The Cost Channel of Monetary Transmission

by

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Abstract

This paper presents evidence that the "cost channel" may be an important part of the monetary transmission mechanism. We first highlight three puzzles that might be explained by a cost channel of monetary transmission. We then provide evidence on the importance of working capital and argue why monetary contractions can affect output through a supply channel as well as the traditional demand-type channels. Using a VAR analysis, we investigate the effects across industries. Following a monetary contraction, many industries exhibit periods of falling output and *rising* price-wage ratios, consistent with a supply shock. The effects are noticeably more pronounced during the period before 1979.

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I. Introduction.

Traditional economic models posit that changes in monetary policy exert an effect upon the economy through a demand channel of transmission. This view of monetary policy has a long history that has been fraught with debate over whether monetary policy affects real economic variables, and if so, how powerful these effects may be. Much of this research has been devoted to identification of a demand-side transmission mechanism for monetary policy and quantifying its effects. Alternatively, some researchers have proposed that there may be important supply-side, or cost-side, effects of monetary policy (e.g. Blinder (1987), Fuerst (1992), Christiano & Eichenbaum (1992), Christiano, Eichenbaum & Evans (1997) and Farmer (1984, 1988a, b)). One version of this view, which ignores long-run effects, has been called the "Wright Patman Effect," after Congressman Wright Patman who argued that raising interest rates to fight inflation was like "throwing gasoline on fire" (1970).

This paper presents aggregate and industry-level evidence that suggests that these cost-side theories of monetary policy transmission deserve more serious consideration. It is not the purpose of this paper to deny the existence of demand-side effects. Rather, this paper presents evidence implicating supply-side channels as powerful collaborators in the transmission of the real, short-run effects of monetary policy changes. In fact, for many important manufacturing industries, the evidence presented here implies that a cost channel has been the primary mechanism of monetary transmission.

A cost channel of monetary transmission can potentially explain three important empirical puzzles. The first puzzle, noted by Bernanke & Gertler (1995), is the degree of amplification. Empirical evidence suggests that monetary policy shocks that induce relatively small and transitory movements in open market interest rates have large and persistent effects on output. Bernanke & Gertler use this result to support their argument that a credit channel working in tandem with the traditional monetary channel better explains the data. A complementary means to explain the observed amplification is to allow monetary policy shocks to have both supply-side and demand-side effects. If this is the case then a shock to monetary policy could be viewed as shifting both the aggregate supply and aggregate demand curves in the same direction, leading to a large change in output accompanied by a small change in prices.

The response of prices to a monetary contraction is a second empirical puzzle that may be explained by a cost channel. Standard VAR methods suggest that the price level rises in the short run in response to a monetary contraction. This "price puzzle" was first noted by Sims (1992), and has been confirmed by much subsequent work.[1] It is our view that this may result from short-run, "cost-push" inflation brought on by an increase in interest rates.

A third puzzle, which we will document shortly, is the differential effect of monetary shocks on key macroeconomic variables when compared to other "aggregate demand" shifters. Using several measures of aggregate demand shifters and technology shocks, we show that a monetary shock creates economic responses more similar to those due to a technology shock than to an aggregate demand shock. These results are consistent with our hypothesis that monetary policy shocks affect the short-run productive capacity of the economy.

The literature offers several theoretical foundations for monetary policy as a cost shock. For example, Bernanke & Gertler's (1989) model contains both a demand and supply component of balance sheet effects. Several other credit channel papers suggest that there might be a cost-side channel of monetary policy (e.g. Kashyap, Lamont, & Stein (1994), Kashyap, Stein &

[1] Leeper, Sims & Zha (1996) and Leeper & Zha (2000) eliminate the price puzzle by estimating a system in which they allow simultaneity in the response of the Federal funds rate and output to each other. In order to achieve identification, though, they must make strong assumptions about structural parameters. We follow Bernanke &

Wilcox (1993), and Gertler & Gilchrist (1994)). Most of these papers are empirical, though, and do not explicitly model the supply-side effects. Nevertheless, the discussion of the results indicates the possibility of supply-side effects. Consider, for example, Gertler & Gilchrist's (1994) study of the cyclical properties of small versus large firms, in which they show that a monetary contraction leads to a decrease in the sales of small firms relative to large firms. The implication is that tight credit is impeding the ability of small firms to produce.[2]

There are several other examples of general equilibrium macroeconomic models that explicitly analyze the supply-side effects of monetary policy through working capital. Blinder (1987), Christiano & Eichenbaum (1992), Christiano, Eichenbaum & Evans (CEE) (1997) and Farmer (1984, 1988a, b)) all begin with the assumption that firms must pay their factors of production before they receive revenues from sales, and must borrow to finance these payments. In most of the models, an increase in the nominal interest rate serves to raise production costs. Thus, a monetary contraction leads to a decline in output through an effect on supply. It is important to note that some type of rigidity is still required for money to be non-neutral. If prices and portfolios adjust immediately, then monetary policy has no initial effect on interest rates, so that neither aggregate demand nor aggregate supply shifts.

The paper proceeds as follows. Section II presents aggregate evidence that the effects of monetary policy shocks look more like technology shocks than demand shocks. Section III investigates the importance of working capital in production. Section IV presents evidence derived from two-digit level industry data. The results of this analysis show clear indications of

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Blinder (1992) and Christiano, Eichenbaum & Evans (1999) in assuming that a shock the to the Federal funds rate has a negligible impact on output in the same month.

[2] Some earlier empirical work studied whether rises in interest rates are passed on to prices. Seelig (1974) found small or insignificant effects on markups. Shapiro (1981), on the other hand, estimated a Cobb-Douglas markup equation on aggregate data and found significant interest rate effects on the price level. To our knowledge, there has been little or no recent empirical work on the subject.

the strength of monetary policy as a cost shock at the industry level: many industries display falling output and rising price-wage ratios. Furthermore, the effect appears to be much more pronounced during the period from 1959 to 1979. This is also the period in which monetary policy shocks have larger and longer effects on output. Section V addresses possible alternative explanations of the empirical results presented in the preceding sections. Finally, Section VI concludes with implications and suggestions for further research.

II. A Comparison of the Effects of Monetary Shocks and Other Shocks

A useful starting point in an analysis of the supply-side effects of monetary policy is a comparison of the responses engendered by identified technology and demand shocks on key macroeconomic variables with the responses of those variables to an unexpected monetary contraction. Unfortunately, the literature is not replete with universally-accepted measures of demand and supply shocks.[3] Undaunted, we pursue two alternative strategies. The first extends work by Gali (1999) and Francis & Ramey (2001) by using long-run restrictions to identify technology (supply) and other shocks. The second approach uses defense build-ups as an example of an exogenous non-technology (demand) shock. Neither approach is completely uncontroversial, but the similarity of results across the two approaches strengthens our case.

[3] We were intrigued by Shea's (1993) input-output instruments, but decided against them for the following reason: Of the 26 industries studied, Shea uses residential construction as an instrument for 16 industries and transportation equipment for 2 industries. If monetary policy is impacting residential investment and motor vehicles at the same time it is affecting the cost of working capital in upstream industries such as concrete and tires, then output in residential construction or motor vehicles is not a valid demand instrument for the upstream firm.

A. The Effects of Shocks Identified Using Long-Run Restrictions

In the first approach, we use a VAR with long-run restrictions to investigate the effects of three types of shocks. We follow Gali (1999) by identifying technology shocks as the only shocks that have permanent effects on productivity. This assumption is relatively unrestrictive as it allows for temporary effects of non-technology shocks on measured productivity through variations in capital utilization and effort. Using a bivariate system with labor productivity and hours, Gali identified two shocks: a technology shock and another shock to labor, which he interpreted as a demand shock. Interestingly, it is this second shock that appears to drive the business cycle movements in the economy. Adding nominal variables to the system did not significantly alter his results. Francis & Ramey (2001) present evidence in support of the plausibility of the technology shock interpretation by investigating the effect of this shock on other key macro variables, such as consumption, investment and real wages.

We use a combination of variables from the systems estimated by Gali and Francis & Ramey in order to compare the effects of the various shocks. Consider the following moving-average representation:

(1) $y_t = C(L) u_t$,

In equation (1), y_t is a 6 x 1 vector consisting of the log differences of labor productivity (x_t), hours (n_t), real wages (w_t), the price level (p_t), money supply as measured by M2 (m_t), and the level of the Federal funds rate (f_t). *C(L)* is a polynomial in the lag operator with 6 x 6 matrix coefficients. Shocks to the system, $\varepsilon_t^x, \varepsilon_t^n, \varepsilon_t^w, \varepsilon_t^p, \varepsilon_t^m, \varepsilon_t^f$, are represented by the vector u_t. Note that private output is simply the product of output per hour and total hours.

In order to impose the restriction that no shocks other than ε^x have a permanent effect on productivity, we require $C^{1j}(1) = 0$ for j = 2, 3, …, 6, where C(1) represents the sum of all moving-average coefficient matrices.[4] To derive a shock comparable to Gali's demand shock, which is the shock to the hours equation, we further impose the restrictions that $C^{2j}(0) = 0$ for j= 3, 4, 5, 6. These restrictions essentially put the labor input variable ahead of the other four variables in the ordering. Finally, we require the shock to the Federal funds rate to be contemporaneously uncorrelated with the other system variables, and following Bernanke & Blinder (1992) and Christiano, Eichenbaum & Evans (1999), we assume that the shocks to that equation represent monetary policy shocks.

A unit root in productivity is key to identifying the shock. We also assume that hours, real wages, the price level, and the money supply have unit roots, while the Federal funds rate is stationary. As Gali shows and as additional experimentation by us confirmed, the results are not sensitive to changing these auxiliary assumptions. We include four quarterly lags of each variable in the estimation.

To summarize, our goal is to identify three key shocks. The "technology shock" is found by imposing the long-run restriction that only a technology shock can have a permanent effect on productivity. The non-monetary "demand shock" is assumed to be the shock to the hours equation, which Gali has argued behaves most like a demand shock. Furthermore, Francis & Ramey have found that while this shock is correlated with military dates and oil shock dates, it is uncorrelated with the Romer dates. Finally, the monetary policy shock is identified as the shock to the Federal funds rate. We use quarterly data from 1959:1 to 2000:3 to estimate the model. The Data Appendix gives complete details about the data used.

Figure 1 shows the separate effects of a negative technology shock, a negative demand shock, and a contractionary monetary shock on the variables of interest. First note that all three shocks have a negative impact on private output. Both the technology shock and the monetary shock lead to a sustained fall in output. The demand shock, on the other hand, leads to a less persistent fall. All three shocks also lead to falls in hours. Consistent with Gali's original results, hours first rise in response to a negative technology shock, but fall immediately in response to the demand shock. The effect of the monetary policy shock on employment is delayed until the third quarter after the shock.

It is in the responses of productivity and real wages that the monetary shock really looks more like a technology shock than a demand shock. The technology shock and the Federal funds rate shock both cause a fall in productivity, although the effect is less persistent for the monetary shock, as one would expect for a transitory shock. In contrast, after an initial negative effect for three quarters, the demand shock leads productivity to rise.

The response patterns for real wages are very similar to those of productivity, as would be predicted by theory. Both a negative technology and monetary shock lead to declines in real wages, and again, the monetary shock is relatively transitory, while the technology shock exhibits more persistence. The response of real wages to a monetary shock is consistent with the results of Christiano, Eichenbaum & Evans (1997). Both responses are consistent with a negative shock to production possibilities that leads to a decline in labor demand. Real wages respond diametrically to a negative demand shock, rising, as would be consistent with a stable production function, leading to higher labor productivity and hence real wages.

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[4] Francis & Ramey show that similar results are obtained with the alternative restrictions that only set $C^{12}(1) = 0$ and $C^{1j}(0) = 0$ for j = 3, 4, 5, 6.

Figure 1 also shows the effects of the three shocks on the price level and the funds rate. A negative technology shock causes a sustained rise in the price level. A monetary policy shock leads to a temporary increase in the price level, whereas the demand shock does not have much effect. Finally, the funds rate falls in response to a negative demand shock, while it rises in response to a negative technology shock and a monetary contraction (by definition).

A noticeable pattern emerges from the graphs. The response of variables to a monetary policy shock is typically more similar in sign and pattern to a technology shock but is less persistent. Further, as one might expect under a hypothesis that monetary contractions beget both supply and demand effects, the responses to a monetary contraction generally lie between, or appear to be a mixture of, technology and demand shocks.

B. A Comparison of Exogenous Monetary versus Defense Shocks

As our second line of attack, we present evidence that monetary shocks differ significantly from demand shocks, identified as exogenous defense build-ups, in their effects on output and real wages. To begin, we present some stark evidence in the form of two graphs of variables in the aircraft and parts industry (SIC 372) from the period 1977 to 1995. Military spending is an important component of demand for aerospace goods. At the height of the last build-up, the Department of Defense accounted for almost 60 percent of total shipments from the aircraft and parts industry. Thus, fluctuations in defense spending are an important exogenous source of demand variation.

Figure 2 charts real defense spending on aircraft and parts plotted against both industrial production and the real product wage in SIC 372. The real product wage is measured as average hourly earnings in the industry divided by the producer price index for aircraft and parts. The graph plots the logarithms of the data, which have not been detrended or normalized.

