.48	0.67	0.52	0.65	1.00

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Table 1. Monetary-Policy-Induced Recessions: Aggregate VAR

	Trough Quarter	PI Loss at Trough	Recovery Quarter	Total PI Loss
Full Sample 1960 - 2002	7	0.250	>20	3.074
Pre-Volcker 1960 - 1978	8	0.595	>20	9.355
Volcker-Greenspan 1983 - 2002	11	0.115	>20	0.971

Full Sample: 1960:I - 2002:IV; Pre-Volcker: 1960:I - 1978:IV; Volcker-Greenspan: 1983:I - 2002:IV. For the Volcker-Greenspan period, the trough is the quarter with the largest PI loss following the initial expectations-adjustment interval. The recovery quarter is the first quarter of positive PI growth after the trough.

Table 2. Monetary-Policy-Induced Recessions: Regional VAR

	Region	Trough Quarter	PI Loss at Trough	Recovery Quarter	Total PI Loss (Gain)
Full Sample 1960-2002	New England	7	0.141	17	1.264
	Mideast	6	0.131	16	1.091
	Great Lakes	7	0.311	18	3.014
	Plains	6	0.233	16	1.591
	Southeast	6	0.215	18	1.960
	Southwest	7	0.139	>20	2.248
	Rocky Mountain	6	0.202	>20	2.531
	Far West	7	0.218	>20	2.568
	Aggregate of Regions	6	0.170	18	1.630
Pre-Volcker 1960-1978	New England	6	0.433	18	4.347
	Mideast	5	0.366	>20	4.001
	Great Lakes	5	0.590	15	4.803
	Plains	7	0.501	14	3.019
	Southeast	7	0.467	>20	4.684
	Southwest	8	0.350	>20	4.310
	Rocky Mountain	7	0.278	13	1.568
	Far West	7	0.350	16	3.079
	Aggregate of Regions	7	0.375	16	3.662
Volcker-Greenspan 1983-2002	New England	7	0.221	12	0.237
	Mideast	6	0.132	11	(0.055)
	Great Lakes	6	0.215	12	0.476
	Plains	8	0.078	13	(0.149)
	Southeast	8	0.150	13	0.485
	Southwest	7	0.017	8	(0.751)
	Rocky Mountain	7	0.061	11	(0.735)
	Far West	7	0.014	8	(0.877)
	Aggregate of Regions	7	0.110	11	0.098

Full Sample: 1960:I - 2002:IV; Pre-Volcker: 1960:I - 1978:IV; Volcker-Greenspan: 1983:I - 2002:IV. For the Volcker-Greenspan period, the trough is the quarter with the largest PI loss following the expectations-adjustment interval. The recovery quarter is the first quarter of positive PI growth after the trough.

Table 3. Monetary-Policy-Induced Recessions: Sub-Regional VAR

Sub-Region	Full Sample		Volcker-Greenspan	
	PI Loss at Trough	Total PI Loss	PI Loss at Trough	Total PI Loss (Gain)
North New England	0.177	2.659	0.088	(0.008)
South New England	0.160	2.777	0.076	(0.172)
North Mideast	0.149	2.295	0.086	(0.251)
South Mideast	0.144	1.894	0.081	(0.142)
East Great Lakes	0.304	2.702	0.113	0.565
West Great Lakes	0.198	2.039	0.125	0.167
Northeast Plains	0.286	1.254	0.367	(0.263)
Northwest Plains	0.238	2.243	0.159	(0.200)
South Plains	0.233	2.129	0.125	0.142
Central Southeast	0.244	2.368	0.114	0.436
East Southeast	0.219	3.177	0.132	0.688
North Southeast	0.179	2.314	0.097	(0.156)
West Southeast	0.225	1.774	0.136	0.345
East Southwest	0.186	2.008	0.253	(0.832)
West Southwest	0.244	3.131	0.114	0.605
North Rocky Mountain	0.176	1.026	0.105	(0.868)
South Rocky Mountain	0.174	2.143	0.135	(0.723)
North Far West	0.192	2.384	0.167	(0.037)
South Far West	0.195	2.752	0.113	(1.019)

