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The Cost Channel of Monetary Transmission

1. *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 and Eichenbaum, 1992; Christiano, Eichenbaum, and 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 de-

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serve 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 and 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 and 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 vector autoregression (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. 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 and Gertler's (1989) model contains both a demand and a 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, and Stein, 1994; Kashyap, Stein, and Wilcox, 1993; and Gertler and 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 vs. 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.[1]

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 and Eichenbaum (1992), Christiano, Eichenbaum, and 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 nonneutral. 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 2 presents aggregate evidence that the effects of monetary policy shocks look more like technology shocks than like demand shocks. Section 3 investigates the importance of working capital in production. Section 4 presents evidence derived from two-digit-level industry data. The results of this analysis show clear indications of 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 5 addresses possible alternative explanations of the empirical results presented in the preceding sections. Finally, Section 6 concludes.

2. *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

1. 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.

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.[2] Nor is it clear what exactly is meant by "aggregate demand" and "aggregate supply" shocks in a fully specified dynamic general-equilibrium model. Undaunted, we pursue two alternative strategies. The first extends work by Shapiro and Watson (1988), Gali (1999), and Francis and Ramey (2001) by using long-run restrictions to identify technology (supply) and other shocks. The second approach uses defense buildups as an example of an exogenous nontechnology (demand) shock. Neither approach is completely uncontroversial, but the similarity of results across the two approaches strengthens our case.

2.1 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) in identifying technology shocks as the only shocks that have permanent effects on productivity. This assumption is fairly unrestrictive, as it allows for temporary effects of nontechnology 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 an aggregate 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 and 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 by Francis and Ramey in order to compare the effects of the various shocks. Consider the following moving-average representation:

$$y_t = C(L)u_t. \tag{1}$$

Here y_t is a 6×1 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

2. 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 affecting residential investment and motor vehicles at the same time as 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.

measured by M2 (m_t), and the level of the federal funds rate (f_t). The function $C(L)$ is a polynomial in the lag operator with 6×6 matrix coefficients. Shocks to the system, ε_t^x, ε_t^n, ε_t^w, ε_t^p, ε_t^m, ε_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 $j = 2, 3, \ldots, 6$, where C(1) represents the sum of all moving-average coefficient matrices.[3] To derive a shock comparable to Gali's aggregate-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 (except productivity), and, following Bernanke and Blinder (1992) and Christiano, Eichenbaum, and Evans (1999), we assume that the shocks to that equation represent monetary policy shocks.

