Monetary Policy Transmission Through the Consumption-Wealth Channel

Additional Specifications and Technical Appendix *

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1 Alternative Specifications

In this section we briefly explore three alternative specifications of the VAR systems studied above. First, we conduct our experiments using stock market wealth and nonstock market wealth separately, in place of total household net worth. Second, we estimate the VAR separately in two subsamples, 1966:1 to 1979:1 and 1979:2 to 2000:3.

USING STOCK AND NONSTOCK WEALTH SEPARATELY. Because consumer theory does not typically rationalize distinct roles for stock and nonstock wealth, we have focused our analysis so far on models using total household net worth as our measure of wealth. Nevertheless, as a practical matter, it would be useful to know whether the wealth channel to consumption is greatly affected by what type of wealth goes in the consumption equation. Thus, as discussed in the Data Appendix, we split total wealth into stock and nonstock wealth. In practice, nonstock wealth is primarily housing, but also includes nonstock forms of financial assets, net of consumer liabilities. To carry out this exercise, we reestimated the impulse response functions and counterfactual experiments for the five variable model replacing total wealth first with stock market wealth, and then with nonstock market wealth.[1] The results for stock market wealth using nondurables and services expenditures, c_t, are shown in Figures 9 and 11; the results for the nonstock wealth are shown in Figures 10 and 12.

A comparison of Figures 9 and 10 shows that innovations in FF_t depress stock market wealth, but have little impact on nonstock market wealth. Higher inflation is bad for both forms of wealth however, and the Federal Reserve appears to respond vigorously to innovations in either type of wealth, each of which engender significant inflationary pressures in our sample. Consumption responds positively, on impact, to an innovation in stock market wealth, whereas consumption's response to a nonstock wealth shock is hump-shaped.

The counterfactual simulations in Figure 11 show that shutting down the stock wealth channel does reduce the negative impact of a funds rate increase on consumption, but like the results using total wealth, the difference lies within the standard error bands of the baseline consumption response. By contrast, Figure 12 indicates that shutting off the nonstock wealth channel has virtually no impact on the consumption response to an FF_t shock. In short, the

[1] Ideally, one would include both forms of wealth in the system separately, but this would require additional identifying assumptions regarding the joint relationship between stock and nonstock wealth. Unfortunately, it is unclear what additional substantive assumptions might achieve such identification.

qualitative nature of the results using total wealth are quite similar to the results using stock market wealth; the dynamic properties of nonstock wealth appear to be somewhat different and point to an even smaller role for the wealth channel in the transmission of monetary policy to consumer spending.

SUBSAMPLE ANALYSIS. It is often suggested that the conduct of monetary policy, and therefore the monetary policy reaction function, has changed at certain times during the post-war period. One such time that has received much attention is the break in the sample corresponding to data before and after the time in which Paul Volcker was Chairman of the Federal Reserve. As a crude way of investigating the possible impact of such instabilities in our system, we reestimated the impulse response functions and counterfactual experiments for our benchmark five variable models (without commodity prices) over two subsamples, 1966:Q1-1979:Q2 (pre-Volcker) and 1983:Q1-2000:Q3 (recent). We omit the interim years from 1979 to 1983 in which the Federal Reserve was experimenting with a nonborrowed reserve operating procedure. The results for the pre-Volcker period using nondurables and services expenditure, c_t, are shown in Figures 13 and 15; the results for the recent period are shown in Figures 14 and 16.[2]

There are several ways in which the impulse responses differ across the two subsamples. First, the federal funds rate responds much more vigorously to a wealth shock in the pre-Volcker sample than it does in the recent sample, possibly owing to the finding that wealth innovations appear to be more strongly associated with higher prices in the former period than in the latter. Nevertheless, a shock to prices depresses real consumption, income and wealth across both periods. Second, the sharpest decline in wealth resulting from a federal funds rate shock is in the pre-Volcker period (although the response itself is found to be rather choppy). Federal funds rate shocks in the recent period have very little effect on wealth, if not a positive effect. This latter finding is similar to that obtained over the full sample in the six variable system, discussed above. This may occur because of the decline in the indicative role of commodity prices in explaining inflation over the more recent period. Some authors have suggested that the Fed is more effective at countervailing early inflationary signals now than it was in the pre-Volcker era, implying that mounting price pressures that were previously captured by cp_t may now be summarized by movements in π_t alone (Goto and

[2] We also reestimated the impulse response functions over the subsample 1983:Q1-2000:Q3, eliminating the so-called "Volker experiment" from the last subsample. None of the conclusions we draw below were affected by choosing this subperiod over the entire post-Volker regime, 1979:Q3-2000:Q3.

Valkanov (2000)). If this hypothesis is correct, the Federal Reserve's endogenous policy response to these price pressures may be well captured by its response to π_t. (In addition, such a hypothesis could explain why funds rate innovations have relatively little impact on consumption and labor income (Figure 14) in this sample.) If the majority of the impact of Federal Reserve policy on asset values is attributable to the central bank's response to inflationary pressures, and not to higher short-term interest rates as such, this would explain why an innovation in FF_t does not depress asset values in the five variable system over the more recent subsample, even though such a result held over the full sample only in the six variable system that included commodity prices.

Figure 15 shows, for the pre-Volcker period, the response of consumption to an FF_t shock under the baseline scenario and under the counterfactual scenario with the wealth channel to consumption shut down. Figure 16 shows the analogous figure for the recent period. Compared to the full sample results, it appears that the consumption-wealth linkage was a more important channel of monetary transmission in the earlier period than in the latter period. The decline of consumption in the pre-Volcker period in response to a funds rate shock with the wealth channel shut off is less than it is under the baseline scenario. However, consumption under the counterfactual scenario still does not lie outside of the one-standard error bands of the baseline scenario response. By contrast, Figure 16 shows, for the recent period, that the IRF under the baseline scenario lies above that of the counterfactual scenario; as before, this is attributable to the finding that funds rate shocks have no negative impact on wealth in the recent subsample. It is possible that this difference between the counterfactual responses in the two periods reflects the possibility that the Federal Reserve's endogenous response to price pressures are better captured in this five variable system over the later period than they are over the earlier period. Alternatively, these differences may imply that the wealth channel of monetary transmission to consumption was stronger in pre-Volcker period than in the recent period.

Technical Appendix

This appendix provides a technical description of how we identify and estimate the structural VARs used in our study.