From 1977 to 1988, real defense spending on aircraft and parts rose 375 percent. From 1988 to 1995 it fell by almost the same amount. As Figure 2 clearly demonstrates, the path of defense spending on aircraft has a strong positive correlation with industrial production of aircraft and parts. The correlation is 0.44. In contrast, the real product wage in the industry moves countercyclically. As defense spending rose, real wages plummeted and as defense spending collapsed, real wages rose; the correlation between the two series is -0.75.

These strongly countercyclical responses to exogenous fluctuations in demand are entirely consistent with the effects of a demand shock in a standard neoclassical model with flexible prices. With a stable production function and slow accumulation of capital, an increase in output is necessarily accompanied by a decline in labor productivity and hence a decline in real wages. These patterns are not consistent with a theory of countercyclical markups.

As Ramey & Shapiro (1998) demonstrated more generally, defense spending has similar effects on more aggregate product wages. To highlight the different effects of monetary versus defense shocks, we compare the impact on real wages and output of a Romer monetary date (Romer & Romer (1989, 1994)) to a Ramey-Shapiro military date. In each case, we regress the variable of interest on its own eight lags and current and eight lags of the dummy variable. The comparison is complicated by the fact that the Romer dates signal a contraction in output whereas the Ramey-Shapiro dates, which index sudden political events that lead to defense build-ups, signal an expansion of output. Leaving aside important potential issues about asymmetry, for comparability we reverse the sign of the Ramey-Shapiro dates to make the shocks in both experiments contractionary.

Figure 3 graphs the response of the logarithm of real GDP and real wages in response to each shock. Although both shocks lead to declines in output, they have opposite impacts on real wages. Defense-induced changes in output are negatively correlated with real wages while monetary-induced changes in output are positively correlated with real wages.

In contrast with our hypothesis and the evidence presented above, most sticky price and countercyclical markup models predict that monetary, government spending, and other demand shocks should have similar economic effects. Rotemberg & Woodford (1991), King & Goodfriend (1997), and various others have argued that either collusive behavior or sticky prices can lead to countercyclical markups. Since the mark-up is inversely related to the real wage, *countercyclical markups imply procyclical wages*. One would expect the effects of defense spending changes and money supply changes to have similar but inverse effects on real wages and markups. The results presented here suggest that the transmission mechanism for monetary policy is very different from the transmission mechanism for other non-technology shocks.

III. The Mechanics of the Cost Channel

The last section presented qualitative aggregate evidence consistent with a cost channel of monetary policy. We now discuss the quantitative plausibility of the cost channel hypothesis as well as its relationship to the credit channel. The key link in our hypothesis is the role of working capital. We argue that just as interest rates and credit conditions affect firms' long-run ability to produce by investing in fixed capital, they can also be expected to alter firms' short-run ability to produce by investing in working capital.

The data support the importance of investment in working capital, whether measured against sales or against fixed capital. One way to measure the magnitude of working capital is to calculate how many months of final sales are held as working capital. Consider the following two measures of working capital: *gross working capital*, which is equal to the value of inventories plus trade receivables; and *net working capital*, which nets out trade payables. On average over the period 1959 to 2000, gross working capital was equal to 17 months of final sales and net working capital was equal to 11 months of sales.[5] Thus, even the smaller net working capital measure implies that nearly a year's worth of final sales is tied up in working capital. The level of investment in working capital is in fact comparable to the investment in fixed capital. In manufacturing and trade, the value of gross working capital equals the value of fixed capital, about $1.5 billion each.[6]

In order to calculate the effect of interest rate changes on production costs, we need to specify a model in which working capital is part of the production process. There are various ways to incorporate working capital into a model of production. For example, Ramey (1989) includes inventories as a factor of production and Ramey (1992) argues for trade credit as a factor of production. An alternative method is to embed a delay between factor payments and sales receipts, as in the models of Fuerst (1992), Christiano & Eichenbaum (1992) and CEE (1997). They assume that firms must pay workers before selling their goods, so firms must borrow cash from the bank in order to produce. The need to borrow introduces an additional component to the cost of labor. In this setting, the marginal cost of hiring labor is the real wage multiplied by the gross nominal interest rate. In CEE's (1997) version of the model, labor demand is given by:

$$(2) \qquad \ln N_t = \frac{1}{\alpha}[\ln(1-\mu) - \ln\mu - \ln R_t - \ln\frac{W_t}{P_t}]$$

[5] The inventory and sales data are from the BEA and the trade credit data are from the *Flow of Funds*.

[6] From *Quarterly Financial Reports*, second quarter 2000.

where α is the coefficient on capital in a Cobb-Douglas production function, μ is a constant markup, R is the gross nominal interest rate, and W/P is the real wage.

CEE study a calibrated general equilibrium model in which all of the effects last only one period. They find that the magnitude of the effects on output and labor depends significantly on the labor supply elasticity. If the labor supply elasticity is as high as five, a monetary contraction results in an 83 basis point rise in the nominal interest rate, a 1.4 percent decline in hours and a small rise in prices. It is difficult to find microeconomic evidence in support of such a high elasticity, though. Thus, the cost channel hypothesis shares the same problem with most economic models that assume workers remain on their labor supply curves: a high labor supply elasticity is essential for matching the quantitative aspects of the data.

Equation (2) is useful for considering the possible magnitude of the direct effects on labor demand of a rise in the nominal interest rate, holding real wages constant. Our evidence on working capital investment suggests that a year lag between paying factors and finally receiving payment is not an unreasonable assumption. Hence, it makes sense to consider an annualized interest rate. If the share of capital is 0.3, then a 100 basis point increase in the nominal interest rate lowers labor demand by three percent, holding real wages constant. The average rise in the Federal funds rate during tightening cycles associated with Romer dates is almost 400 basis points. Thus, the direct effects of monetary-induced jumps in the nominal interest rate can have a significant impact on labor demand and output more generally.

The direct effect on the Federal funds rate, however, is likely only part of the story. Insights from the credit channel suggest a mechanism by which shocks that initially work through demand may be propagated through the supply side. As demand falls off, firms are faced with accumulating inventories and accounts receivable, and falling cash flow. The dropoff in internally generated funds as the stock of working capital rises forces firms to turn to external financing precisely when interest rates are increasing.

The opportunity cost of internal funds increases directly with the Federal funds rate, but when firms are force to turn to external funds their marginal financing cost typically jumps discretely due to information asymmetries between the firms and their creditors. In recent quarters, an industrial company rated BBB was usually charged a spread of about 80 basis points over LIBOR on existing lines of credit.[7] Since this spread usually rises during periods of tightening credit or during recessions, firms that are forced to renegotiate their lines of credit at such times will face an even greater jump in marginal financing rates. When added to a 400 basis point increase in the Federal funds rate, equation (2) would imply a 15 percent decline in labor demand with real wages held constant.

As mentioned in the introduction, the cost channel and the credit channel are complementary channels of monetary transmission. The credit channel argues that credit market frictions amplify the effects of shocks that hit the economy. Because the effective price of external funds is greater than the opportunity cost of internal funds, deterioration of balance sheets can substantially raise the cost of capital. These balance sheet effects can influence demand or supply, and thus are complementary to both the traditional demand channel approach and cost channel hypothesis.

Finally, we would like to emphasize that we view the cost channel as being only a short-run phenomenon. The evidence for long-run monetary neutrality is strong, and we are not suggesting that it does not hold. Figure 1 as well as other figures featured later in the paper show

[7] Based on data from Loan Pricing Corporation. LIBOR has been the base rate for most firms since the mid-1980s. Prior to that, firms paid a spread over the Prime rate, which is typically above a market rate like LIBOR. Hence the above is likely a conservative estimate of the jump in marginal cost of external funding for our data sample.

that the rise in prices is temporary; the price level does finally end up falling. The cost channel may have a larger impact than the demand channel in the short-run because of the nature of the commitments. In the short-run, firms cannot find alternative sources for working capital, and may have to cut back dramatically on production. The necessary cutbacks may be amplified because the firm may have commitments to long-term capital investment projects that cannot be cut. As time progresses, firms have more flexibility to reduce investment spending. Bernanke & Gertler's (1995) finding of a delayed effect of a monetary contraction on business fixed investment is consistent with this hypothesis.

IV. Industry-Level Evidence of Monetary Policy as a Supply Shock.

We now explore cross-sectional variation among manufacturing industries for evidence of a cost channel of monetary transmission. There are two motivations for doing so. First, it is interesting to study the extent to which the same patterns we see at the aggregate level also hold at the industry level. Second, if there is heterogeneity in the industry responses, we can determine whether there is a link between the responses and features of the industry that might make the cost channel more important.

The discussion above about the effect of working capital cost on labor demand easily extends to the industry level. We change the two variables on which we focus, however. First, we use industrial production rather than hours because of data availability. Since hours and output are so highly correlated, it is doubtful that we will be misled by this variable change. Second, to facilitate later discussion about the price puzzle and counter-cyclical markups, it is more convenient to focus on the behavior of the inverse of the real product wage, or *P/W*.

The comovement between P/W and output reveals the nature of the monetary transmission mechanism for particular industries. If a monetary contraction affects an industry primarily through a demand channel, then both industrial production and *P/W* should fall. (That is, the real product wage should rise.) If a monetary contraction affects an industry primarily by raising its working capital costs, then falling industrial production should be accompanied by rising *P/W*. Prices should rise relative to wages because working capital costs are rising. If both channels are equally strong, we would not expect much movement in P/W.[8]

A. Empirical Framework.

We again follow the work of Bernanke & Blinder (1992) and Christiano, Eichenbaum & Evans (1999) (CEE) by identifying monetary shocks as innovations to the Federal funds rate (hereafter FFR) after controlling for the Federal Reserve's "feedback function." The model features a relatively simple partial identification scheme that allows for control of the so-called "price puzzle" and flexibility in examining the responses of individual time series to monetary policy shocks.

As discussed in the introduction, the price puzzle is the finding that aggregate prices rise in the short-run following a monetary contraction identified by the unexplained portion of the Federal funds rate. The proposed solution to this puzzle is that the Federal Reserve possesses better information about coming inflation than is captured in a parsimonious VAR and reacts appropriately. CEE, following Sims (1992), improve their model's information set by including commodity prices as a leading indicator of inflation to which the Federal Reserve passively

[8] Unfortunately, we cannot use CEE's (1997) study of the response of industry real wages to monetary shocks to assess our hypothesis. They do not compare industry wages to industry price and output. Instead, they examine each industry's wage deflated by a general price deflator.

responds. CEE demonstrate that this eliminates the price puzzle (note that this is not true in pre-1979 sub-samples; see Part C of this section).

Although we have argued that a cost channel could explain this type of behavior of prices, in the interest of conservatism we include two controls for incipient inflation to which the Fed might respond: commodity prices and oil price shock dummies. Hoover & Perez (1994) note that identified (negative) monetary policy shifts are highly correlated with oil shocks. We control for the cost effects of oil shocks by including dummy variables in each equation that take the value one during a "Hoover & Perez date" and zero otherwise.[9] Based on Hamilton's (1985) evidence that oil price shocks take an average nine months to induce recessions, we include current and twelve lags of the Hoover & Perez dummies.[10]

Our equation system consists of two blocks. The "macro" block features aggregate industrial production, the price level, commodity prices, M2, and the Federal funds rate, in that order. The second block consists of two equations for variables of interest, one for industry output and one for the industry price-wage ratio. To achieve more efficient estimation and consistent identification of the Federal funds rate shock, the coefficients of the series of interest in the macro-variable equations (including the FFR equation) are constrained to be zero for each of the industries examined. This is the approach pursued by Davis & Haltiwanger (1997), who point out that this is in essence a pseudo-panel data VAR, since the coefficients of the macro-

[9] That is, months identified by Hoover & Perez (1994) as having an exogenous political event that leads to an oil supply shock based on their reading of Hamilton's (1985) history of post-war oil shocks. Hoover & Perez supplement Hamilton's exogenous political events with the Iraqi invasion of Kuwait in August 1990. We add to this list the election of Hugo Chavez as President of Venezuela in December 1998 upon the advice of Trevor Reeve, oil economist at the Federal Reserve. Chavez served as the catalyst for OPEC's new-found cohesion in cutting production in early 1999.

[10] Hoover & Perez's dummy variable has slightly more explanatory power for industrial production than Hamilton's (1996) net oil price change variable.

variable equations are fixed across regressions, but the coefficients in the series of interest equations are allowed to vary across industries.

To make the above more explicit, consider the following system of seven equations:

(3)
$$Y_t = F'SD_t + \sum_{j=0}^{12} G_j' HP_{t-j} + \sum_{k=1}^{7} A_k Y_{t-k} + \varepsilon_t \text{ where}$$
$$Y_t' = \left[IP_{t,} P_{t,} PC_{t,} M2_{t,} FFR_{t,} Q_{i,t,} P_{i,t} / W_{i,t,}\right], \text{ and } \underset{7\times 7}{A_k} = \begin{bmatrix} \underset{5\times 5}{A_k^{1,1}} & \underset{5\times 2}{0} \\ \underset{2\times 5}{A_k^{2,1}} & \underset{2\times 2}{A_k^{2,2}} \end{bmatrix}$$

Here, IP_t is industrial production (a proxy for output), P_t is the personal consumption expenditure deflator (a monthly measure of general price levels), PC_t is a price index for commodities, $M2_t$ is the monthly average of M2, FFR_t is the monthly average of the Federal funds rate, $Q_{i,t}$ is industrial production in industry *i*, and $P_{i,t} / W_{i,t}$ is the ratio of price to wage in industry *i*. SD_t is a matrix of a constant and seasonal dummies and HP_t is a Hoover & Perez dummy. *A* is a matrix of endogenous variable coefficients with zero restrictions on the industry variables in the macro-variable equations. Following Bernanke, Gertler & Watson (1997), we used seven lags.[11] All series are in natural log levels except FFR_t. Details on data construction are given in the Data Appendix.