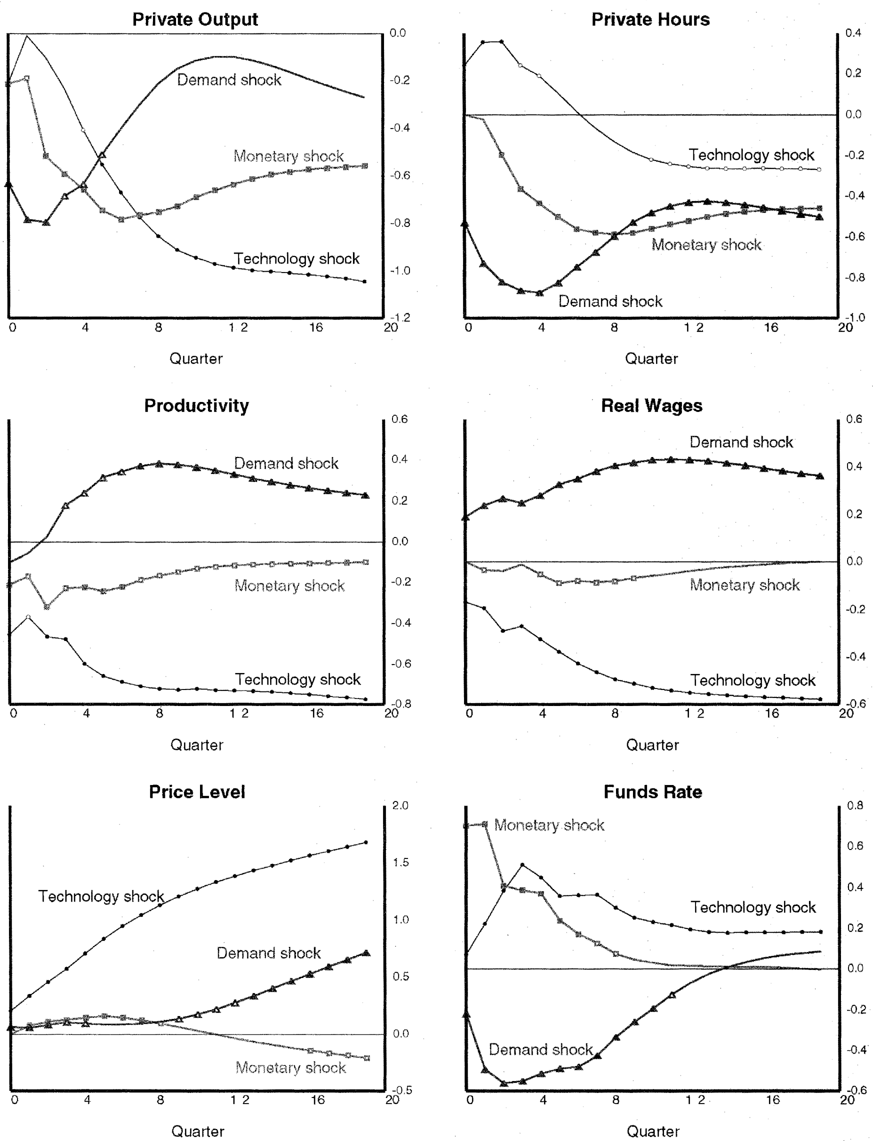
A unit root in productivity is key to identifying the shock. We also assume that hours, real wages, the price level, and the money supply have unit roots, while the federal funds rate is stationary. As Gali shows, the results are not sensitive to changing these auxiliary assumptions. We include four 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 nonmonetary, nontechnology shock is assumed to be the shock to the hours equation, which Gali has argued behaves most like a *demand shock*. Furthermore, Francis and 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 January 1959 to March 2000 to estimate the model. The Data Appendix gives complete details about the data used, as well as how the standard errors are calculated.

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

3. Francis and 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 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%.

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 like 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. Thus, the usual explanation given for the decline in labor productivity—a fall in capital utilization—does not appear to apply to declines in hours caused by other demand shocks.

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 responses are consistent with a negative shock to production possibilities that leads to a decline in labor demand. Real wages respond oppositely to a negative demand shock, rising, as would be consistent with a stable production function, and leading to higher labor productivity and hence real wages.

The real-wage results are consistent with several other results from the literature. For example, using a standard recursive VAR, Christiano, Eichenbaum, and Evans (1997) also find that real wages decline in response to a contractionary monetary shock. Using Shapiro and Watson's (1988) long-run identifying restrictions that aggregate-demand shocks can have no long-run effect on output, Fleischman (2000) finds that aggregate-demand shocks lead to countercyclical movements in real wages. Thus, the response of real wages to monetary shocks is very different from the response to other aggregate-demand shocks.

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 or 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.

2.2 A COMPARISON OF EXOGENOUS MONETARY VS. DEFENSE SHOCKS

As our second line of attack, we present evidence that monetary shocks differ significantly from demand shocks, identified as exogenous defense buildups, 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 buildup, the Department of Defense accounted for almost 60% of total shipments from the aircraft and parts industry. Thus, fluctuations in defense spending are an important exogenous source of demand variation.

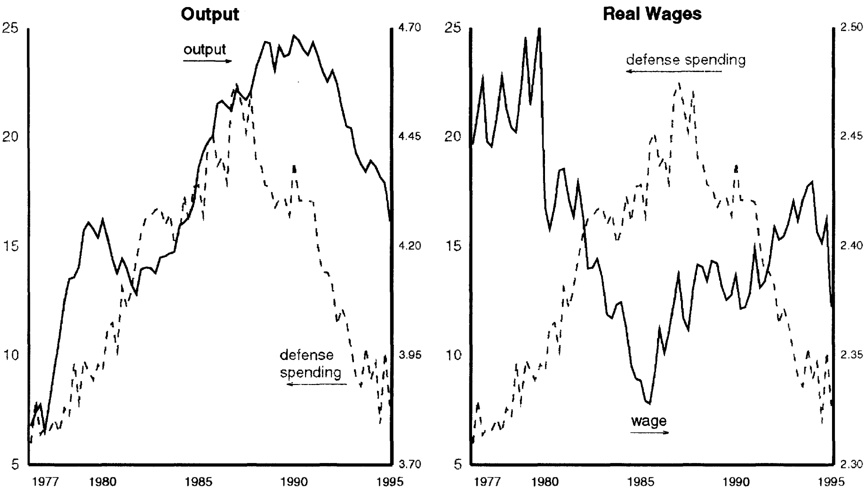
Figure 2a charts real defense spending on aircraft and parts plotted against both industrial production and the real product wage in SIC 372. The real product wage is measured as average hourly earnings in the industry divided by the producer price index for aircraft and parts. The graph plots the logarithms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