The structural model of the contemporaneous relationships between the variables in our benchmark system is given as follows:

$$\mathbf{B}_0\mathbf{z}_t = \mathbf{k} + \mathbf{B}_1\mathbf{z}_{t-1}+\mathbf{B}_2\mathbf{z}_{t-2}+... + \mathbf{B}_p\mathbf{z}_{t-p}+\mathbf{u}_t, \tag{1}$$

where p denotes the lag order of the system. In our benchmark application, $\mathbf{z}_t = (\pi_t, y_t, c_t, a_t, FF_t)'$ and $n = 5$. The structural model may be written more compactly as

$$\mathbf{B}_0\mathbf{z}_t = \mathbf{\Gamma}\mathbf{x}_t+\mathbf{u}_t, \tag{2}$$

where

$$\mathbf{\Gamma} \equiv [\mathbf{k}\ \mathbf{B}_1\ \mathbf{B}_2\ ...\ \mathbf{B}_p],$$

$$\mathbf{x}_t \equiv \begin{bmatrix} 1 \\ \mathbf{z}_{t-1} \\ \mathbf{z}_{t-2} \\ . \\ . \\ . \\ \mathbf{z}_{t-p} \end{bmatrix}.$$

The reduced-form of this structural model is the VAR, which we write in the form

$$\mathbf{z}_t= \mathbf{\Pi}'\mathbf{x}_t+\boldsymbol{\epsilon}_t, \tag{3}$$

where $\mathbf{\Pi}' = \mathbf{B}_0^{-1}\mathbf{\Gamma}$, and $\boldsymbol{\epsilon}_t= \mathbf{B}_0^{-1}\mathbf{u}_t$.

Denote the covariance matrix of reduced-form errors, $E(\boldsymbol{\epsilon}_t\boldsymbol{\epsilon}_t') = \mathbf{\Omega}$ and the covariance matrix of structural errors, $E(\mathbf{u}_t\mathbf{u}_t') = \mathbf{D}$. We assume that $\mathbf{D}$ is a diagonal matrix, i.e., the disturbances in the structural equations are serially uncorrelated and uncorrelated with each other.

The first step in our analysis requires that we identify the structural innovations, $\mathbf{u}_t$. To do so, we follow the approach of Bernanke (1986), Blanchard and Watson (1986), and Sims

(1986) and specify a set of restrictions on $\mathbf{B}_0$ and $\mathbf{D}$ such that unique values of parameters in $\mathbf{B}_0$ and $\mathbf{D}$ can be found that satisfy $\mathbf{\Omega} = \mathbf{B}_0^{-1}\mathbf{D}(\mathbf{B}_0^{-1})'$. Once the values of these parameters are determined, we may trace-out the dynamic influence of the jth variable on other variables in the system, i.e., we calculate

$$\frac{\partial \mathbf{z}_{t+s}}{\partial u_{jt}} = \frac{\partial \mathbf{z}_{t+s}}{\partial \boldsymbol{\epsilon}'_t}\frac{\partial \boldsymbol{\epsilon}_t}{\partial u_{jt}} = \mathbf{\Psi}_s \mathbf{b}^j \sqrt{d_{jj}}, \tag{4}$$

where u_{jt} is the jth element of the vector $\mathbf{u}_t$, d_{jj} is the element in the jth row and jth column of $\mathbf{D}$, $\mathbf{b}^j$ is the jth column of $\mathbf{B}_0^{-1}$, and $\mathbf{\Psi}_s$ is the matrix of coefficients for the sth lag of the $MA(\infty)$ representation of (3).

Several aspects of this approach as it relates to our particular application bear noting. First, a common method of obtaining the orthogonal innovations, $\mathbf{u}_t$, from the reduced-form residuals, $\boldsymbol{\epsilon}_t$, (based on a Cholesky decomposition of $\mathbf{\Omega}$) is to assume, for a specified ordering of the variables in $\mathbf{z}_t$, that $\mathbf{B}_0$ is lower triangular. This approach requires the presumption that the true structural model in (2) is strictly recursive. If the true economic model is not thought to be recursive, however, the orthogonal "shocks" obtained using this approach have no particular meaning.[3] As we argue below, the relationships between the variables in our application are not likely to be recursive (i.e., $\mathbf{B}_0$ is not plausibly lower triangular). For example, it is often assumed in the VAR literature on monetary policy that nonpolicy variables such as prices, output, and consumption are Wold-causally prior to the federal funds rate. This assumption may be reasonable for "slow-moving" macroeconomic variables, but is clearly less plausible for asset values, which can react almost instantaneously to news about monetary policy. Yet the converse also seems plausible: it is clearly possible for monetary policy to react within a quarter or even a month to movements in asset values. It follows that a traditional recursive structure is unlikely to capture the true contemporaneous relationships between consumption, asset wealth and monetary policy. We therefore suggest an alternative set of structural assumptions, placing restrictions on $\mathbf{B}_0$, in order to obtain the orthogonal innovations, $\mathbf{u}_t$. We discuss these restrictions in detail below.

Second, in this paper we focus on the dynamic response of c_t to an FF_t shock, and ask how important the marginal effect of the endogenous response of a_t is in transmitting that shock to c_t. Since we are not concerned with identifying the effects of innovations in the other variables in the system, we may "sweep out" the block of variables not directly involved in the consumption–wealth–federal-funds relationship (i.e., π_t and y_t) and achieve

[3]This point was argued forcibly by Bernanke (1986).

identification by placing restrictions on the lower right-hand submatrix of $\mathbf{B}_0$, which governs the contemporaneous relations between FF_t, a_t, and c_t. We then allow the variables in that block to enter the system in a recursive manner relative to one another; the ordering of the variables in that block will not affect the analysis of how funds rate innovations influence consumption via their influence on wealth. Thus, recalling that $\mathbf{z}_t = (\pi_t, y_t, c_t, a_t, FF_t)'$, we write $\mathbf{B}_0$ as

$$\mathbf{B}_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \beta_{21} & 1 & 0 & 0 & 0 \\ \beta_{31} & \beta_{32} & 1 & \beta_{34} & \beta_{35} \\ \beta_{41} & \beta_{42} & \beta_{43} & 1 & \beta_{45} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & 1 \end{bmatrix}, \tag{5}$$

and focus on placing the number of further restrictions needed on the lower right-hand, 3×3 submatrix to insure identification of the structural model (2). We place only the number restrictions necessary to exactly identify the structural model (2). Although overidentified models can be estimated, we consider only exactly identified models because (as is typically the case) substantive overidentifying assumptions are not obvious. We discuss these restrictions in detail below.