We estimated vector autoregressions of this form for total manufacturing, durable manufacturing and non-durable manufacturing, 20 two-digit industries, and one three-digit industry within these categories over three sample periods: the entire period from February 1959 to March 2000, and the two sub-sample periods from February 1959 to September 1979 and

[11] There is little qualitative difference in the results using as many as 13 lags.

from January 1983 to March 2000. Explicitly, we tested the null hypothesis that the change in industry price relative to industry wage is less than or equal to zero following a monetary contraction. We take rejection of this hypothesis as evidence that a cost channel rather than a demand channel is the most important avenue of monetary transmission for that industry.

B. Industry Results.

The results are presented in a series of graphs and tables. Figures 4A through 4C show the effect of a positive Federal funds rate shock on the price-to-wage ratio and output for the manufacturing aggregates as well as the individual two and three-digit industries using our entire data sample for estimation. For 10 of the 21 industries examined and for all three aggregates, the impulse response functions show that in response to a positive shock to the Federal funds rate output falls and prices rise relative to wages. Columns two and three in Table 1 summarize the results by describing the behavior of the data during the first 24 months for each industry. The third column of Table 1 presents the results of a test of the null hypothesis that none of the price levels are significantly above zero during the first 24 months. The results clearly reject the null hypothesis at the 10 percent level for six of industries analyzed and we can thus reject the claim that monetary policy exerts its effects solely through a demand channel of transmission. In fact, for important cyclical industries, and even for manufacturing as a whole, the results indicate that monetary policy's primary effects on real variables are transmitted through a supply-side channel.

There is clear evidence of the importance of a demand channel of transmission for eight industries (Food, Lumber, Pulp & Paper, Chemicals, Hides & Skins, Primary Metals, Fabricated Metals, and Other Durables). Recall, however, the nature of our test: it will only show the presence of a supply channel when its effects clearly dominate those of a demand channel whose existence we do not deny. That the price response of Lumber exhibits typical a demand-shock pattern does not imply that there is not a cost channel of transmission for Lumber. The Lumber industry too may suffer from a cost channel of transmission, but it is the demand channel whose effects dominate.

If monetary shocks have an effect primarily through increases in costs, however, prices should rise as output falls. This is exactly what we observe in Figure 4C. Look at the price and output responses of Motor Vehicles: prices steeply rise and then decay slowly after a peak at nine months; the output response is nearly the mirror image, falling to a trough at nine months and slowly increasing from there.

Nor are these unimportant or non-influential industries showing significant cost effects of monetary policy. Among those with significant evidence of cost shock effects are Textiles, Apparel, Industrial Machinery, Electrical Machinery, and Transportation Equipment. But these results are not limited to the industry level. Total manufacturing exhibits supply-side effects as well. Taken together this evidence provides a case for a supply-side channel of monetary transmission as a powerful force supplementing the often-assumed demand channel in creating real effects.

Some of the industries that exhibit strong cost-side effects run counter to our prior expectations. One such example is Motor Vehicles & Parts, which shows a very pronounced increase in the ratio of price to wages. One might think that an industry governed by such large firms would not experience large cost effects of a monetary contraction, since they have easy access to commercial paper. A possible explanation is that the primary cost-side effect of a monetary contraction is through changes in market interest rates, rather than bank loan behavior, so that even large firms experience significant increases in their costs. Another possible explanation is that the small companies that supply parts face loan reductions from their banks.

We now explore the extent to which the effects we identified may have changed over the sample period. To this end, we split the sample into the period February 1959 to September 1979 (the pre-Volcker period) and from January 1983 to March 2000 (the Volcker-Greenspan period). We choose these two sub-samples based on the works of Faust (1998) and Gordon & Leeper (1994), who report substantial empirical differences between the aggregate effects of VAR-based identification of monetary policy in these two periods. Additionally, the choice of these two sub-samples removes the volatility of monetary policy and economic aggregates experienced between late 1979 and 1982 from the data.

Figures 5A through 5C show the results for the pre-Volcker period. To conserve space we do not show the graphs for the Volcker-Greenspan period. The information for both periods is summarized in columns four through seven of Table 1.

The difference between the two periods is substantial. Overall, we see that the early period through 1979 shows very strong cost channel effects, whereas the later period shows little evidence of cost channel effects. In the pre-Volcker period, all three manufacturing aggregates, as well as nearly every industry exhibit some evidence of a cost channel price effect. For total manufacturing and for fifteen of the individual industries, the price effects are significant at the ten percent level. In contrast, only Lumber and Leather & Hides exhibit dominant demand channel effects during this period, and only Lumber significantly.

During the Volcker-Greenspan period the cost channel effects are much weaker. While 16 industries exhibit rises prices, only three do significantly, and the paths of relative prices and output are not as clearly consistent with a supply shock as in the pre-Volcker period.

The results of this section display a good deal of heterogeneity, both across time and across industries. The next two sections will explore whether that heterogeneity can be linked to features that would change the strength of the cost channel.

C. Interpreting the Time Pattern of the Responses

In this section we argue that the changes in the responses we observe over time may be linked with a weakening of the cost channel mechanism in the later period. We discuss institutional changes and we provide evidence on the changing impact of monetary policy on aggregate variables.

As has been discussed by many observers (e.g. Friedman (1986)), the financial structure of the U.S. changed significantly during the late 1970s and early 1980s. The private sector financial innovations beginning in the 1970s and the deregulation of the early 1980s led to more efficient and less regionally segmented financial markets. The banking and credit regulations of the earlier period, which limited the scope of lenders and borrowers to respond to sudden monetary contractions, may have allowed monetary policy to restrict the availability of working capital. In the later period, banks and firms had more alternative sources of funds.

A different type of institutional change also occurred over this time period. Owens & Schreft (1992) and Romer & Romer (1993) use narrative approaches to show that during the earlier period, contractionary monetary policy was often accompanied by "credit actions," in which the Federal Reserve sought to limit directly the amount of bank lending. The consequent non-price rationing led to particularly acute credit crunches, which could have led to severe limitations in working capital. Thus, well-documented differences in financial markets and Federal Reserve policy combined with theory postulating the presence of a cost channel of monetary transmission may explain the variation we see in the effects of monetary policy through time.

We now present another type of evidence in support of the view that the nature of the monetary transmission mechanism changed over time. Recall from the introduction that, as noted by Bernanke & Gertler (1995), if monetary policy shifts both supply and demand in the same direction, the effect on output is greater than if it shifts only demand. Thus, if the cost channel of monetary transmission were more important during the earlier sub-period, we might expect that the effects of monetary policy on output would be greater in magnitude and last longer in the earlier period.

To test this hypothesis, we estimate the basic macro part of the model for the two sub-periods (that is, system (3) minus the last two equations). Because we wish to compare the magnitude of the response of output to a given shock to monetary policy, we set the innovation for both periods equal to 25 basis points, the typical interval of change in Federal Reserve policy[12].

Figure 6 shows the responses of the Federal funds rate, industrial production and the aggregate price level to a 25 basis point Federal funds shock for the model estimated over each of the two sub-samples (February 1959 to September 1979 and January 1983 to March 2000) and the entire sample (February 1959 to March 2000). Consider first the difference in the behavior of the Federal funds rate, in Figure 6A. The peak responses of both the early and later period are very similar, but their duration is very different. The funds rate takes almost two years to return to its original level during the early period, but takes only about 9 months to return to normal during the later period.

Consider now the impulse responses of output, in Figure 6B. Comparison of the figures shows that the trough of output is almost four times as deep during the early period as the later period. Moreover, the duration of the effect on output appears to be much longer during the early period. The trough occurs more than two years after the initial shock during the early period, but less than one year after the initial shock during the later period. Furthermore, during the early period output is still well below its previous level even four years after the shock. During the later period, output rebounds within two years of the shock to the Federal funds rate. Thus, both in magnitude and duration, a given monetary shock had much greater effects during the earlier period. The difference in the effects cannot be fully accounted for by the difference in the response of the Federal funds rate over these two periods.

Finally, consider the behavior of prices in response to a monetary contraction. Despite including commodity prices and oil shock dates in the reaction function, the price puzzle appears to be fully operational in the early period.[13] After a contractionary monetary policy shock, prices rise for over two years before beginning to fall. By contrast, during the later sample period, prices are mostly unresponsive after a brief spike higher in the first five months.

Our finding that in the pre-Volcker period aggregate prices rise in the short-run following a monetary contraction is consistent with the results of Hanson (1998). Recall that Sims' (1992) original motivation for including an index of commodity prices in a VAR to identify the Fed's feedback function was as a leading indicator of incipient inflation. Hanson tests a variety of variables (including commodity prices) that might have power to forecast inflation in a similar VAR identification of monetary policy functions, and finds that in the pre-1979 sample period

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[12] The standard deviation of the innovation to the Federal Funds rate equation for a regression using the pre-Volcker sample is 25.6 basis points; for a regression on the Volcker-Greenspan period it is 18.2 basis points; and for a regression over the entire data sample it is 46.9 basis points.

none of these eliminate the price puzzle. Hanson's work casts doubt on the now widely accepted view that the price puzzle is the result of the Fed possessing better information of coming inflation than is captured in a simple VAR with aggregate output, prices and monetary policy variables (like the Federal funds rate). The results of this paper suggest that the real solution to the price puzzle may lie instead with a cost channel of monetary transmission, which leads to a short-run increase in prices. As noted previously, if monetary policy does transmit its effects on real variables through a cost channel, then *rising prices in the short-run following a contractionary policy shock are not a puzzle*.

Thus, three pieces of evidence suggest that the cost channel may have been a more important part of the monetary transmission mechanism in the period before 1980. First, the industry level regressions show that many more industries experienced rising price-wage ratios and falling output after a monetary contraction. Second, we appeal to the restrictive regulations and policy actions during the earlier period as leading to particularly acute credit crunches. Third, we show that the amplification and duration effects on output and the price puzzle effects are substantially greater during the earlier period.

D. Analysis of the Cross-Industry Heterogeneity of the Responses

The industry results display a great deal of heterogeneity that can potentially shed light on the monetary transmission mechanism. A comprehensive analysis of the cross-industry heterogeneity in the price-to-wage responses would require estimation of a structural model, since the responses depend on both the demand and supply effects of monetary policy. Such an

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[13] The rise in prices during this period is significant at the ten-percent level for more than three years following the Federal funds rate shock.

analysis is beyond the scope of this paper. We can, however, offer suggestive evidence linking balance sheet variables to the behavior of price-to-wage ratios.

Data from the *Quarterly Financial Reports* suggests that the rise in the relative prices of these industries may be directly related to financing costs. The QFR report aggregated balance sheet and income statement data, back to fourth quarter 1973, for 14 of the two-digit manufacturing industries which we study. For each of these industries, we constructed from these data a measure of interest expense normalized by net industry sales. The Data Appendix contains the details.

To compare these measures with the price-to-wage responses previously described, we considered two summary measures of these responses: the peak response, and the integral of the response function. Since the interest expense time series for all industries exhibit a strong upward trend and several are highly volatile, we smoothed these data using a Hodrick-Prescott filter and took two cross-sectional snapshots of the data, one for each of the sub-sample periods. Using NBER dates for recessions, we chose the second quarter of a recession for each sample period to take a cross-sectional snapshot. The two periods chosen were presumably stressful periods of financing for manufactures since the Federal funds rate was still high and sales had begun to decline in each industry. The cross-sectional snapshot for the first period is first quarter 1974, and for the later sample period we chose the fourth quarter of 1990.

Table 2 presents the correlation between the two summary measures of the price-wage response and interest expense as a ratio of net sales. For the early period both summary statistics of the price-wage ratio have a correlation with industry interest expense of just over 0.5. That is, those industries that have the largest relative price responses also tend to have the most burdensome interest expenses, consistent with a cost-channel hypothesis for monetary transmission. Surprisingly, despite the relative weakness of cost-channel effects apparent in the price responses of the later period, Table 2 suggests that the cost-channel effects may still be present. While the correlation across industries between the price-wage response and interest expense does decline slightly, it is still strongly positive at about 0.4.[14] Thus, there appears to be a strong link between the response of industry prices and a key balance sheet variable.

V. Possible Alternative Explanations.

This section considers three possible alternative explanations of price and output responses discussed in the previous sections. The first is that our finding of rising price-to-wage ratios is due mostly to falling wages, rather than rising prices. Wages might be more variable than prices if initial cuts in output involve the elimination of overtime hours and overtime premia. The second alternative explanation is that we are not adequately addressing the Fed's forecasts of future inflation in our estimated reaction function. The third alternative explanation, *countercyclical markups*, has been the subject of intense research in recent years by several authors. We discuss each of these possible explanations.

Sticky Prices and Flexible Wages

One possible explanation for the results of this paper is that the price-wage ratio rises in some industries after a monetary contraction because prices are sticky whereas wages are not. If a monetary contraction reduces the demand for an industry's output, firms respond by lowering their output and, consequently labor demand. If, for some reason, prices cannot adjust immediately but wages can, then wages would fall relative to prices.