Table 4. Summary Statistics: Characteristics of Sub-Regions

Variable	Full Sample		Volcker-Greenspan	
	Mean	Standard Deviation	Mean	Standard Deviation
Personal income loss at trough	0.21	0.04	0.14	0.07
Total personal income loss (gain)	2.27	0.55	-0.09	0.51
Manufacturing share of non-farm employment (Bureau of Labor Statistics; full sample: 1969-2001; Volcker-Greenspan: 1983-2001)	14.60	3.90	12.95	3.12
Average employment share of firms with < 100 employees (Statistics of U.S. Business, Census Bureau)[a]	17.64	2.34	17.64	2.34
Average firm size (Statistics of U.S. Business, Census Bureau, 1988-2001)[a]	40.72	4.44	40.72	4.44
Weighted average of state deposit shares of three largest banks (average of 1983 and 1989; State and Metropolitan Area Data Book, Census Bureau)[a]	43.58	12.70	43.58	12.70
Weighted average of state deposit shares of five largest banks (average of 1983 and 1989; State and Metropolitan Area Data Book, Census Bureau)[a]	56.01	15.00	56.01	15.00

[a] Because of data availability, the same data were used for the full-sample and Volcker-Greenspan era estimations.

Table 5. The Channels of Monetary Policy, Full Sample

	PI Loss at Trough				Total PI Loss			
Constant	0.1790 (0.1428)	0.2280* (0.1184)	0.1697 (0.1473)	0.1920 (0.1229)	3.2651* (0.8638)	-2.0982* (0.8766)	3.4009* (1.0184)	-1.9938* (0.9280)
Manufacturing share	0.0013 (0.0043)	-0.0001 (0.0039)	0.0011 (0.0043)	-0.0005 (0.0038)	0.0349 (0.0205)	0.0389 (0.0248)	0.0430* (0.0213)	0.0516* (0.0263)
Small firms' share	0.0016 (0.0030)		0.0014 (0.0032)		-0.0732* (0.0181)		-0.0780* (0.0201)	
Average firm size		0.0016 (0.0050)		0.0027 (0.0048)		0.1272* (0.0488)		0.1194* (0.0546)
Share of 5 largest banks	-0.0010 (0.0007)	-0.0009 (0.0008)			0.0263* (0.0050)	0.0277* (0.0054)		
Share of 3 largest banks			-0.0008 (0.0010)	-0.0006 (0.0009)			0.0325* (0.0057)	0.0321* (0.0063)
Observations	19	19	19	19	19	19	19	19
F(3,15)	0.71	1.18	0.27	0.71	17.49	12.88	20.20	12.34
R^2	0.121	0.109	0.061	0.060	0.782	0.730	0.796	0.702
Root MSE	0.045	0.045	0.047	0.047	0.284	0.316	0.275	0.332

White-corrected standard errors are in parentheses. An '*' indicates statistical significance at the 10-percent level.

Table 6. The Channels of Monetary Policy, Volcker-Greenspan Era

	PI Loss at Trough				Total PI Loss			
Constant	0.2036 (0.2161)	0.4651* (0.2392)	0.1765 (0.2239)	0.4226* (0.2355)	-0.7063 (1.2490)	-1.7288 (1.0807)	-0.7367 (1.1887)	-1.9903 (1.1763)
Manufacturing share	-0.0068 (0.0043)	-0.0072 (0.0045)	-0.0071 (0.0048)	-0.0079 (0.0051)	0.0829* (0.0438)	0.0828 (0.0492)	0.0849* (0.0393)	0.0845* (0.0434)
Small firms' share	0.0036 (0.0055)		0.0038 (0.0057)		-0.0137 (0.0244)		0.0170 (0.0262)	
Average firm size		-0.0056 (0.0089)		-0.0047 (0.0086)		0.0254 (0.0608)		0.0316 (0.0603)
Share of 5 largest banks	-0.0022* (0.0012)	-0.0023* (0.0013)			0.0018 (0.0095)	0.0021 (0.0106)		
Share of 3 largest banks			-0.0024 (0.0015)	-0.0023 (0.0015)			0.0055 (0.0129)	0.0057 (0.0136)
Observations	19	19	19	19	19	19	19	19
F(3,15)	1.20	1.15	0.92	0.88	4.41	4.76	4.75	5.08
R^2	0.343	0.324	0.288	0.262	0.327	0.360	0.341	0.339
Root MSE	0.061	0.062	0.063	0.065	0.455	0.456	0.450	0.451

White-corrected standard errors are in parentheses. An '*' indicates statistical significance at the 10-percent level.