Third, to obtain a solution to the nonlinear system of equations $\mathbf{B}_0^{-1}\mathbf{D}(\mathbf{B}_0^{-1})' = \mathbf{\Omega}$, both an order condition and a rank condition must be satisfied (Bernanke (1986)). The order condition is that the number of free parameters in $\mathbf{B}_0$ and $\mathbf{D}$ be less than or equal to the number of distinct elements in $\mathbf{\Omega}$, in this case equal to 15. If $\mathbf{D}$ is diagonal, it has five free parameters in our benchmark model, allowing us to identify only 10 parameters in (5). Since (5) currently has 13 free parameters, our application requires three further restrictions on the lower right-hand submatrix of $\mathbf{B}_0$. The rank condition is that the system of nonlinear equations given by $\mathbf{B}_0^{-1}\mathbf{D}(\mathbf{B}_0^{-1})' = \mathbf{\Omega}$ have at least one solution. In practice, this condition may be verified by making a guess as to the values of the structural parameters and checking whether the matrix of partial derivatives of $\mathbf{\Omega}$ is of full rank. We performed such an exercise to check the order condition for the 5 variable system.

To round out our identification of the structural model, we make the following assumptions allowing us to place restrictions on the lower right-hand submatrix of $\mathbf{B}_0$.

First, following Bernanke and Blinder (1992) and many other authors, we assume that federal funds rate responds contemporaneously to developments in the macroeconomy (i.e., consumption and labor income), but changes in interest rates (given planning and production lags) can only affect these variables with a one-period lag.[4] This assumption allows us to both place the block of macroeconomic variables not included in the consumption-wealth-FF link first in $\mathbf{z}_t$, as above, and implies that β_{35}–the within-period effect of FF_t on c_t–equals zero.

Second, we assume that wealth, a_t, which is measured at the *beginning of the period*, is not influenced contemporaneously by c_t, a flow *over the period*, implying that β_{43} is zero.[5] We justify this assumption with another one, namely that the log of aggregate consumption is close to a random walk, consistent with permanent-income type behavior.[6] Since wealth is measured at the beginning of the period, consumption can only affect asset values contemporaneously if it captures expectations of consumption as of the end of the previous period. But if consumption is close to a random walk, lagged consumption–already accounted for in the asset wealth equation–completely summarizes expectations of consumption as of the end of last period. Of course, quarterly spending is not exactly a random walk; there is a small predictable component in consumption growth related to a small predictable component in labor income growth (Campbell and Mankiw (1989)). So, more generally, we assume that

[4]This assumption is admittedly more plausible in monthly data than it is in our quarterly data, and admittedly less plausible for the commodity price index, which we include in the system later.

[5]A timing convention is needed because the level of consumption is a flow during the quarter rather than a point-in-time value (consumption data are time-averaged). If we think of consumption for a given quarter as measuring spending at the beginning of the quarter, then the appropriate measure of wealth is beginning-of-period wealth. This seems to us the most reasonable assumption since in this scenario households can "stock their refrigerator" at the beginning of the period and consume over the period by running down that stock during the period. On the other hand, if we think of consumption for a given quarter as measuring spending at the end of the quarter, then the appropriate measure of wealth is end-of-period wealth. This latter convention requires the implausible assumption that households consume in one instant on the last day of the period after the markets close. Thus we do not report those results here. Nevertheless, as a robustness check, we performed our empirical tests under both timing assumptions and find that the conclusions we present here are not altered by whether wealth is measured at the beginning or end of the period. The treatment of timing here is the same as that used to derive the consumption functions specified in Campbell and Mankiw (1989) and Deaton (1991).

[6]For evidence that the log of nondurables and services expenditure can be well characterized by a random walk process, see Harvey and Stock (1988), Cochrane (1994), Ludvigson and Steindel (1999), Lettau and Ludvigson (2001a), and Lettau and Ludvigson (2001b). Although quarterly spending growth does display some modest first-order serial correlation, such serial correlation may be plausibly explained by data construction methodologies such as the time-averaging of quarterly expenditure data and the interpolation of service flows from annual surveys.

the key variables which capture expectations of future consumption are already contained in the asset wealth equation. Thus, thinking of these equations as structural relations, only those variables either known as of the end of $t-1$, or plausibly related to expectations formed as of the end of $t-1$, should influence a_t contemporaneously, implying β_{43} is zero.

Third, we allow asset wealth, a_t, and the federal funds rate, FF_t, to influence each other simultaneously within the period, but we restrict the way in which asset values influence policy. Specifically, we assume that the Federal Reserve does not target asset values directly, but only cares about them in-so-far as they signal important movements in real variables or prices. This assumption is consistent with results in Bernanke and Gertler (1999) who find no evidence that the Federal Reserve responds to stock market returns independently of their implication for forecasts of inflation and the output gap.[7] In addition, we assume that the Federal Reserve does not attempt to use asset values to forecast real variables or inflation more than one quarter hence. Although in-sample regressions suggest that asset values have led some real variables and inflation at some times over the post-war period, such forecasting power is found to be unstable and, as a consequence, is not evident in out-of-sample forecasting tests (Stock and Watson (2000)). Accordingly, we assume the Federal Reserve does not attempt to exploit such unreliable forecasting power in predicting macroeconomic variables more than one-quarter in advance, despite the possibility that there may be some episodes in history during which asset prices are found, *ex-post*, to have led real variables and inflation. Taken together, these assumptions imply that β_{54} in (5) equals zero. Notice that asset values are allowed to respond contemporaneously to changes in the federal funds rate since β_{45} is left unrestricted.

[7] We also conducted a test of this assumption, similar to that conducted by Bernanke and Gertler (1999). Specifically, we estimated a single equation "reaction function" for the federal funds rate, FF_t, by instrumental variables (IV), using, as instruments, variables known at time t or earlier. Thus FF_t is estimated as the dependent variable in an IV regression on Δc_t, Δy_t, Δp_t, plus the log difference of a spot commodity price index, Δcp_t. Three quarterly lags of each of these variables, and of the funds rate, were used as instruments. In addition, we add the current and three lagged values of the log difference in asset wealth, Δa_t. If monetary policy reacts *directly* to asset values, the contemporaneous and lagged value of Δa_t should have independent forecasting power for FF_t in the IV regressions. In a sample spanning the first quarter of 1966 to the third quarter of 2000, we find, consistent with the results in Bernanke and Gertler (1999), no evidence that the Federal Reserve reacts directly to asset values. The coefficients on the contemporaneous and lagged value of Δa_t are not jointly significant determinants of FF_t, and, more generally, the over-identifying restrictions of this regression are not rejected.