From 1977 to 1988, real defense spending on aircraft and parts rose 375%. From 1988 to 1995 it fell by almost the same amount. As Figure 2a 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.

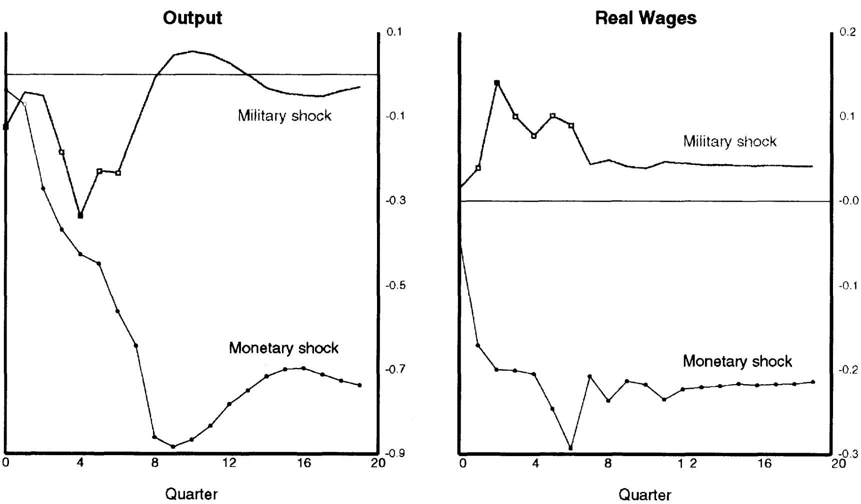
These strongly countercyclical responses to exogenous fluctuations in industry demand are entirely consistent with the effects of a demand shock in a standard neoclassical model with flexible prices. With a stable production function and slow accumulation of capital, an increase in output is necessarily 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 and Shapiro (1998) demonstrated more generally, defense spending has similar effects on more aggregate product wages. To highlight the different effects of monetary vs. defense shocks, we compare the impact on real wages and output of a Romer monetary date (Romer and Romer, 1989, 1994) with that of a Ramey–Shapiro military date. In each case, we estimate a system with real wages, output, and the

Figure 2(a) THE EFFECT OF DEFENSE SPENDING ON AIRCRAFT INDUSTRY OUTPUT AND WAGES (QUARTERLY DATA); (b) THE EFFECT OF ROMER DATES AND RAMEY–SHAPIRO MILITARY DATES



(a)



(b)

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%.

dummy variable of interest. Eight lags of all variables plus the current value of the dummy variable are included. 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 buildups, 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 2b 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 and Woodford (1991), King and Goodfriend (1997), and various others have argued that either collusive behavior or sticky prices can lead to countercyclical markups. Since the markup 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 opposite 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 nontechnology shocks.

3. *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. 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.[4] 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 trillion each.[5]

There are various ways to incorporate working capital into a model of production. Fuerst (1992), Christiano and Eichenbaum (1992), and CEE (1997) embed a delay between factor payments and sales receipts in their models. 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

$$\ln N_t = \frac{1}{\alpha}\left(\ln(1 - \alpha) - \ln \mu - \ln R_t - \ln \frac{W_t}{P_t} \right), \tag{2}$$

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 5, a monetary contraction results in an 83-basis-point rise in the nominal interest rate, a 1.4% 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 invest-

4. The inventory and sales data are from the BEA, and the trade credit data are from the *Flow of Funds*.
5. From *Quarterly Financial Reports*, second quarter 2000.

ment suggests that a 1-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 3%, 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 forced 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.[6] 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% decline in labor demand with real wages held constant.