[14] While we chose these two snapshots to illustrate periods of stress, the results are nearly identical for other periods.

We consider this explanation to be less plausible. Christiano, Eichenbaum & Evans (1997) show that behavior of profits is inconsistent with a sticky-price model of money. They show empirically that profits decline significantly in the wake of a monetary contraction. In contrast, a reasonable specification of a sticky price model predicts *rising* profits in response to a monetary contraction. Thus, it is unlikely that a sticky-price model can explain these facts.

We can also show direct evidence that this type of model cannot explain our results. Figures 7A-7C show the separate responses of nominal prices and wages by industry. We show the results for the period 1959 to 1979, the period with the strongest rises in the price-to-wage ratio. The graphs show that the *nominal price level itself* rises in virtually all of the industries. Nominal wages fall in some industries, but rise or are flat in most industries. It is clear that our earlier results are being driven primarily by rising nominal prices, not by falling nominal wages.

Expected Future Inflation

As discussed earlier, a leading explanation for the price puzzle is misspecification of the Federal Reserve reaction function. In particular, if the Fed changes the Federal funds rate because it is forecasting future inflation that is not anticipated by a parsimonious VAR, then the incorrectly specified reaction function will make it look like shocks to the funds rate raise prices. It may be that industrial production, consumer prices and commodity prices are not sufficient to capture all of the information used the Fed to forecast future inflation.

To address this issue, we include actual Federal Reserve Board forecasts of current and future inflation and output in our policy equation. Romer & Romer (2000) have compiled a series of past forecasts from the Greenbooks prepared by the Federal Reserve's staff prior to each FOMC meeting. They demonstrate that these forecasts incorporate information not available to private forecasters. We use these monthly forecasts of inflation and output for the current quarter and one quarter ahead. We included these series as exogenous variables in the Federal funds rate equation. In doing so, we are making two assumptions. First, only the Federal Reserve has access to its forecasts in the relevant period. Second, the Fed's *ex post* policy actions do not change its forecasts in subsequent months. While the first assumption is unimpeachable, the second is a bit more dubious. The Federal Reserve staff likely would change its forecasts as new information became available, however, this specification should serve as a convenient benchmark for testing the price puzzle hypothesis that *ex ante* the Fed possesses superior knowledge about coming inflation.

Specifically, we estimated equation (3) less the last two industry equations and with the following modification to the fifth equation for the Federal funds rate:

$$(4) \qquad FFR_t = \sum_{i=0}^{1} \left(\alpha_i GB\Delta Y_t^{t+i} + \beta_i GB\Delta P_t^{t+i}\right) + f_5' SD_t + \sum_{j=0}^{12} g_{5,j}' HP_{t-j} + \sum_{k=1}^{7} a_{5,k} Y_{t-k} + \varepsilon_{5,t}$$

where $GB\Delta Y_t^{t+i}$ is the Fed Greenbook forecast for output growth for quarter *t+i* made in month *t*, and similarly, $GB\Delta P_t^{t+i}$ is the forecast of inflation.

Figure 8 shows the effect of controlling for the Fed's inflation forecasts on the aggregate results. As the graphs make clear, using a better measure of inflation forecast does not change the results noticeably. Aggregate prices still rise significantly in the first two years following an unanticipated increase in the Federal funds rate. Thus, it seems unlikely to us that our results could be explained by a misspecified reaction function.[15]

[15] The industry level results on price-to-wage ratio movements are available upon request from the authors, but show little change from those in figures 5A through 5C.

Countercyclical Markups

Countercyclical markups have been offered as a possible factor in cyclical fluctuations in recent years by Rotemberg & Woodford (1991, 1992) and Chevalier & Scharfstein (1996) among others. A countercyclical markup is a spread between price and marginal cost (the markup above marginal cost) that increases in recessions and decreases in booms. The direct link with the evidence presented here is that the above authors often consider the price-to-wage ratio to be an accurate measure of markup. For example, Rotemberg & Woodford (1992) argue that a theory of countercyclical markups is required in order to explain the increase in real product wages after an increase in military spending. Subsequent work by Ramey & Shapiro (1998), also confirmed in Section II of this paper, shows that properly measured real product wages fall in the wake of a military spending increase. Thus, other demand shocks do not appear to be propagated by countercyclical markups.

Chevalier & Scharfstein (1996) present the most compelling evidence of countercyclical markups in their analysis of the pricing behavior of national, regional and local supermarkets during national and regional downturns. They present a model of capital market imperfections in which firms with low cash flow sacrifice long-term market share in order to raise short-term profits. Firms implement this policy by raising their markups. In the data, Chevalier & Scharfstein find that leveraged firms do indeed lower their nominal prices less (or raise them more) during recessions when compared to less leveraged firms.

An equally plausible explanation for the price increases observed for leveraged firms is that their marginal costs rose due to increased external financing premiums. In fact, the markup and cost channel theories are really just variations on a similar theme. The countercyclical markup hypothesis argues that liquidity constraints lead to higher prices because they raise optimal markups; the cost channel theory argues that liquidity constraints raise prices because they raise marginal costs. Without an accurate measure of the marginal costs of these firms (including financing costs), one cannot tell whether markups are indeed going up with prices, or whether marginal costs of production and distribution are rising.

V. Concluding Remarks.

This paper has presented several types of evidence to suggest that monetary policy has supply-side effects on real variables. We first demonstrated that the response of aggregate economic variables, notably productivity and real wages, to a monetary contraction is more similar to that of a contractionary technology shock than to a contractionary demand shock. Second, we showed that in key manufacturing industries, relative prices rise and output falls following an unanticipated monetary contraction, even after controlling for both the price puzzle and the cost effects of oil shocks. We found that the industry-level evidence for a cost channel of monetary transmission is much stronger during the period from 1959 to 1979 than from 1983 to 2000, and that during both periods, industry heterogeneity appears to be related to industry debt-service burdens. During the earlier period, many more industries exhibited rising prices in response to a monetary contraction. Moreover, the effects of monetary policy on output were greater and the price puzzle was more pronounced during this earlier period. These results are consistent with a cost channel of monetary transmission.

Data Appendix

All data used in this paper come from one of the following sources: Bureau of Economic Analysis (BEA) at the Department of Commerce; Bureau of Labor Statistics (BLS) at the department of Labor; Federal Reserve Board (FRB); and the *Quarterly Financial Reports* (QFR) published by the Bureau of Economic Analysis. The exceptions are: the index of sensitive commodity prices, for which we thank Charles Evans at the Federal Reserve Bank of Chicago; "Hoover & Perez" oil dates (monthly, 1947:12, 1953:06, 1956:06, 1957:02, 1969:03, 1970:12, 1974:01, 1978:03, 1979:09, 1981:02, 1990:08), which come from Hoover & Perez (1994) and are supplemented by this paper's authors with 1998:12 (see footnote 9); "Romer & Romer" dates (quarterly, 1947:4, 1955:3, 1968:4, 1974:2, 1978:3, 1979:4, 1988:4) which come from Romer & Romer (1994); and "Ramey & Shapiro" dates (quarterly, 1950:3, 1965:1, 1980:1) which come from Ramey & Shapiro (1998).

Section II:
Figure 1: Productivity: *index of output per hour in business*, BLS; Private Hours: *index of total hours in business*, BLS; Real Wages: *real hourly compensation in business*, BLS; Price Level: *GDP deflator*, BEA; Money: *M2*, FRB; *Federal funds rate*, FRB. All data are quarterly series and in logarithm, except the Federal funds rate which is the quarterly average level.
Figure 2: *Defense purchases of aircraft and equipment, billion of chained 1992 dollars*, BEA; *Industrial production* in SIC 372, FRB; *average hourly earnings of production workers* in SIC 372, BLS; *Producer price index for aircraft and parts*, BLS. (The price data were missing from September to December 1985. We interpolated the data using the price deflator for *Transportation Equipment, excluding Motor Vehicles* derived from BEA shipments data.) All data are quarterly averages of monthly data.
Figure 3: Output: *GDP in chained 1996 dollars*, BEA; Real Wages: *real hourly compensation in business*, BLS; both quarterly logarithms. Romer dates and Ramey-Shapiro dates are given above.

Section IV:
Figures 4-7: Macroeconomic variables: Output: *Total industrial production*, FRB; Price Level: *Personal consumption expenditure deflator*, BEA; Commodity prices: *Index of sensitive commodity prices*, Charles Evans (see above); Money: *M2*, FRB; *Federal funds rate*, FRB. Industry variables: Output: *industrial production* by two-digit and three-digit SIC code, as well as Total manufacturing, durable manufacturing and non-durable manufacturing, FRB; Prices: for total, durable, and non-durable manufacturing producer price indices from the BLS were used, for two- and three-digit SIC industries, deflators derived from BEA shipments data were used; Wages: *Average hourly earnings of production workers*, BLS and DRI. All data are monthly and in logarithms, except the Federal funds rate which is the monthly average level and the industry price/wage ratio which is the log difference of the two applicable series.

Table 2: A measure of interest expense is created from QFR on two-digit manufacturing industry balance sheet data and FRB interest rate data. Actual industry interest expense has only been reported in the QFR since 1998. Gertler & Gilchrist (1994) construct an approximation by multiplying the sum of short-term bank loans and other short-term debt by the commercial paper rate. We compared this measure with actual interest expense, reported from 1998 forward, and

found that it is too small by an order of magnitude, and that the two measures are uncorrelated. The difference appears to come from interest on longer-term debt. To correct for this discrepancy, we added to the Gertler-Gilchrist measure the difference of total and current liabilities multiplied by the yield on BAA-rated corporate bonds. This measure is of the same order of magnitude as reported interest expense and highly correlated. To be specific, we calculate interest expense as the product of the commercial paper rate with the sum of *short-term bank loans* and *other short-term debt*, added to the product of the yield on BAA-rated corporate bonds with the difference between *current* and *total liabilities*. Because the interest expense series for all industries studied have easily apparent time trends and tend to exhibit significant inter-quarter volatility, we smoothed the data using a Hodrick-Prescott filter before taking cross-sectional correlations.

Figure 8: Macroeconomic variables as above. Greenbook data on Federal Reserve Board staff forecasts for coming inflation and output growth kindly come from David & Christina Romer at the University of California, Berkeley. Because the FOMC meetings do not occur every month, there are several months with missing values for the period November 1965 to September 1979. We filled in the missing values using the last available forecast.

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Table 1: Number of periods in 1st two years P/W response is greater than zero, significantly (@ 10% level)						
Regression Sample:	**Whole Sample**		**Pre-Volcker**		**Volcker-Greenspan**	
Industry	**P/W > 0**	**Significant**	**P/W > 0**	**Significant**	**P/W > 0**	**Significant**
Total Mfg.	16	3	21	7	6	0
Durables	6	0	18	0	4	0
Non-Durables	7	1	23	1	16	0
Food SIC 20	1	0	24	15	18	0
Tobacco SIC 21	0	0	23	2	23	11
Textiles SIC 22	24	8	14	0	0	0
Apparel SIC 23	22	18	15	11	0	0
Lumber SIC 24	0	0	0	0	1	0
Furniture SIC 25	3	0	21	6	7	1
Pulp & Paper SIC 26	2	0	19	3	20	0
Printing & Publishing SIC 27	0	0	8	0	0	0
Chemicals SIC 28	0	0	15	7	9	0
Petroleum & Coal SIC 29	1	0	19	13	16	0
Rubber & Plastics SIC 30	0	0	19	14	13	5
Leather SIC 31	0	0	0	0	1	0
Stone, Clay & Glass SIC 32	13	0	17	10	18	0
Primary Metals SIC 33	0	0	20	17	2	0
Fabricated Metals SIC 34	0	0	18	14	6	3
Industrial Mach. SIC 35	24	13	17	6	24	0
Electrical Mach. SIC 36	24	8	21	0	13	0
Trans. Equip. SIC 37	24	20	19	11	6	0
Motor Veh. SIC 371	24	20	22	15	14	0
Instruments SIC 38	11	0	14	3	12	0
Other Durables SIC 39	0	0	21	0	8	0
Total Industries	12	6	19	15	18	4
Total Industries, n>=2	10	6	19	15	16	3

Table 2: Industry P/W response correlation with interest expense		
Early sample P/W response correlation with 1974:1 interest expense		
	Peak Response	Integral
Interest Expense	0.529	0.519
Late sample P/W response correlation with 1990:4 interest expense		
	Peak Response	Integral
Interest Expense	0.434	0.395

Figure 1: Monetary, Technology and Demand Shocks

Line with circles technology shock; with squares monetary shock; with triangles demand shock
Filled marks significant at 10%; open marks significant at 25%