To summarize, we now have the three additional restrictions on $\mathbf{B}_0$ needed to find a solution to the nonlinear system of equations $\mathbf{B}_0^{-1}\mathbf{D}(\mathbf{B}_0^{-1})' = \mathbf{\Omega}$, and to identify the structural model (2). With these restrictions, $\mathbf{B}_0$ takes the form

$$\mathbf{B}_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \beta_{21} & 1 & 0 & 0 & 0 \\ \beta_{31} & \beta_{32} & 1 & \beta_{34} & 0 \\ \beta_{41} & \beta_{42} & 0 & 1 & \beta_{45} \\ \beta_{51} & \beta_{52} & \beta_{53} & 0 & 1 \end{bmatrix}. \tag{6}$$

This matrix is clearly not lower triangular, but it nevertheless leaves the model exactly identified since there are now 10 free parameters in $\mathbf{B}_0$ to be estimated. Thus, to the extent that the identification assumptions we make here are plausible, the discussion so far implies that it would be misleading to make structural inferences about the relationships between the variables studied here from traditional, recursive VAR models.

The parameters in $\mathbf{B}_0$ and $\mathbf{D}$ may be estimated by maximizing the log-likelihood function for the system (2), which, if all the parameters are identified, will produce estimates, $\widehat{\mathbf{B}}_0$ and $\widehat{\mathbf{D}}$ satisfying $\widehat{\mathbf{B}}_0^{-1}\widehat{\mathbf{D}}(\widehat{\mathbf{B}}_0^{-1})' = \widehat{\mathbf{\Omega}}$ (Bernanke (1986)). Standard errors for the parameters in $\widehat{\mathbf{B}}_0$ may be estimated by inverting a second-derivative approximation of the information matrix of the maximum likelihood problem associated with (2). To conserve space, we do not report these standard errors and point estimates (which give the impact effect of a shock to any one of the variables on any other variables in the system), but instead present the entire dynamic response of each variable from IRFs with standard error bands.[8]

As a robustness check, we include the log of a commodity price index, cp_t, in the five-variable baseline model (2). We include this variable in the block of variables not involved in the $c - a - FF$ relationship, so that $\mathbf{z}_t = (\pi_t, cp_t, y_t, c_t, a_t, FF_t)'$and $\mathbf{B}_0$ for this six-variable

[8]Standard error bands for the impulse response functions that follow are computed by drawing from the joint distribution of $\mathbf{\Pi}$ and $\mathbf{\Omega}$ to generate a Monte Carlo sample from the posterior distribution of impulse responses. Note that reliance on this traditional method to generate draws from the joint distribution of reduced-form parameters is possible in our application because the structural model (2) is exactly identified (Sims and Zha (1999)).

system takes the form

$$
\mathbf{B}_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ \beta_{21} & 1 & 0 & 0 & 0 & 0 \\ \beta_{31} & \beta_{32} & 1 & 0 & 0 & 0 \\ \beta_{41} & \beta_{42} & \beta_{43} & 1 & \beta_{45} & 0 \\ \beta_{51} & \beta_{52} & \beta_{53} & 0 & 1 & \beta_{56} \\ \beta_{61} & \beta_{62} & \beta_{63} & \beta_{64} & 0 & 1 \end{bmatrix}.
$$

Like the benchmark five-variable system, this model is also exactly identified since $\mathbf{\Omega}$ now has 21 free parameters, allowing us to identify 6 parameters in $\mathbf{D}$ and 15 parameters in $\mathbf{B}_0$.

COUNTERFACTUAL EXPERIMENTS: Counterfactual scenarios are simulated by setting to zero both the contemporaneous response of consumption to wealth, given by β_{34} in (2), as well as any lagged response of consumption to wealth given by parameters in the third row of $\mathbf{\Gamma}$ governing the influence of lagged wealth on consumption, fixing the covariance matrix of the primitive shocks, $\mathbf{D}$, at its baseline value. This counterfactual scenario effectively eliminates the marginal impact of wealth on consumption when the latter responds to a federal funds rate shock, rather than allowing consumption to respond to the endogenous movement in wealth induced by that shock.