Figure 1. Aggregate VAR, Impulse Responses to Fed Funds Shock
(percentage difference from initial level)

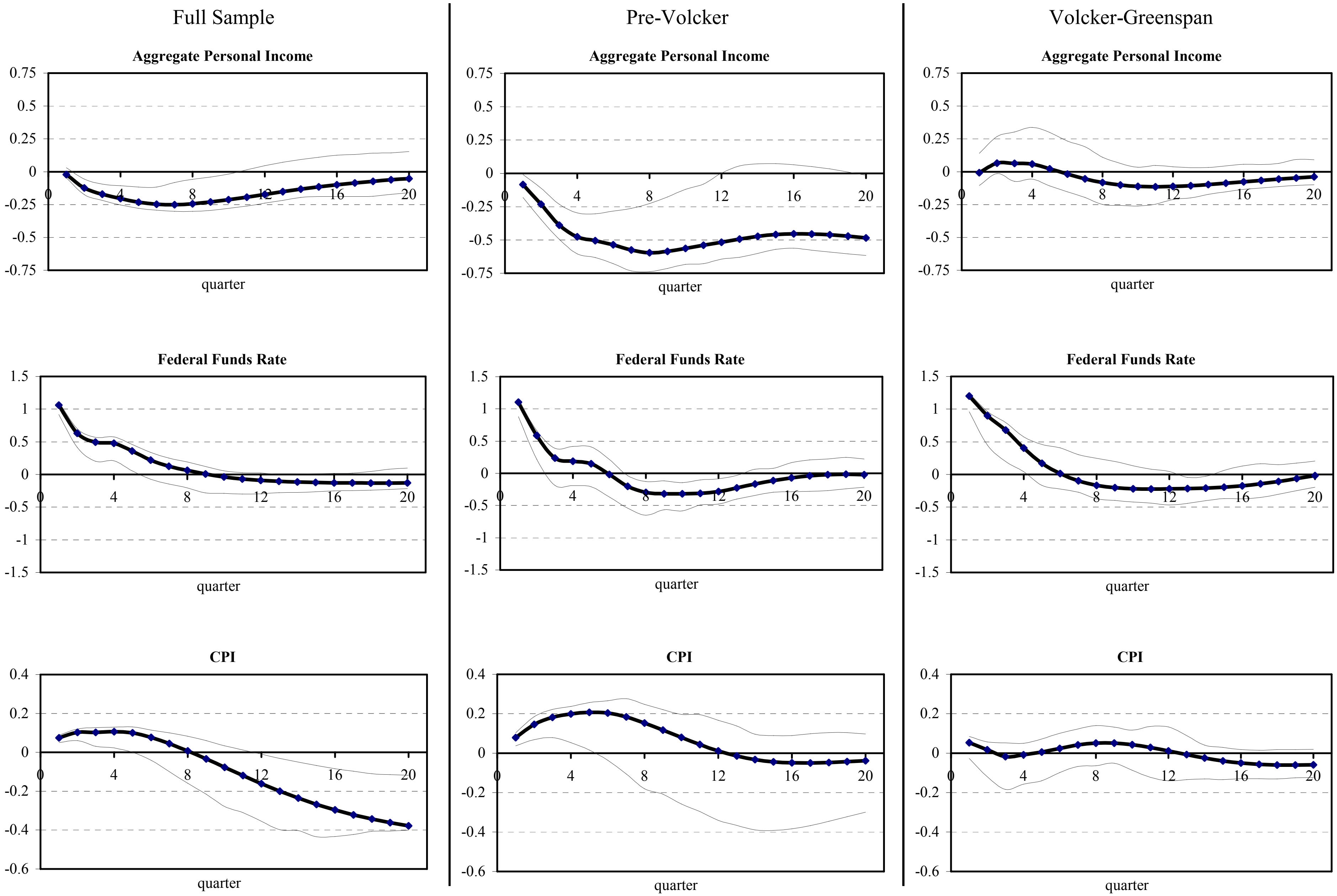

Figure 1. Aggregate VAR, Impulse Responses to Fed Funds Shock
(continued)