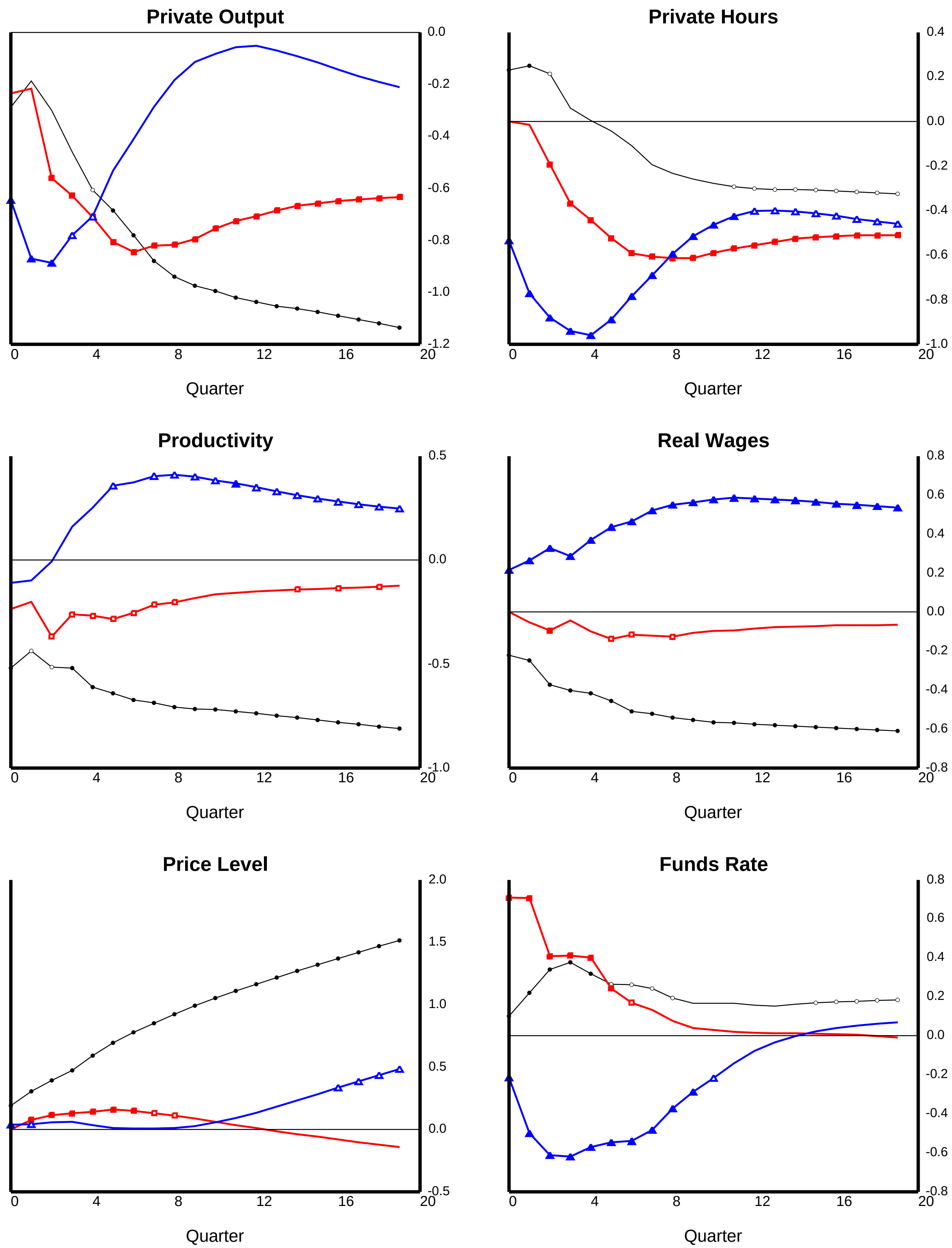


Figure 2: The Effect of Defense Spending on Aircraft Industry Output and Wages
(Quarterly data)

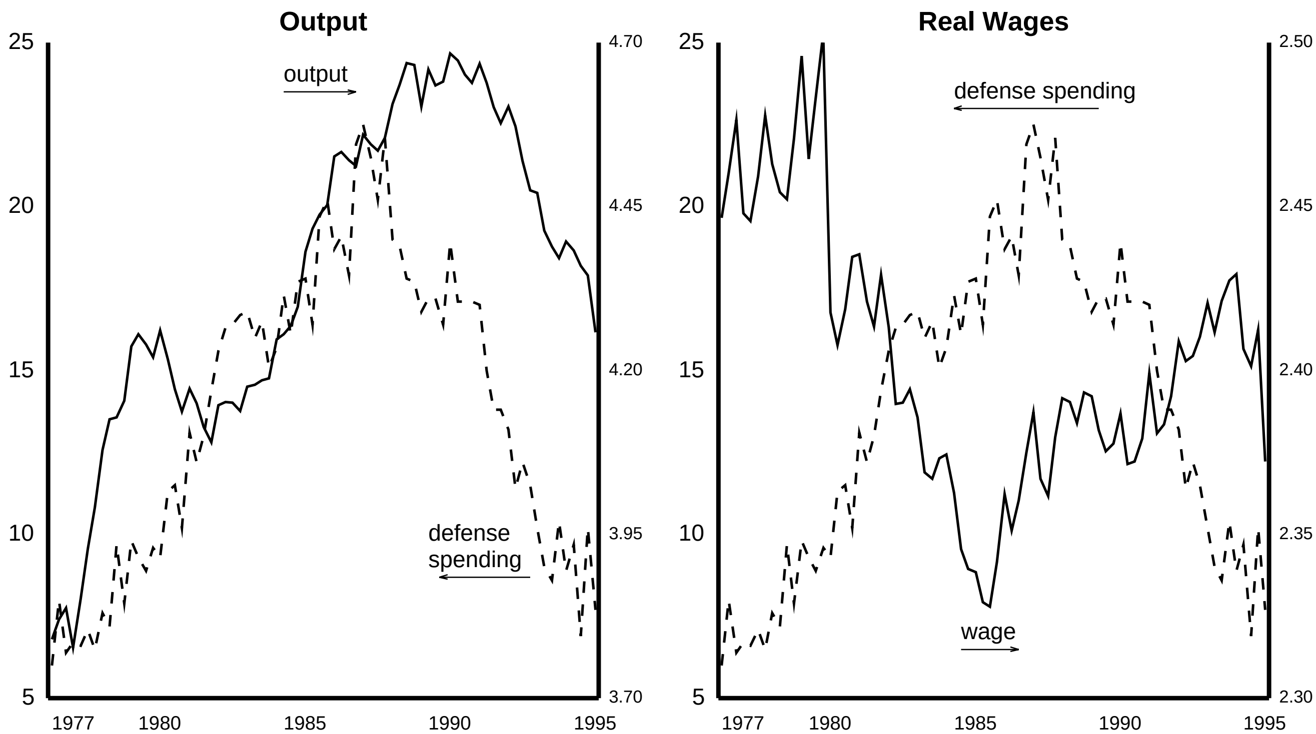


Figure 3: The Effect of Romer Dates and Ramey-Shapiro Military Dates

Line with circles response to a monetary shock, with squares response to a military shock
Filled marks significant at 10%; open marks significant at 25%

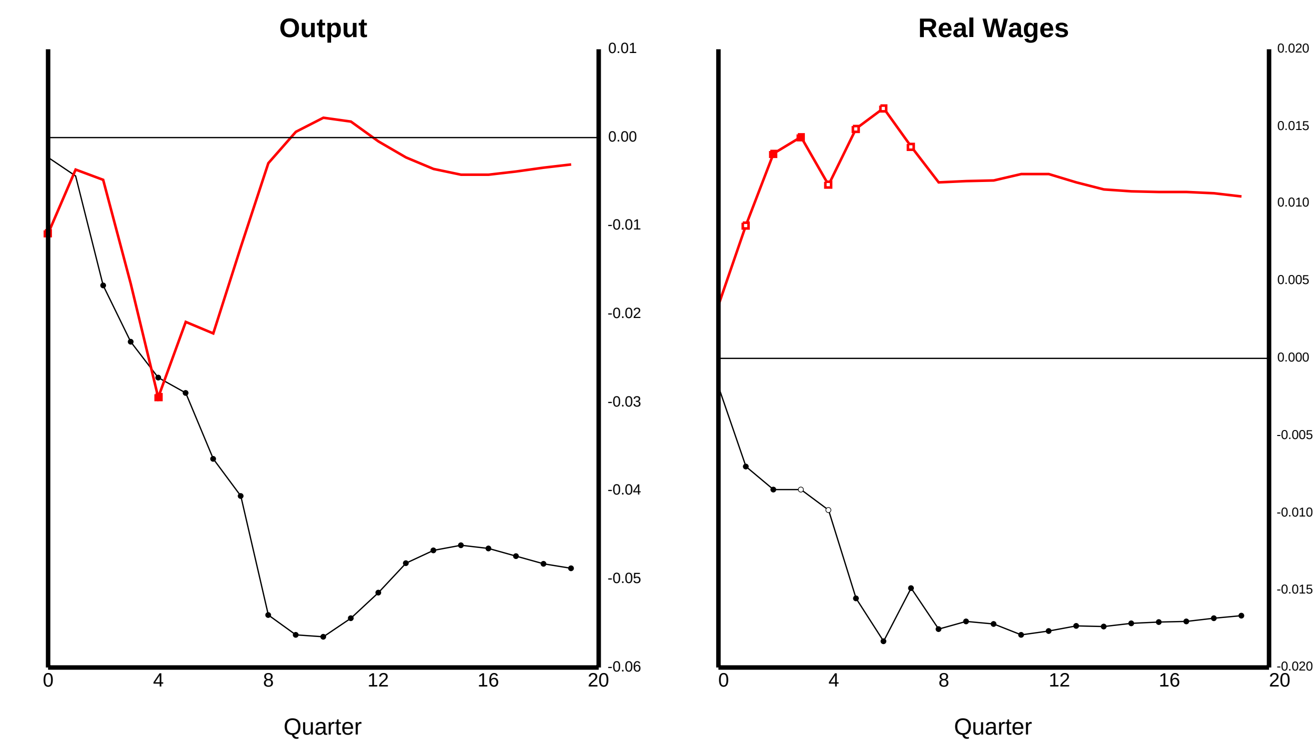


Figure 4A: Industry Output & Relative Price Responses to a Federal Funds Rate Shock
Entire Sample Period: January 1959 to March 2000

Thin line with circles Output; filled significant at 10%, open significant at 25%
Thick line with boxes Price/Wage; filled significant at 10%, open significant at 25%

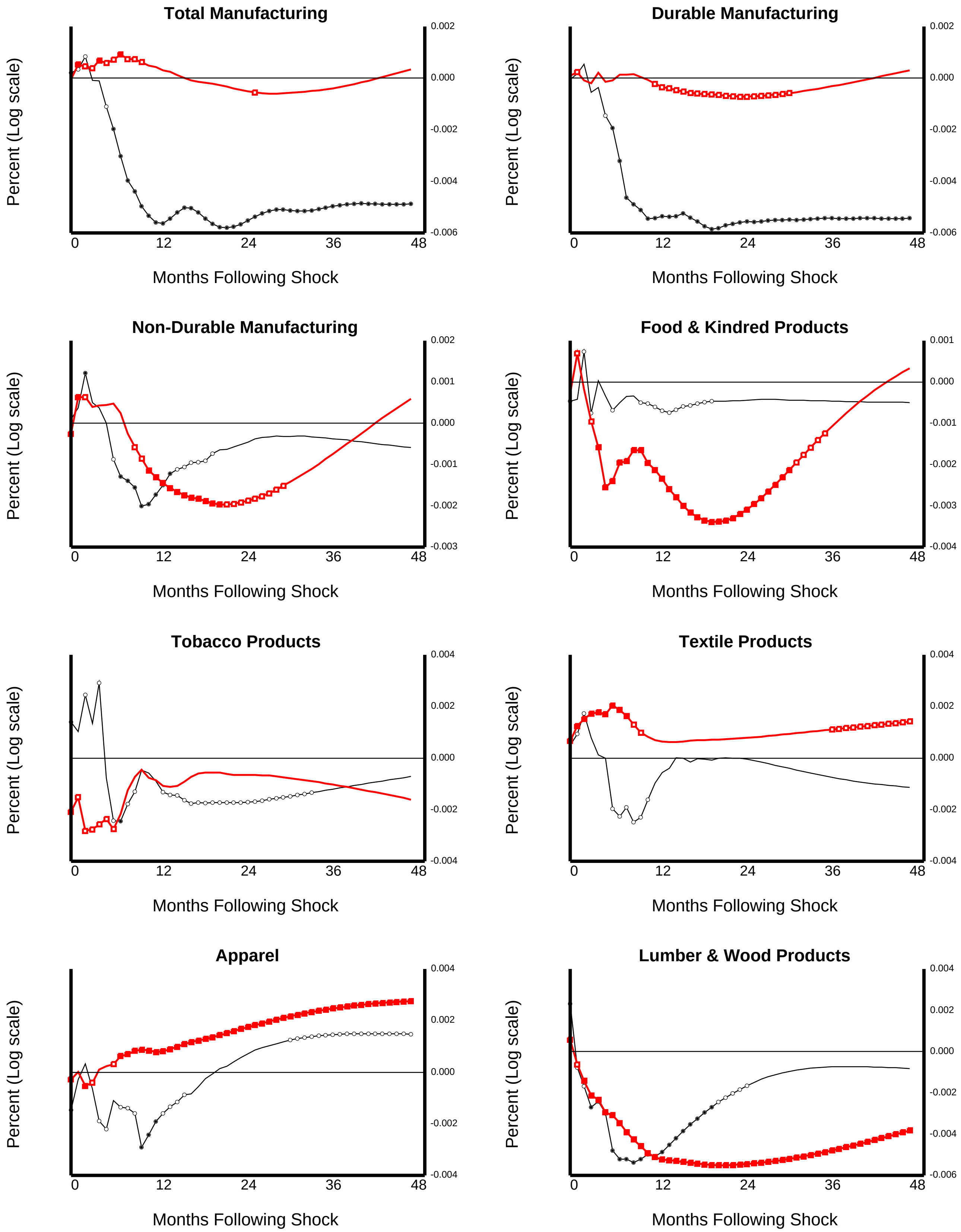


Figure 4B: Industry Output & Relative Price Responses to a Federal Funds Rate Shock
Entire Sample Period: January 1959 to March 2000