The time-lag-in-production model nicely captures several features of the data shown in Figures 1 and 2, but it does not explain how a monetary contraction can reduce labor productivity. A model in which working capital has a direct impact on the marginal product of labor *can* explain such a phenomenon. This can be achieved most directly by including working capital as a factor of production. In fact, there is evidence that this is a valid representation of the role of working capital. Ramey (1989) demonstrates that a model which includes inventories by stage of process as production factors is well supported by the data.

6. 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.

It is at this point, though, that the cost-channel theory runs into the same problem as the credit-channel theory. Both theories suggest that firms should decrease their inventories and accounts receivable in response to a monetary contraction. In fact, it is well known that aggregate inventories and accounts receivable rise relative to sales in response to a monetary contraction, at least in the short run (see for example Bernanke and Gertler, 1995, and Ramey, 1992). Some of this rise can be explained by other mechanisms coming into play at the same time. For example, if a monetary contraction also works through product demand, then firms may have unanticipated buildups in final-goods inventories just when they would prefer to hold fewer inventories. Similarly, firms' credit-constrained customers may delay their payments, leading to rises in accounts receivable just when firms need the extra liquidity.

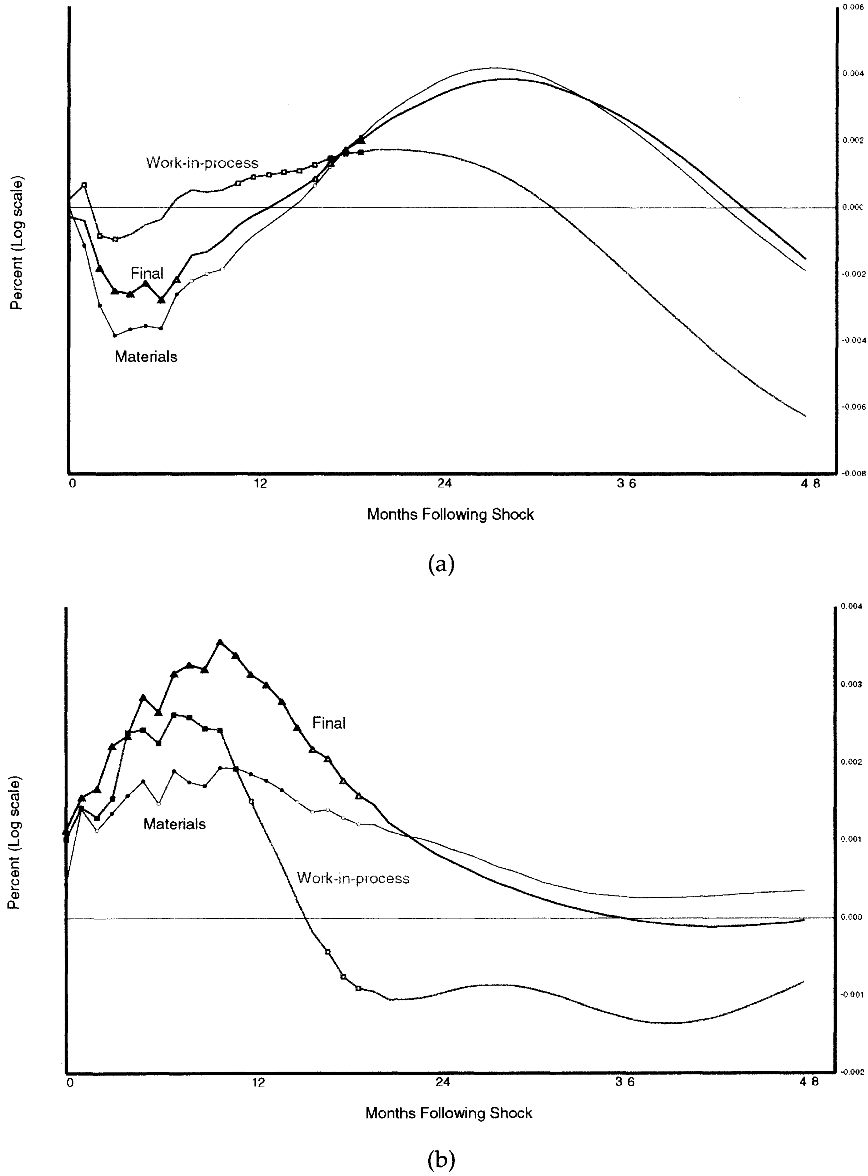
The behavior of the various components of working capital in response to a monetary contraction is an important part of the story and deserves a much more detailed analysis than we can offer here. We present one piece of suggestive evidence that there may be something to the story. Raw-material and work-in-process inventories are not as susceptible to unintentional buildup. Thus, it is interesting to study what happens to the ratio of inventories by stage of processing relative to labor hours after a monetary contraction.