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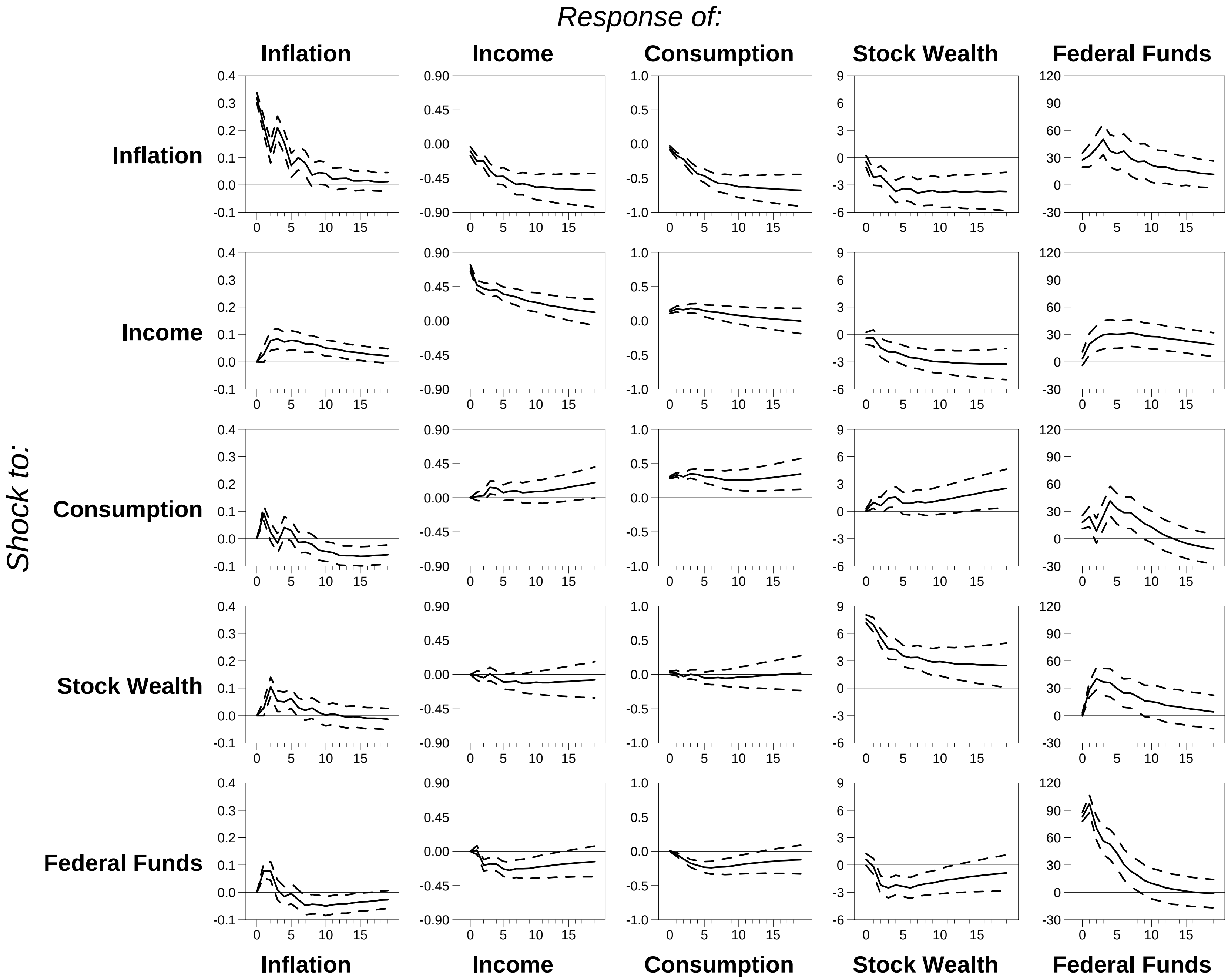
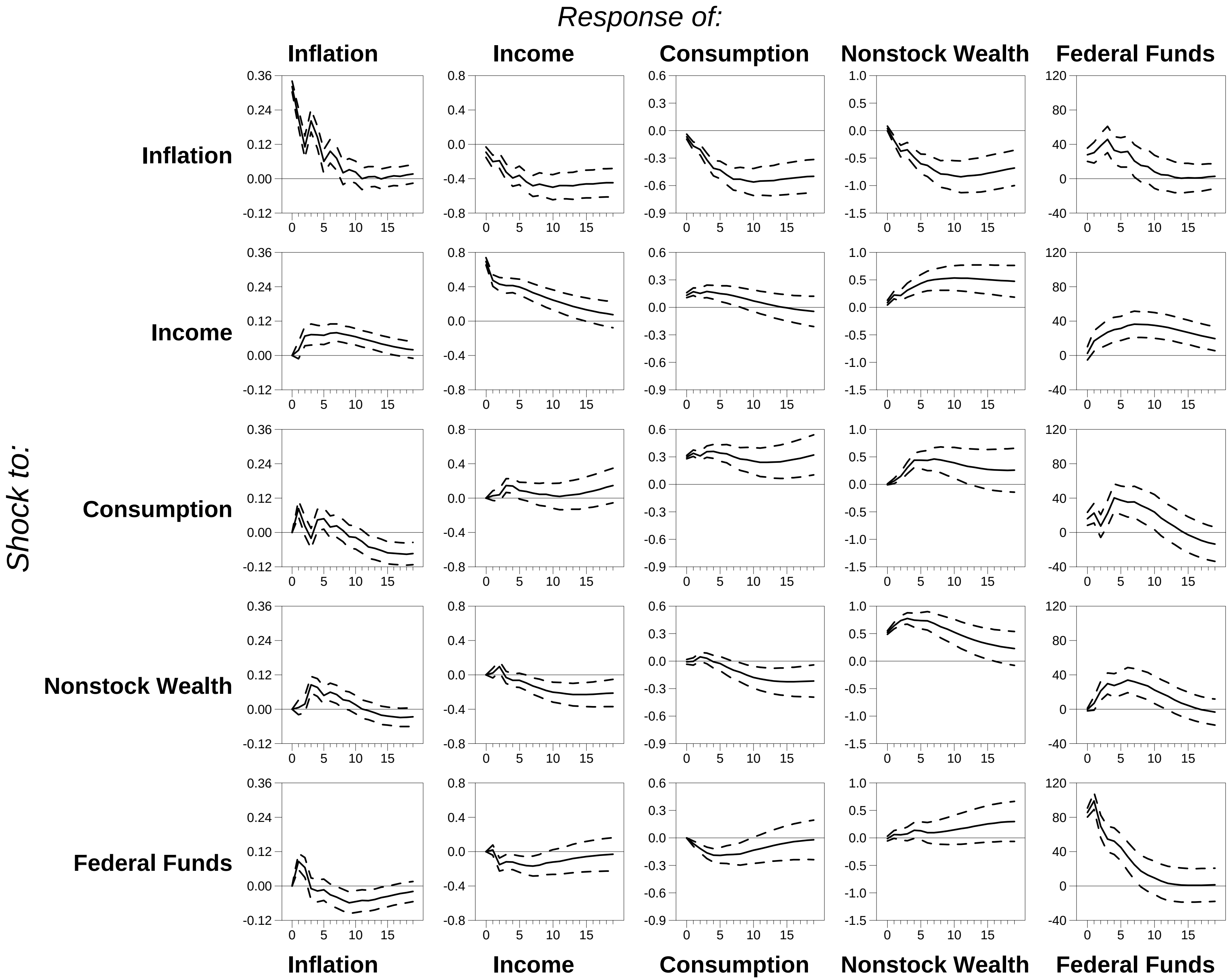
Figure 9: Impulse Responses, Five Variable System