Thin line with circles Output; filled significant at 10%, open significant at 25%
Thick line with boxes Price/Wage; filled significant at 10%, open significant at 25%

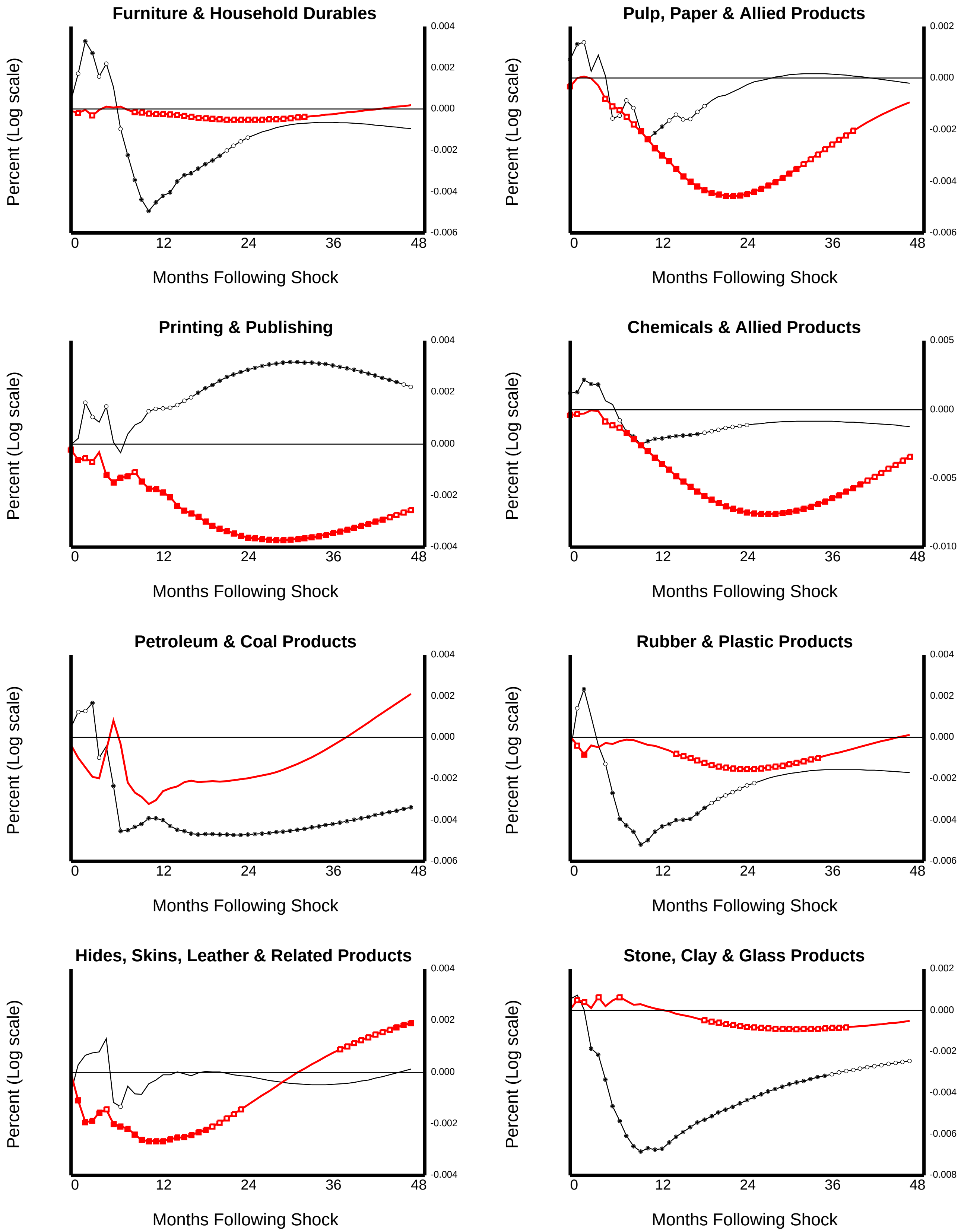


Figure 4C: Industry Output & Relative Price Responses to a Federal Funds Rate Shock
Entire Sample Period: January 1959 to March 2000

Thin line with circles Output; filled significant at 10%, open significant at 25%
Thick line with boxes Price/Wage; filled significant at 10%, open significant at 25%

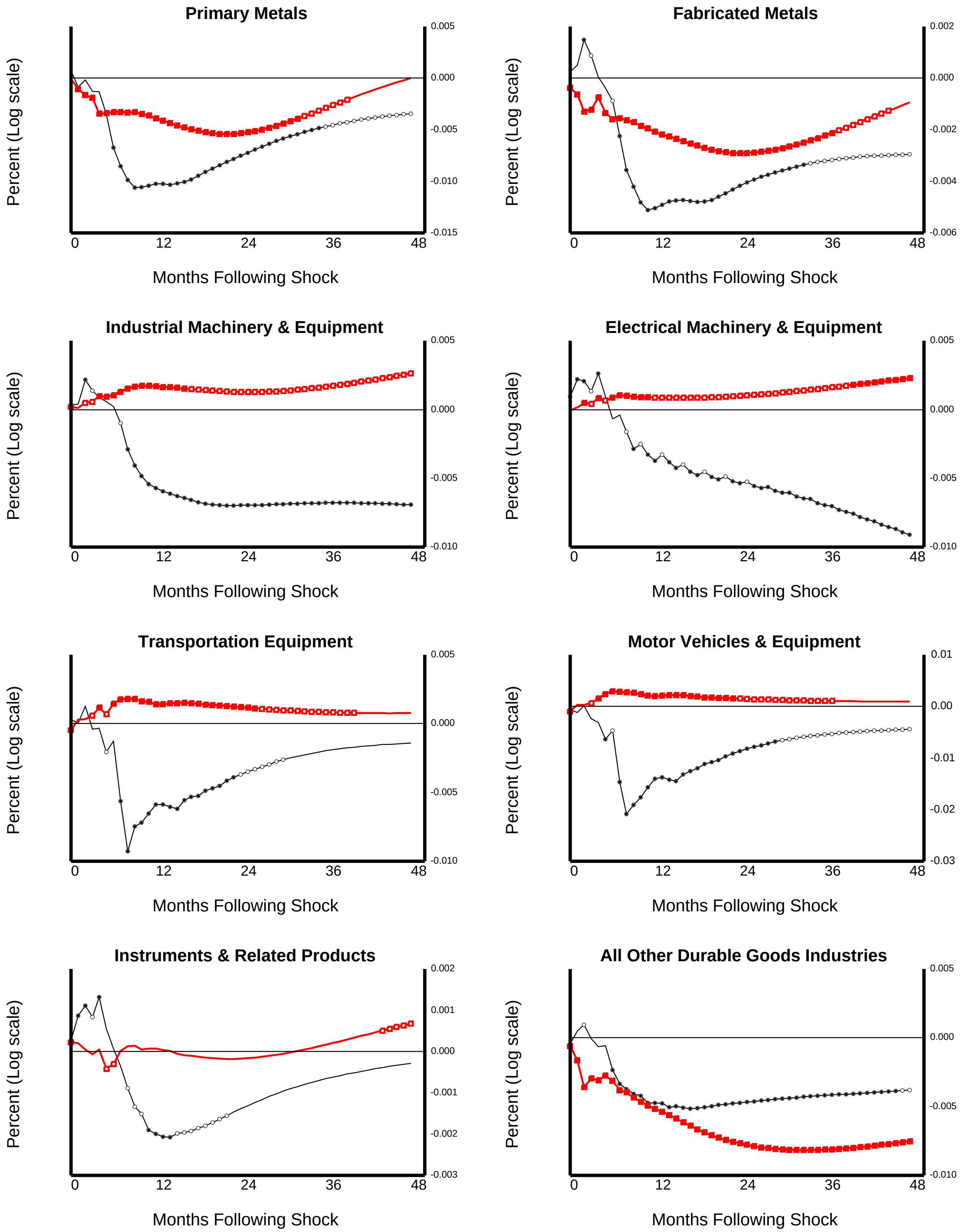


Figure 5A: Industry Output & Relative Price Responses to a Federal Funds Rate Shock
Early Sample Period: January 1959 to September 1979

Thin line with circles Output; filled significant at 10%, open significant at 25%
Thick line with boxes Price/Wage; filled significant at 10%, open significant at 25%

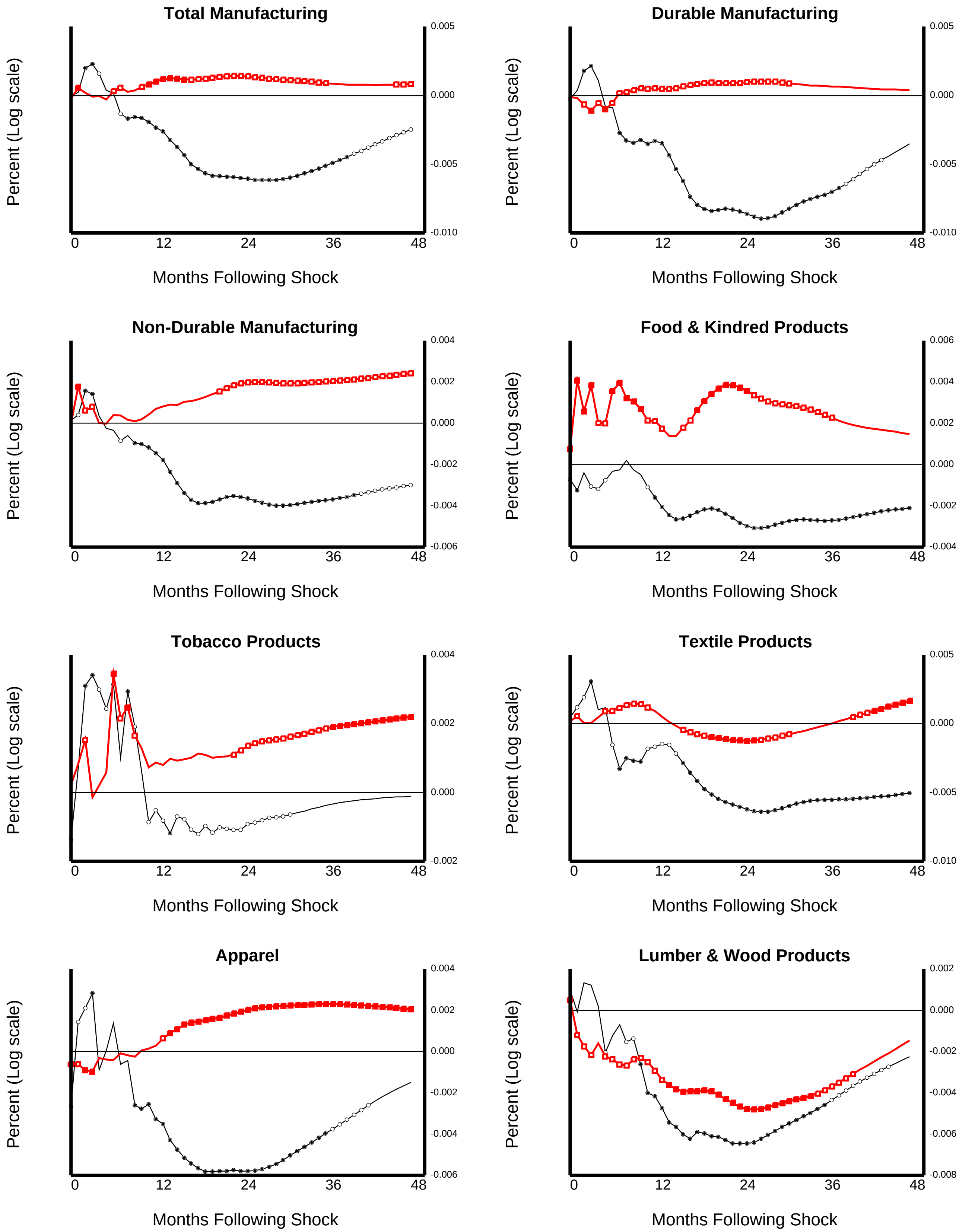


Figure 5B: Industry Output & Relative Price Responses to a Federal Funds Rate Shock

Early Sample Period: January 1959 to September 1979

Thin line with circles Output; filled significant at 10%, open significant at 25%
Thick line with boxes Price/Wage; filled significant at 10%, open significant at 25%