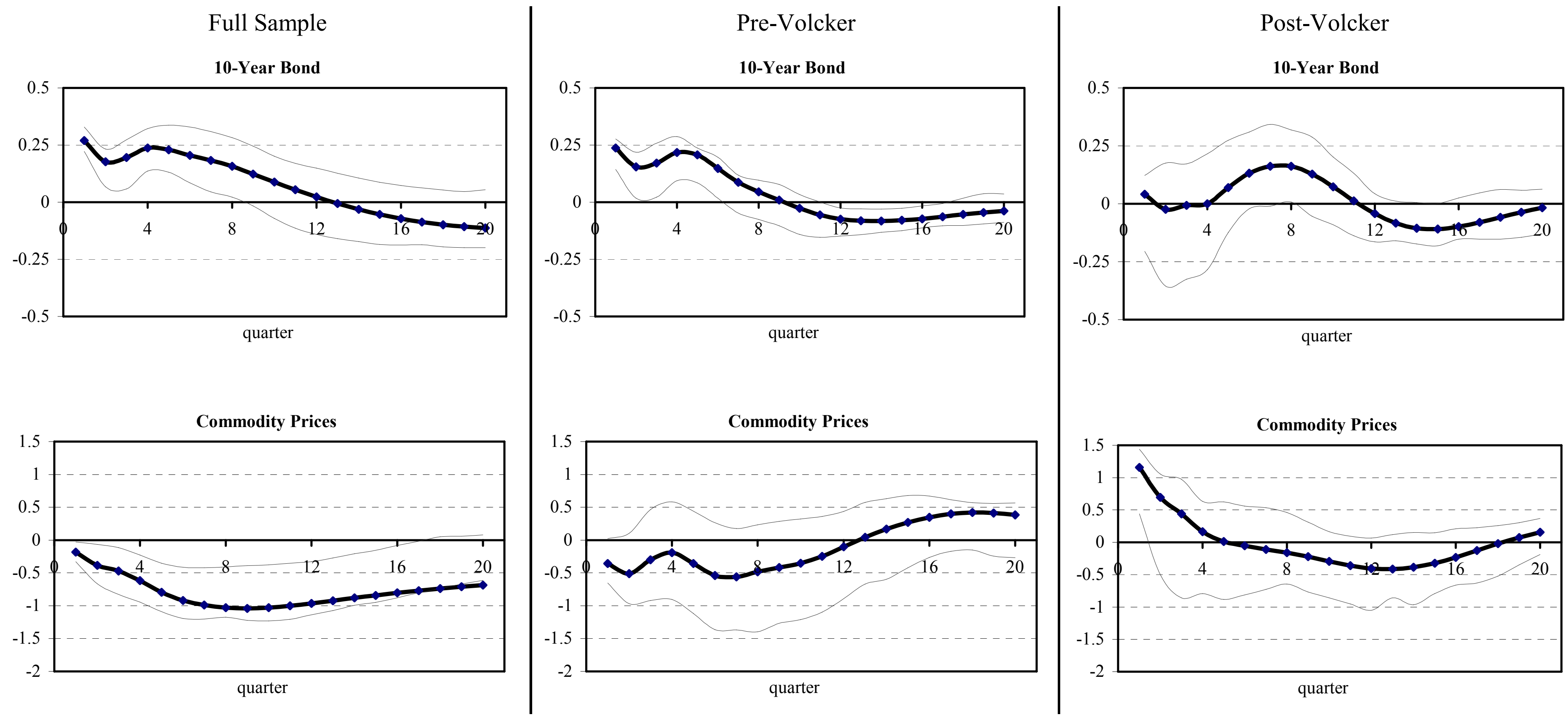

Figure 2. Regional VAR, Impulse Responses to Fed Funds Shock
(percentage difference from initial level)