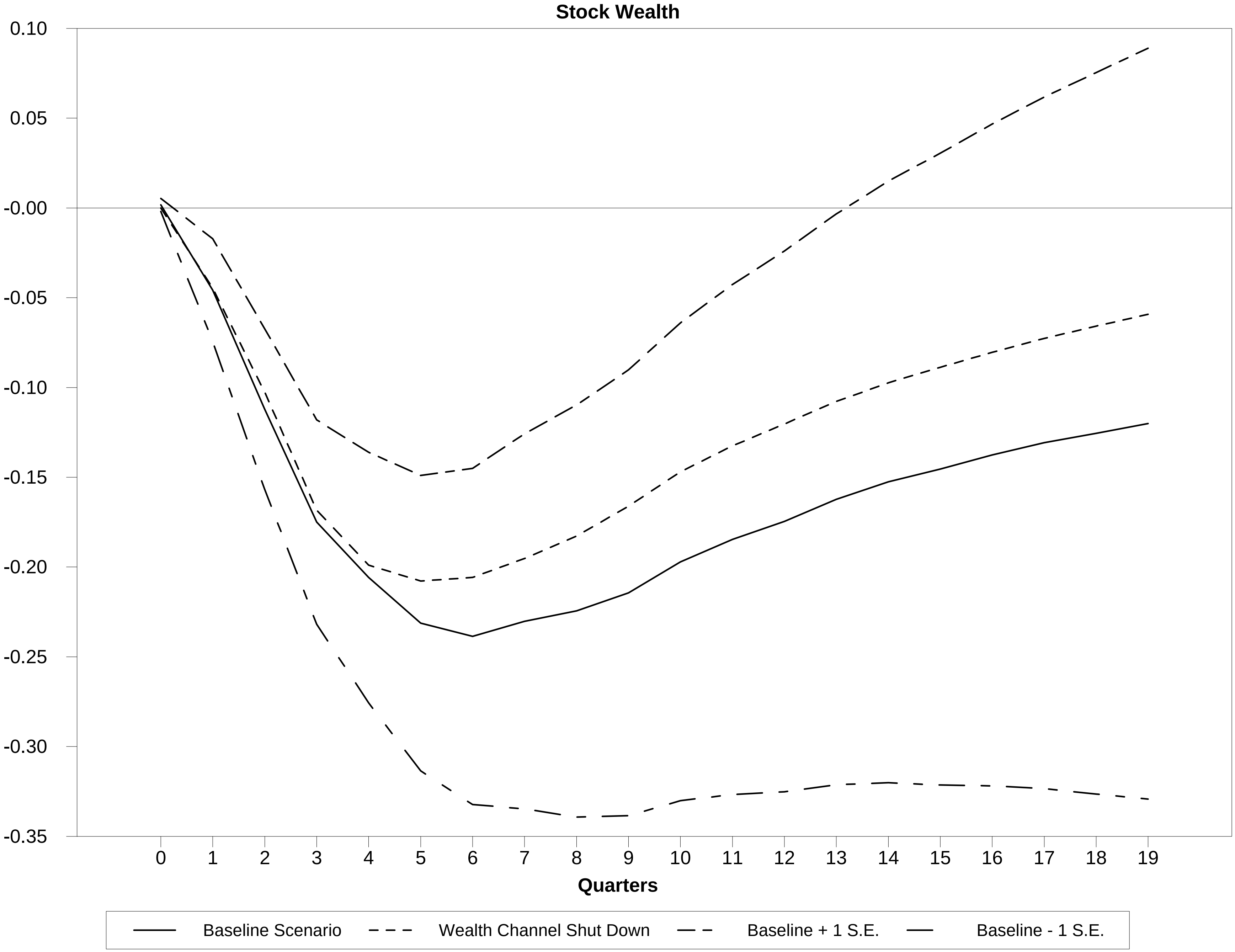
Notes: see notes for Figure 1

Figure 10: Impulse Responses, Five Variable System



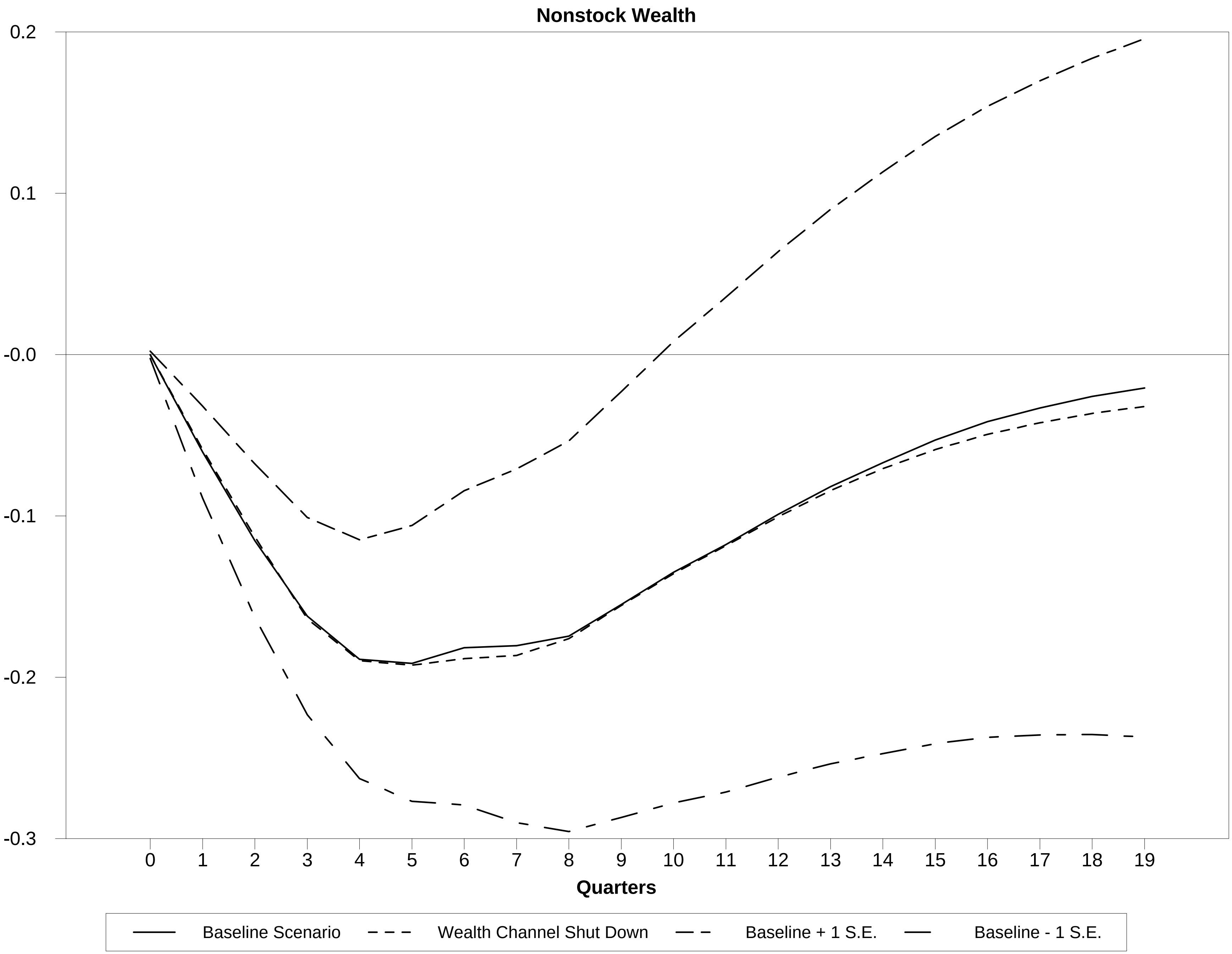
Notes: see notes for Figure 1

Figure 11: Response of Consumption to Federal-funds-rate Shock, Five Variable System