To measure the effect of a monetary contraction on inventories relative to hours, we use the monthly VAR model that will be presented in the next section.[7] We study the response of manufacturing inventories to hours over two different periods of monthly data: January 1959 to September 1979 and January 1983 to March 2000. The sample was split for two reasons. First, the new BEA data on real inventories extend back only to 1967. Therefore, we use the old BEA data for the early period and the new BEA data for the second period. Second, as we will demonstrate in the next section, evidence for a cost channel of monetary transmission is much stronger in the pre-Volcker time-series data than in the post-Volcker period.

Figure 3 shows the response of inventories relative to sales for each period. Consider first the period from January 1959 to September 1979 shown in Figure 3a. All types of inventories fall relative to hours in the short run. Interestingly, materials and final goods fall by similar amounts, whereas work in process falls much less. The materials-inventory response stays negative the longest before becoming positive, at about 13

7. In particular, we estimate equation (3) in which the ratios of materials, work-in-process, and final-goods inventories to hours replace the last two variables in the system.

Figure 3 RESPONSE OF MANUFACTURING INVENTORIES BY STAGE OF PROCESS TO A FEDERAL FUNDS RATE SHOCK: (a) EARLY SAMPLE PERIOD—JANUARY 1959 TO SEPTEMBER 1979; (b) LATE SAMPLE PERIOD–JANUARY 1983 TO MARCH 2000.



Line with circles, materials; with squares, work in process; with triangles, final. Filled marks significant at 10%; open marks significant at 25%.

months. If inventories enhance labor productivity, then this fall in the ratios might help explain the decline in labor productivity.

The behavior of inventories is completely different in the later period, as shown in Figure 3b. In all cases, inventories rise relative to hours. As we shall argue later, the cost channel appears to be much stronger in the early period. These inventory results also support that view.

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, shows that the rise in prices is temporary; the price level does finally end up falling. The cost channel may have a larger effect 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 and Gertler's (1995) finding of a delayed effect of a monetary contraction on business fixed investment is consistent with this hypothesis.

4. *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 change of variables. Second, to facilitate later discussion about the price puzzle and countercyclical markups, it is more convenient to focus on the behavior of the reciprocal 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]

4.1 EMPIRICAL FRAMEWORK

We again follow the work of Bernanke and Blinder (1992) and CEE (1999) 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 price puzzle and flexibility in examining the response 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 FFR. 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 responds. CEE demonstrate that this eliminates the price puzzle (note that this is not true in pre-1979 subsamples; see Section 4.3).

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 and 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

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 with industry price and output. Instead, they examine each industry's wage deflated by a general price deflator.

9. That is, a month identified by Hoover and 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 postwar oil shocks. Hoover and Perez supplement Hamilton's exogenous political events with the Iraqi invasion of Kuwait in August 1990. Upon the advice of Trevor Reeve, oil economist at the Federal Reserve, we add to this list the election of Hugo Chavez as President of Venezuela in December 1998. Chavez served as the catalyst for OPEC's new-found cohesion in cutting production in early 1999.

price shocks take an average 9 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 FFR, 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 FFR 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 and Haltiwanger (1997), who point out that this is in essence a pseudo-panel-data VAR. Since the coefficients of the macro-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:

$$Y_t = F'\,\mathrm{SD}_t + \sum_{j=0}^{12} G_j'\,\mathrm{HP}_{t-j} + \sum_{k=1}^{7} A_k Y_{t-k} + \epsilon_t, \tag{3}$$

where

$$Y_t' = \left[\ \mathrm{IP}_t, P_t, \mathrm{PC}_t, \mathrm{M2}_t, \mathrm{FFR}_t, Q_{i,t}, \frac{P_{i,t}}{W_{i,t}}\ \right] \quad \text{and} \quad \underset{7\times7}{A_k} = \begin{bmatrix} \underset{5\times5}{A_k^{1,1}} & \underset{5\times2}{0} \\ \underset{2\times5}{A_k^{2,1}} & \underset{2\times2}{A_k^{2,2}} \end{bmatrix}.$$

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, $\mathrm{M2}_t$ is the monthly average of M2, FFR_t is the monthly average of the FFR, $Q_{i,t}$ is industrial production in industry i, and $P_{i,t}/W_{i,t}$ is the ratio of price to wage in industry i. In (3), 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, and Watson (1997), we used seven lags.[11] All series are in natural-log levels except FFR_t. Details on data construction and standard errors are given in the Data Appendix.