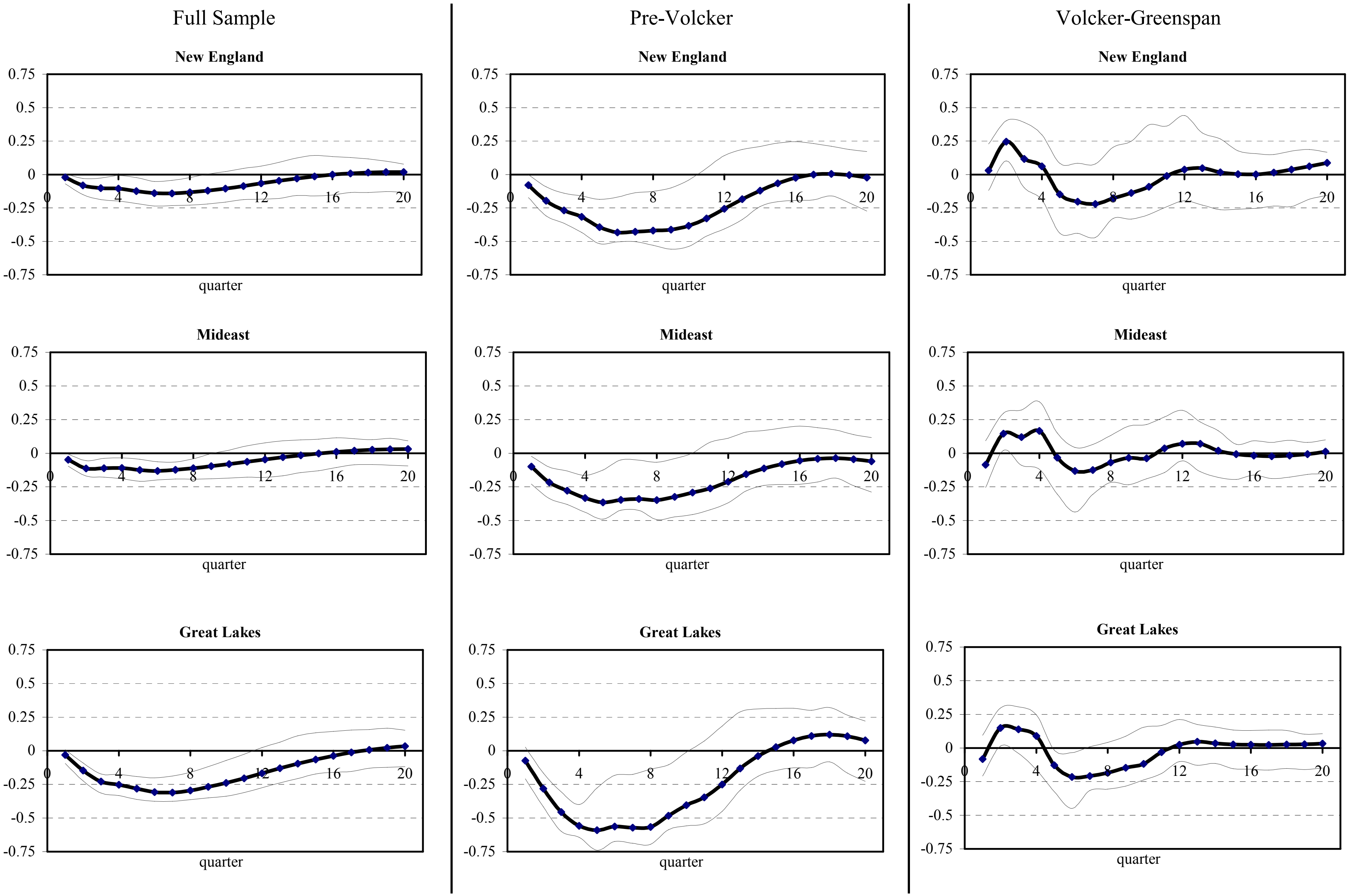

Figure 2. Regional VAR, Impulse Responses to Fed Funds Shock
(continued)