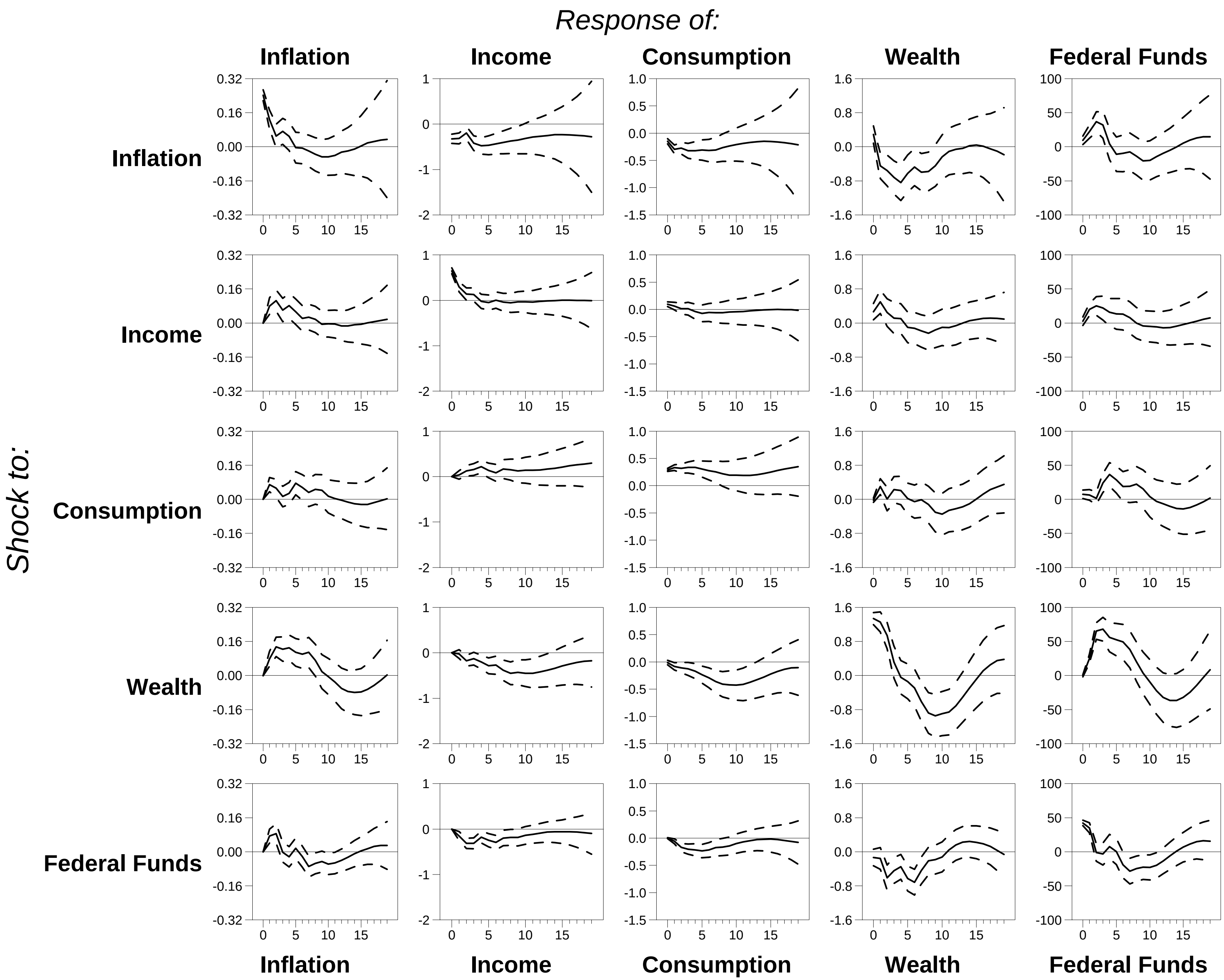
Notes: see notes for Figure 1

Figure 12: Response of Consumption to Federal-funds-rate Shock, Five Variable System