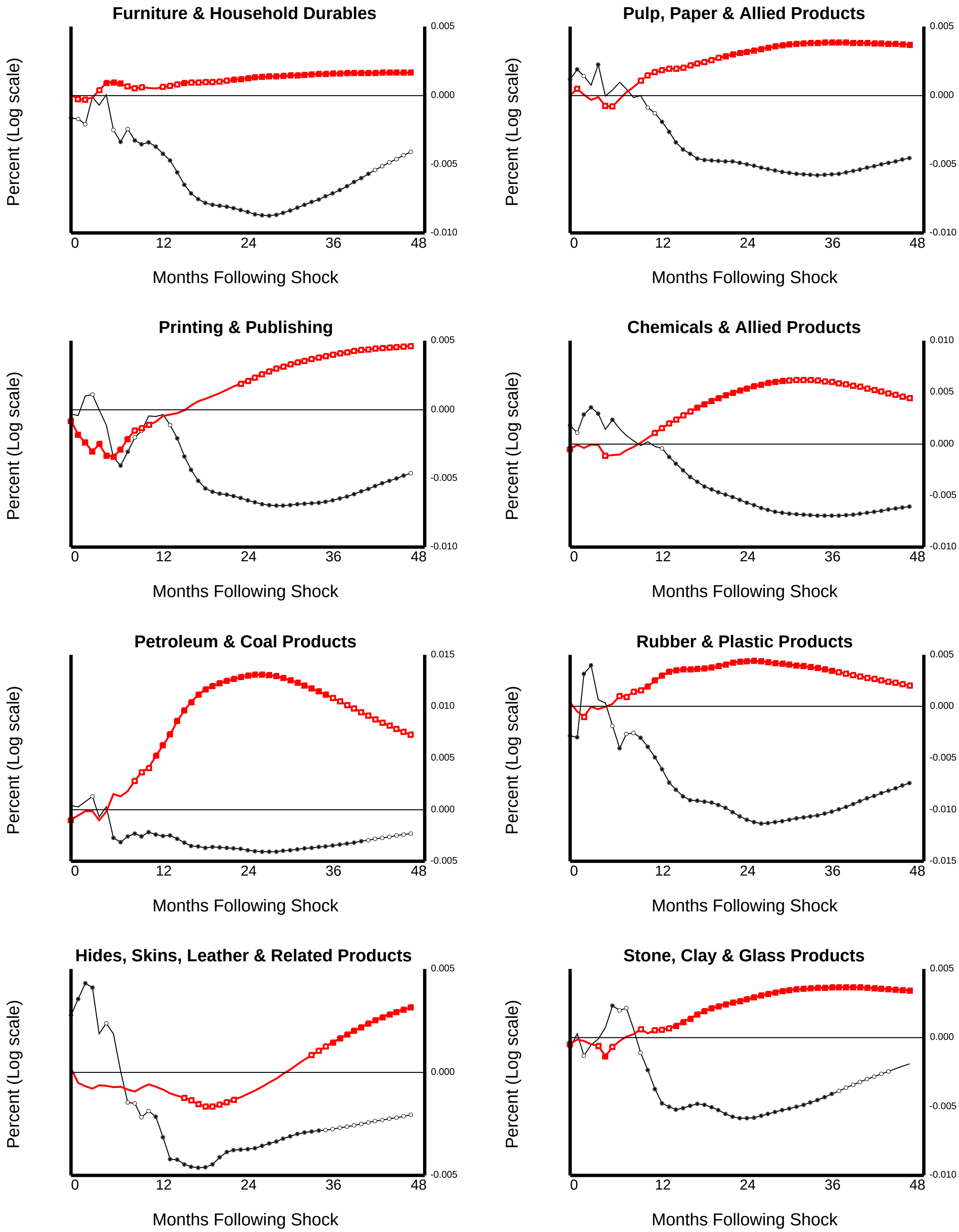


Figure 5C: Industry Output & Relative Price Responses to a Federal Funds Rate Shock
Early Sample Period: January 1959 to September 1979

Thin line with circles Output; filled significant at 10%, open significant at 25%
Thick line with boxes Price/Wage; filled significant at 10%, open significant at 25%

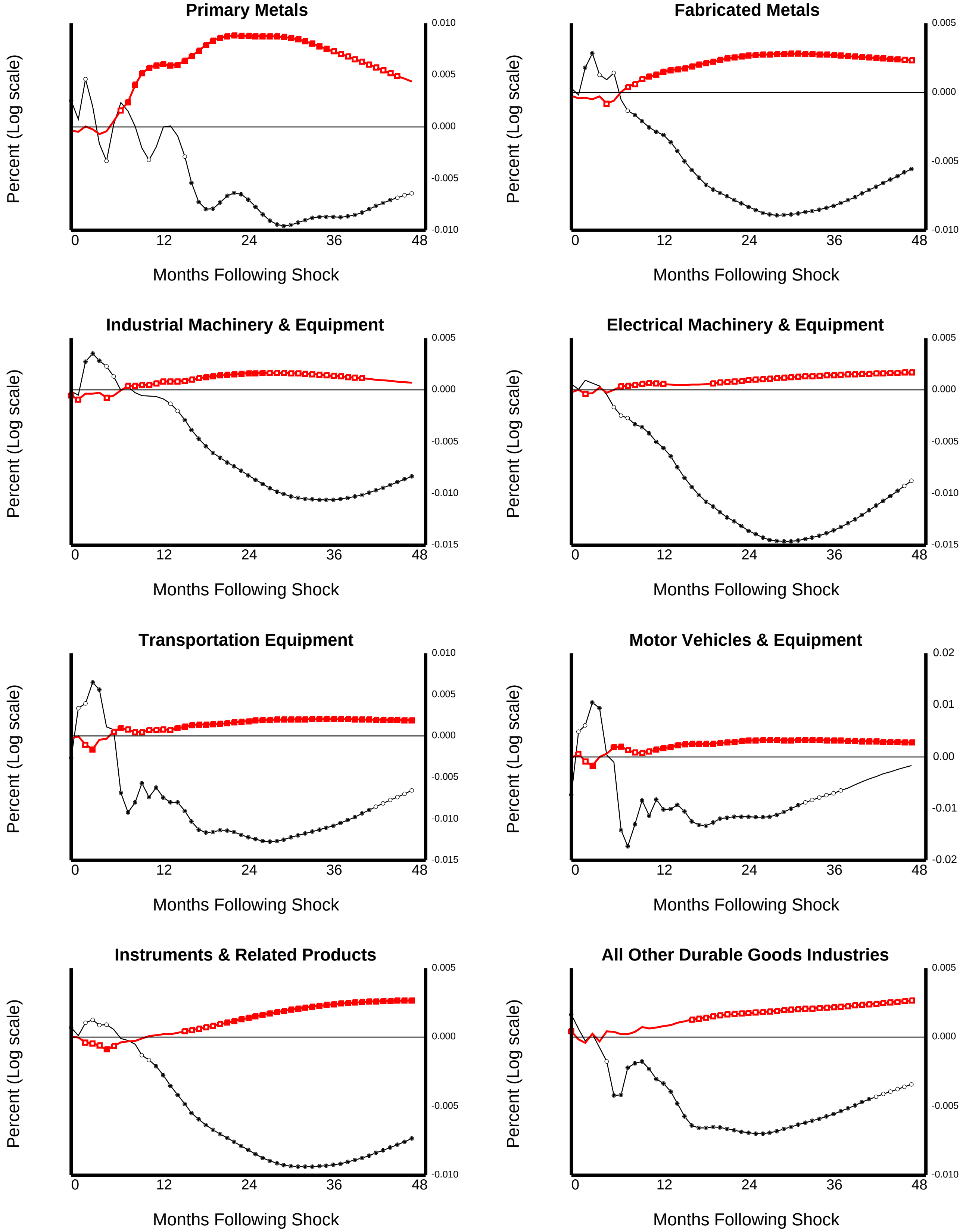
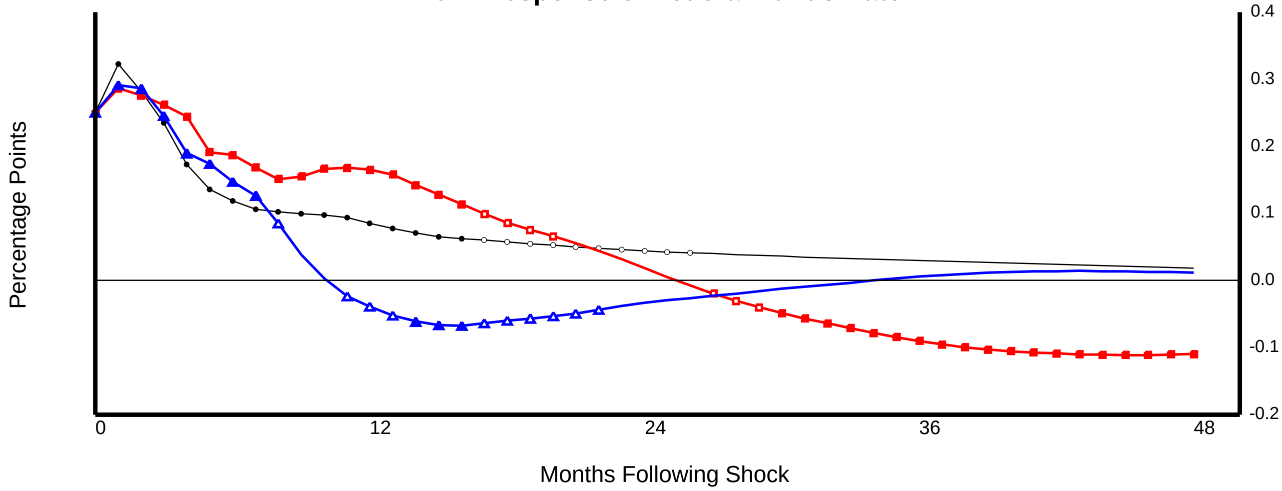


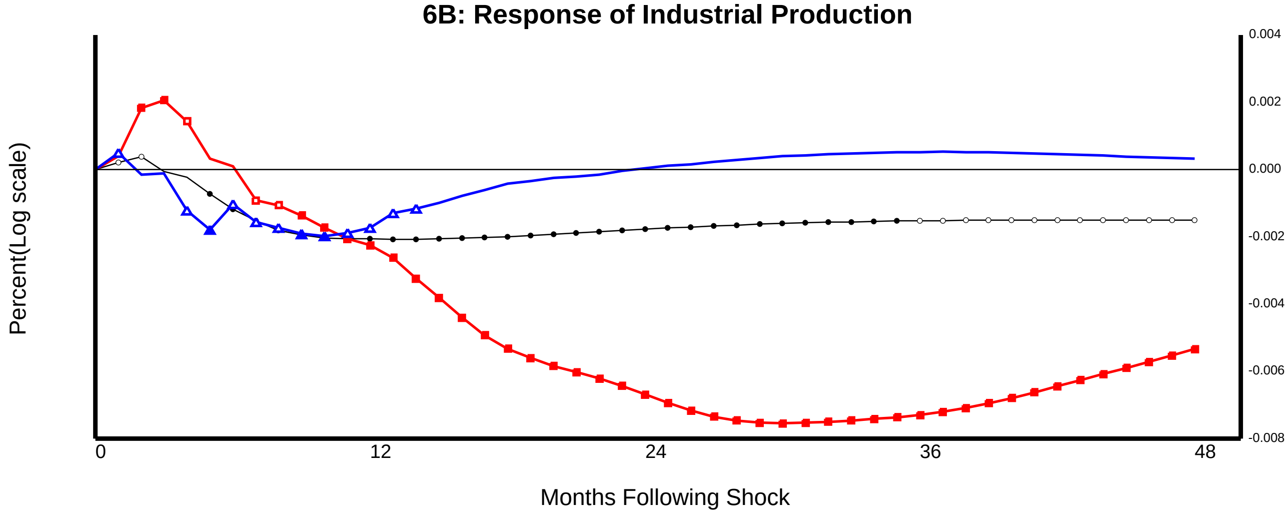
Figure 6: Aggregate Responses to a 25 basis point Federal funds rate shock, Across Data Samples

Line with circles entire sample: January 1959 to March 2000
Line with squares early sample: January 1959 to September 1979
Line with triangles later sample: January 1983 to March 2000
Filled marks significant at 10%; open marks significant at 25%

6A: Response of Federal Funds Rate



6B: Response of Industrial Production



6C: Response of Consumption Deflator

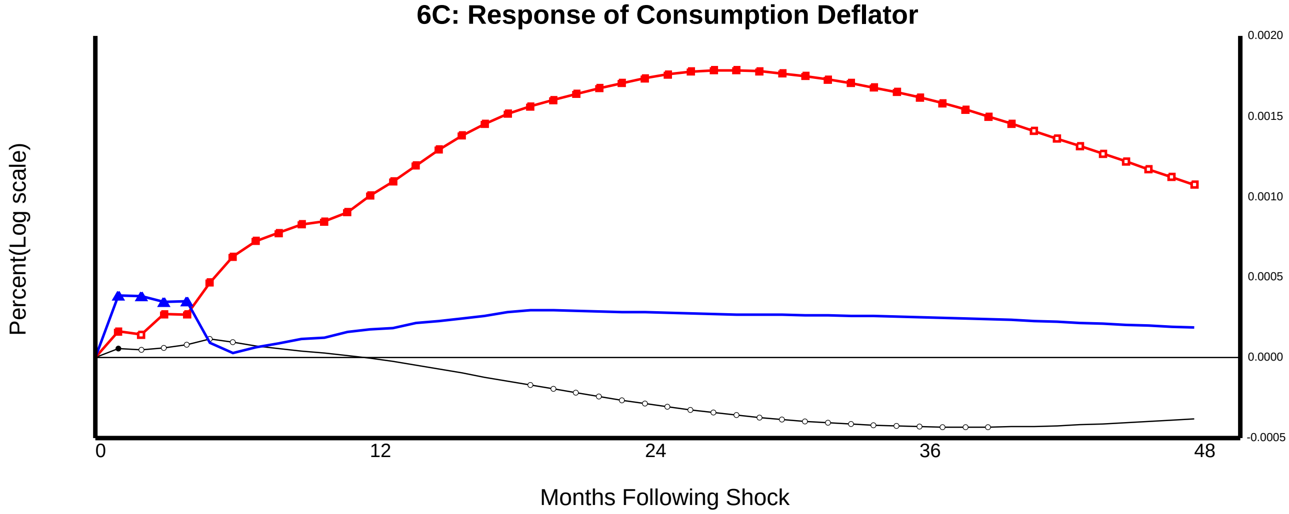


Figure 7A: Industry Price & Wage Responses to a Federal Funds Rate Shock
Early Sample Period: January 1959 to September 1979