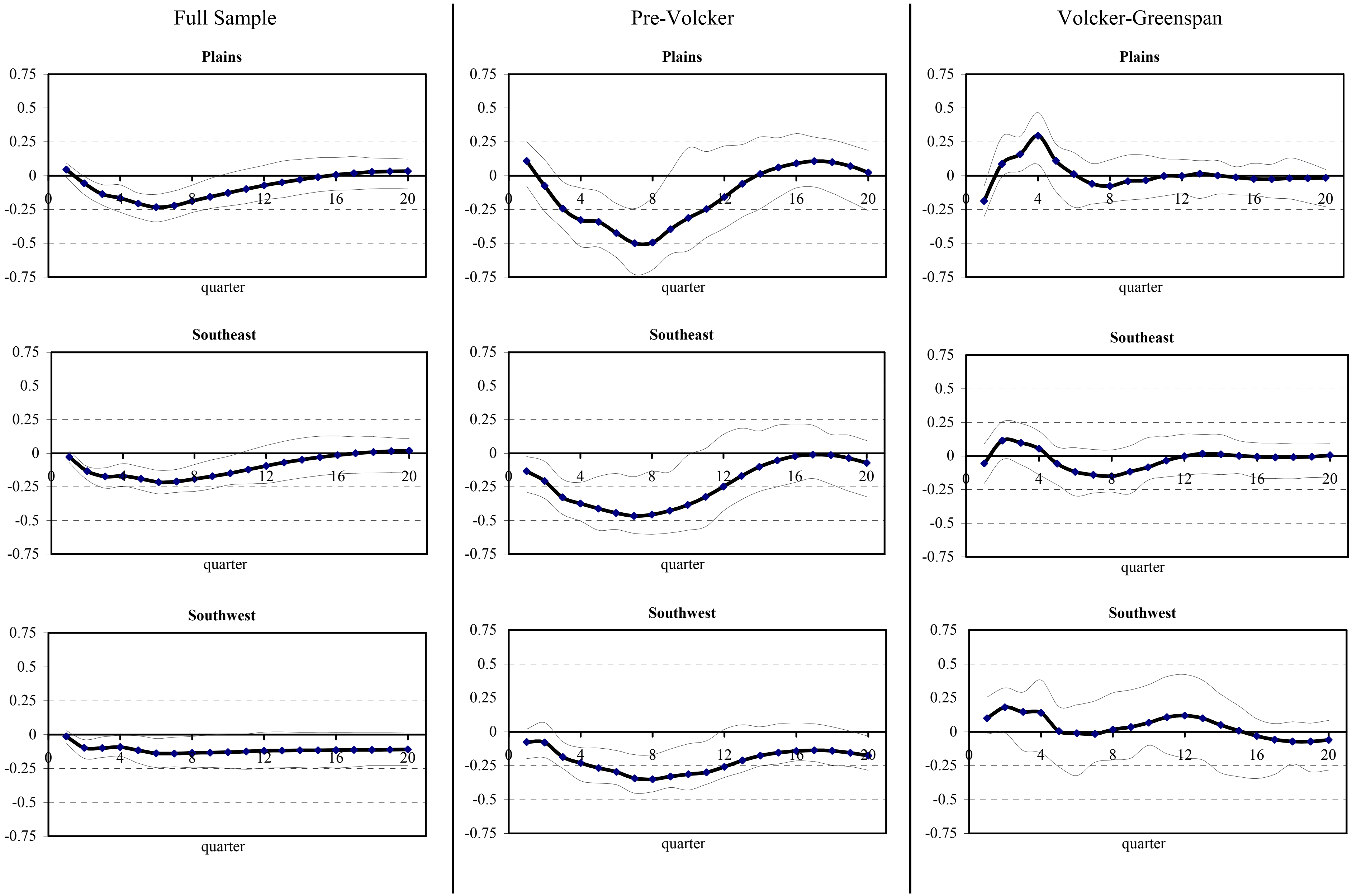

Figure 2. Regional VAR, Impulse Responses to Fed Funds Shock
(continued)