Notes: see notes for Figure 1

Figure 13: Impulse Responses, Five Variable System, 1966:Q1-1979:Q2



Notes: see notes for Figure 1

Figure 14: Impulse Responses, Five Variable System, 1983:Q1-2000:Q3

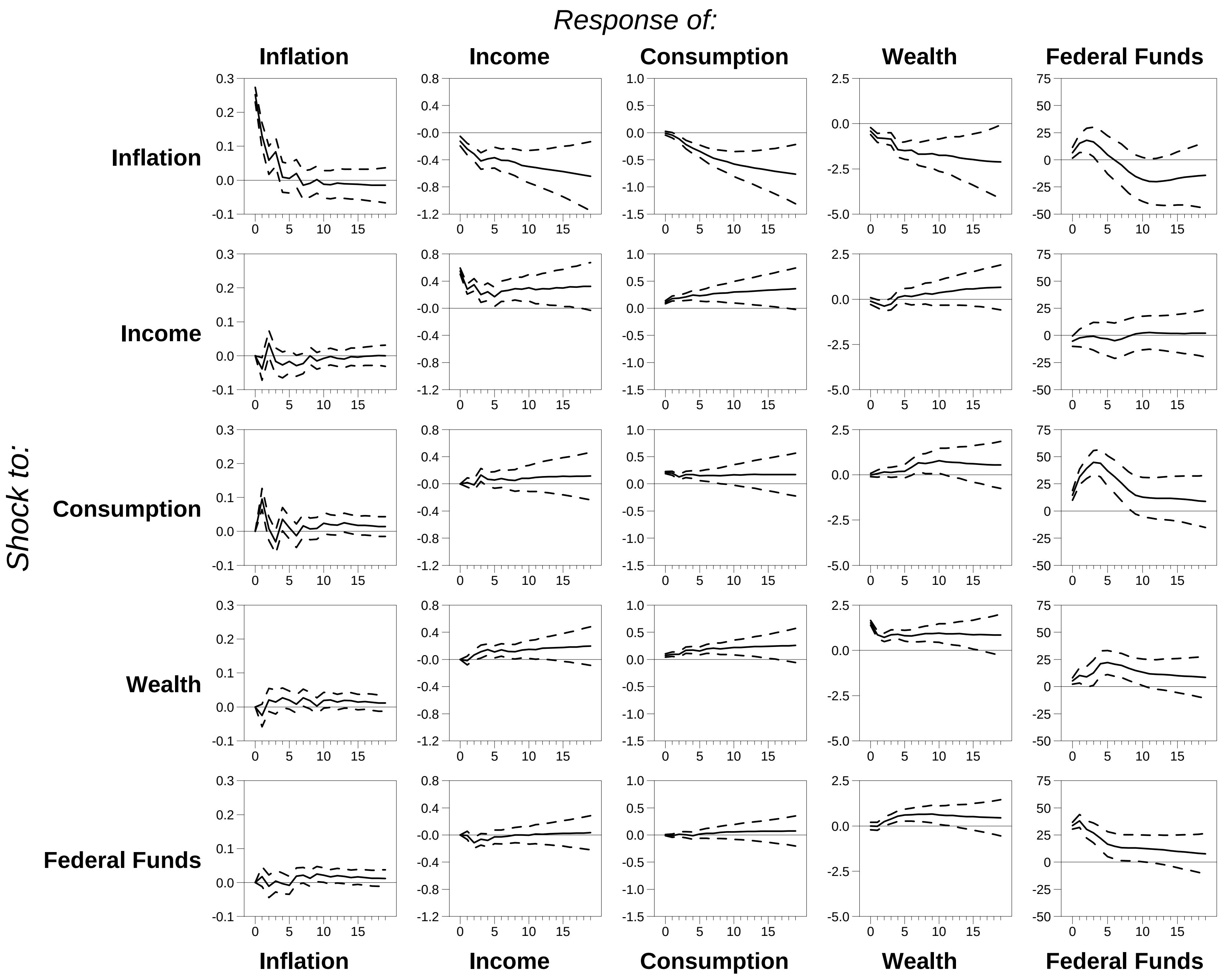
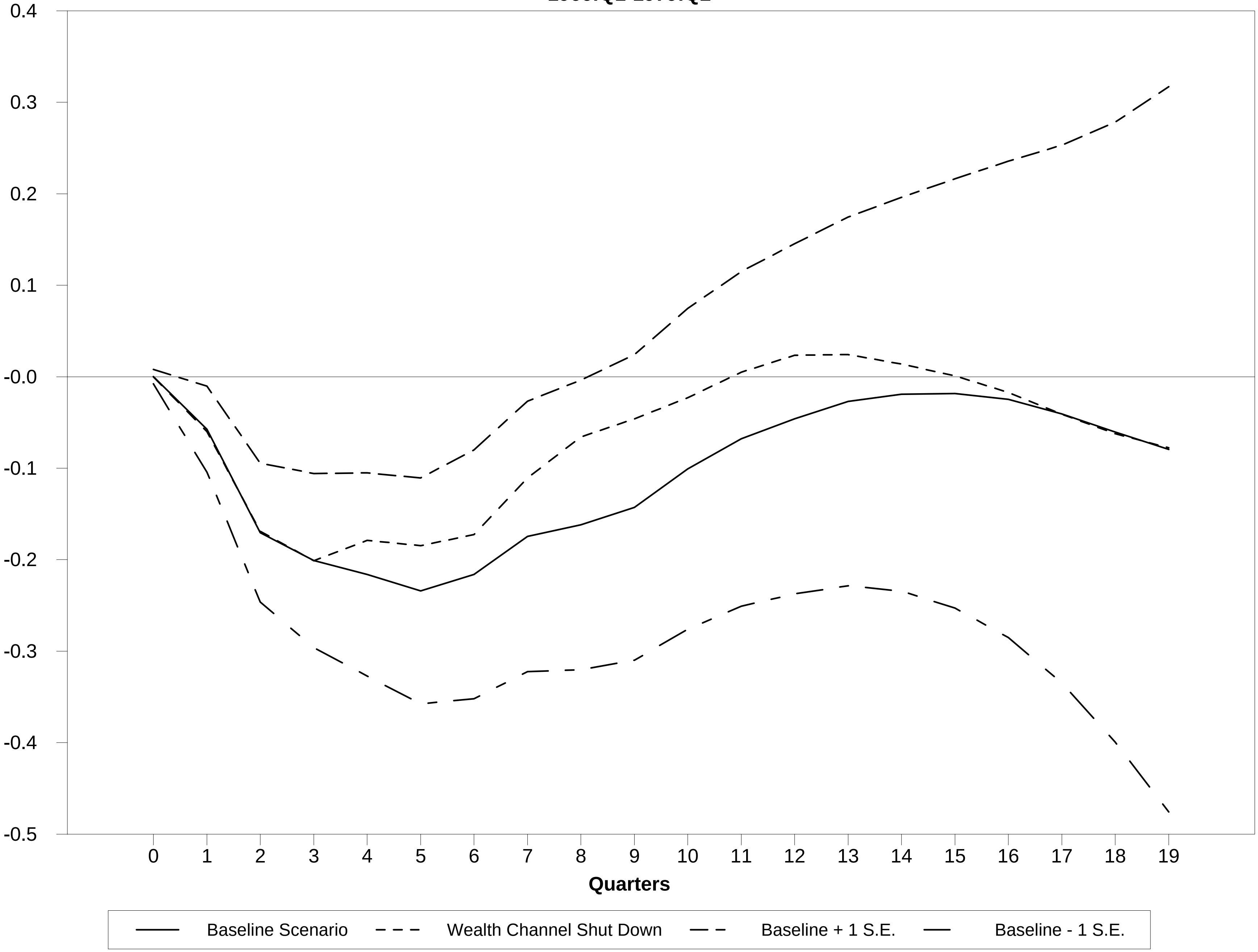


Figure 15: Response of Consumption to Federal-funds-rate Shock, Five Variable System

1966:Q1-1979:Q2



Notes: see notes for Figure 1

Figure 16: Response of Consumption to Federal-funds-rate Shock, Five Variable System

1983:Q1-2000:Q3