Thin line with circles Price; filled significant at 10%, open significant at 25%
Thick line with boxes Wage; filled significant at 10%, open significant at 25%

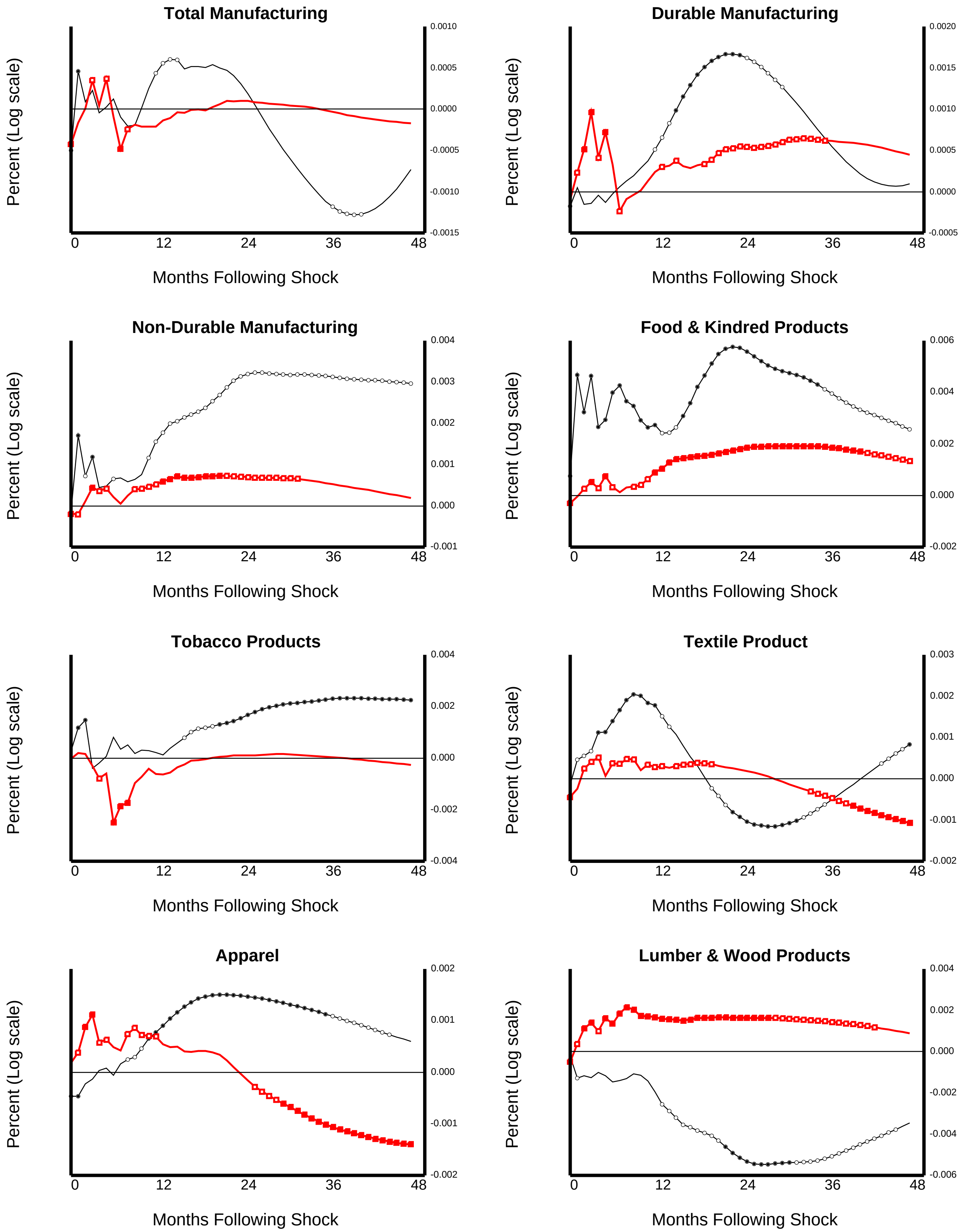


Figure 7B: Industry Price & Wage Responses to a Federal Funds Rate Shock
Early Sample Period: January 1959 to September 1979

Thin line with circles Price; filled significant at 10%, open significant at 25%
Thick line with boxes Wage; filled significant at 10%, open significant at 25%

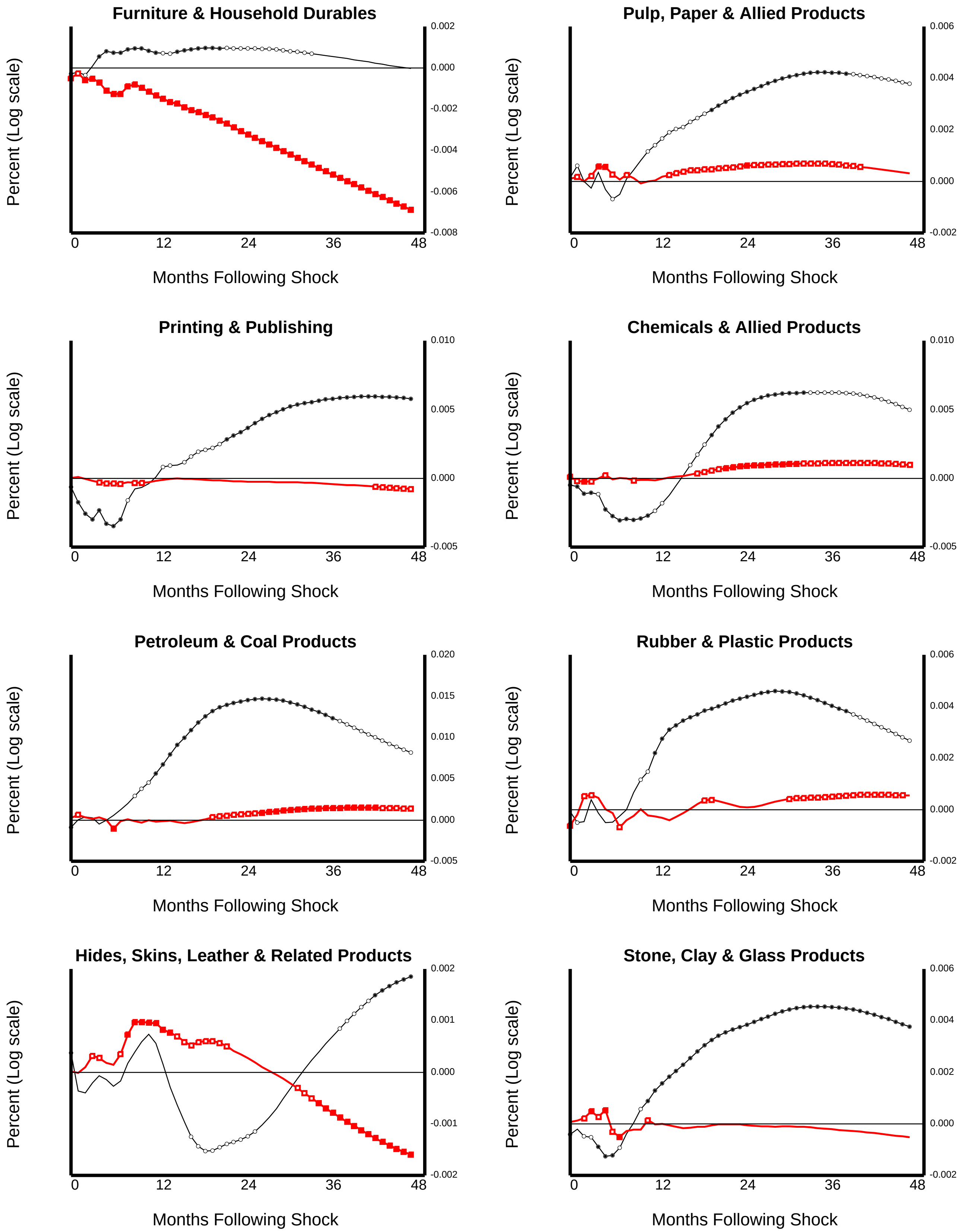


Figure 7C: Industry Price & Wage Responses to a Federal Funds Rate Shock

Early Sample Period: January 1959 to September 1979

Thin line with circles Price; filled significant at 10%, open significant at 25%
Thick line with boxes Wage; filled significant at 10%, open significant at 25%

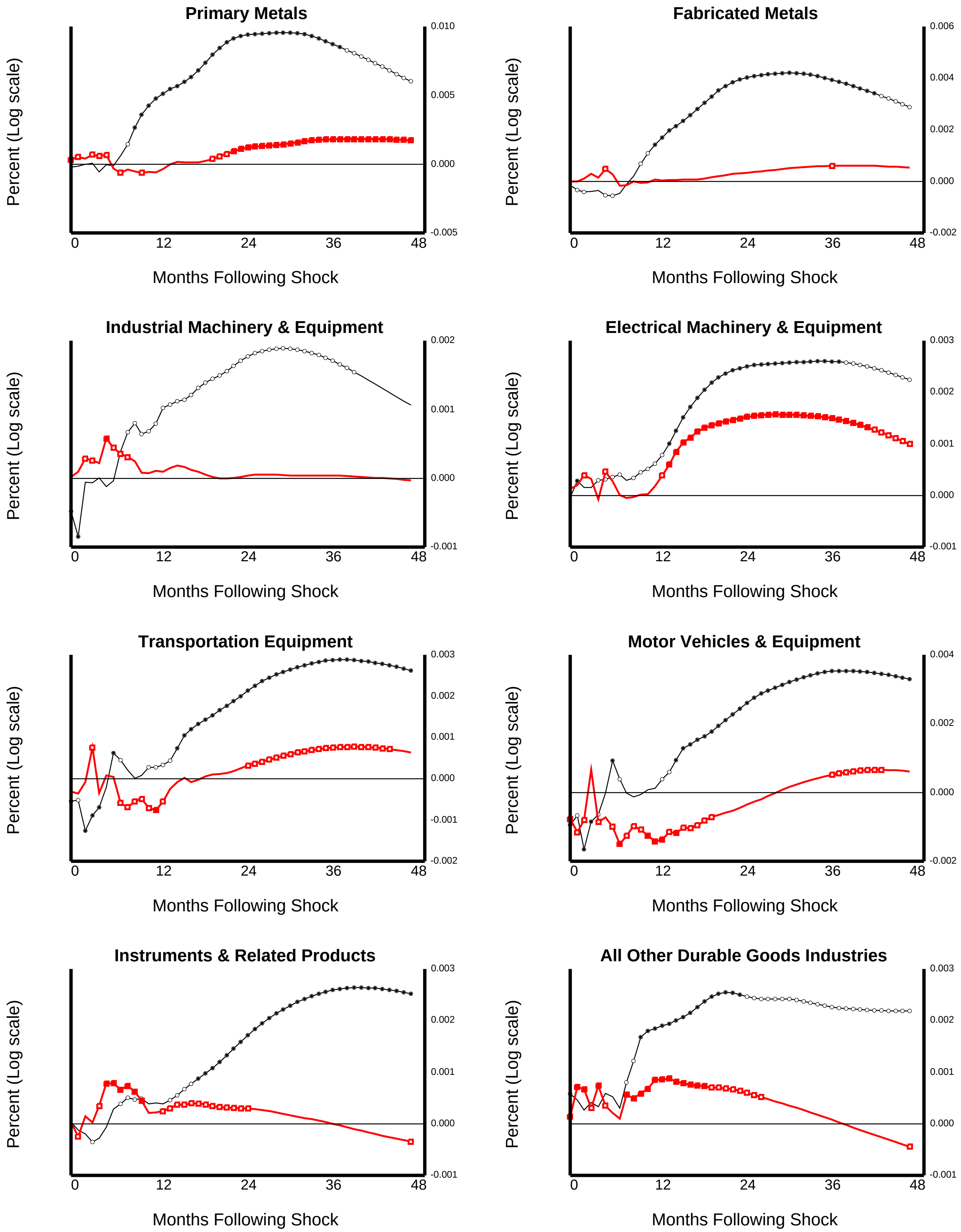


Figure 8: Aggregate Responses to a 25 basis point Federal funds rate shock, using Greenbook forecasts
Sample Period: November 1965 to September 1979

Thin line with circles standard specification; filled significant at 10%, open significant at 25%
Thick line with boxes Greenbook specification; filled significant at 10%, open significant at 25%