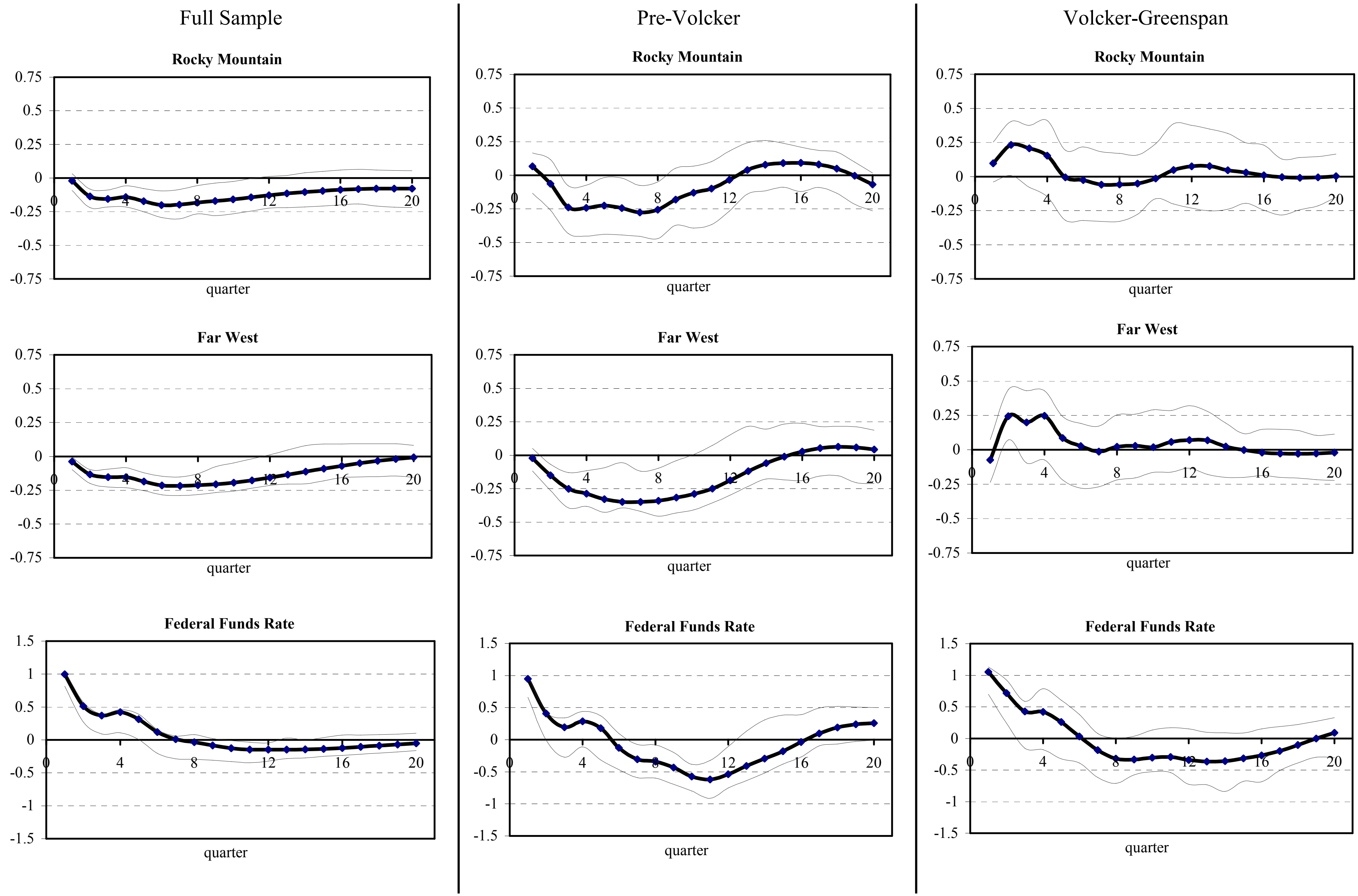

Figure 2. Regional VAR, Impulse Responses to Fed Funds Shock
(percentage difference from initial level)

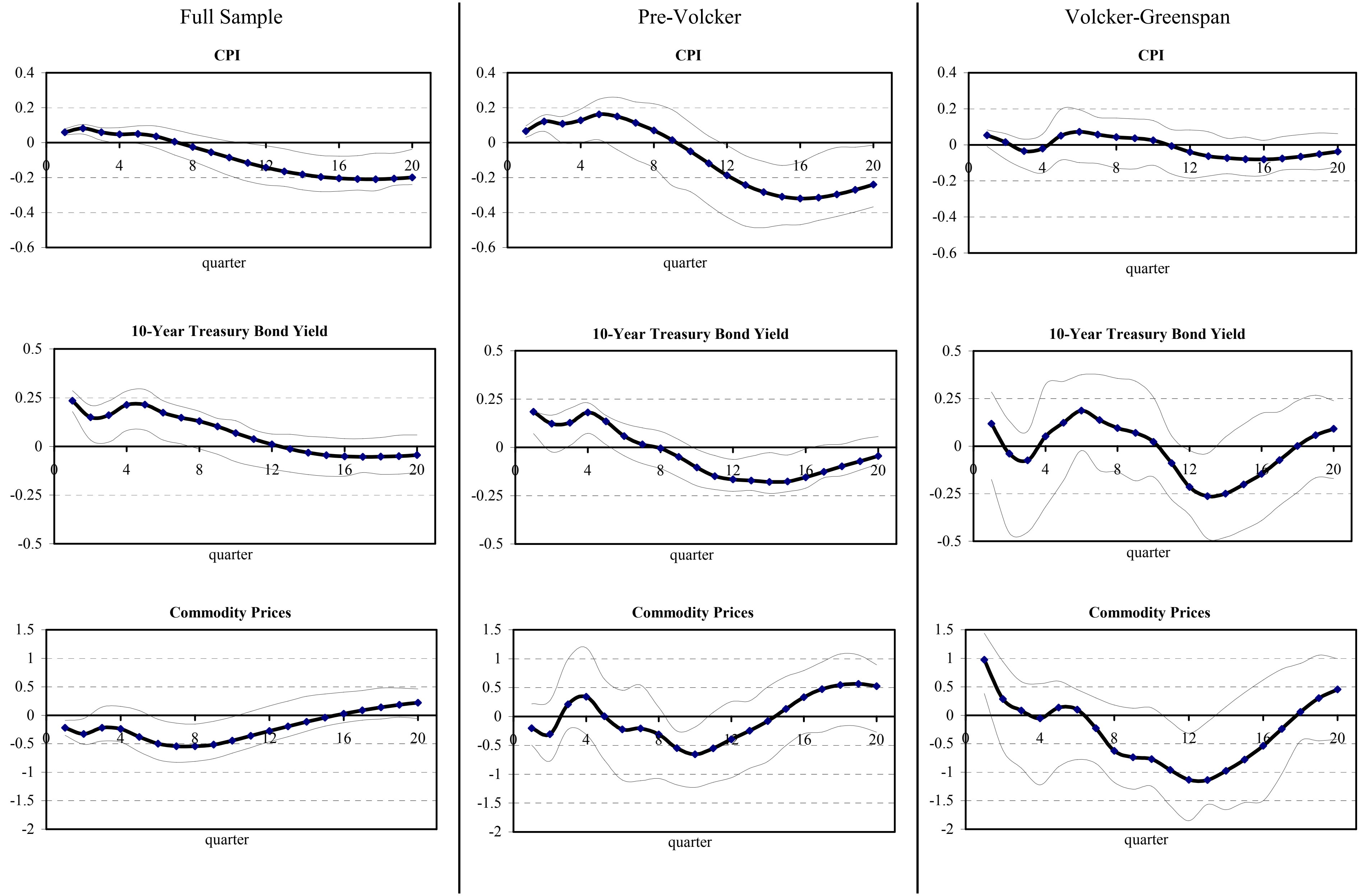

Figure 3. Aggregation Bias in PI Impulse Responses