10. Hoover and Perez's dummy variable has slightly more explanatory power for industrial production than Hamilton's (1996) net-oil-price-change variable.
11. There is little qualitative difference in the results using as many as 13 lags.

We estimated vector autoregressions of this form for total manufacturing, durable manufacturing, and nondurable 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 subsample periods from February 1959 to September 1979 and 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.

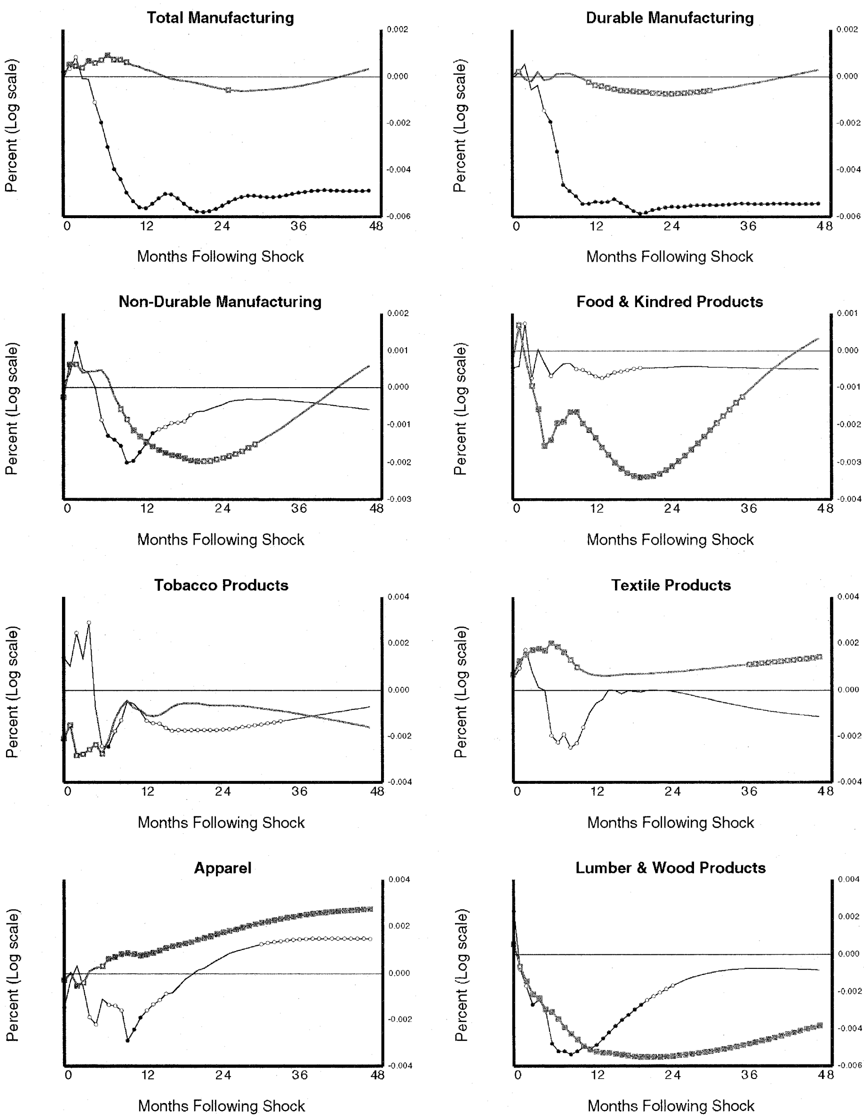
4.2 INDUSTRY RESULTS

The results are represented in a series of graphs and tables. Figure 4a through 4c show the effect of a positive FFR 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 FFR, output falls and prices rise relative to wages. The second and third columns in Table 1 summarize the results by describing the behavior of the data during the first 24 months for each industry. The third column 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% level for six of the 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 and paper, chemicals, hides and 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 a typical 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

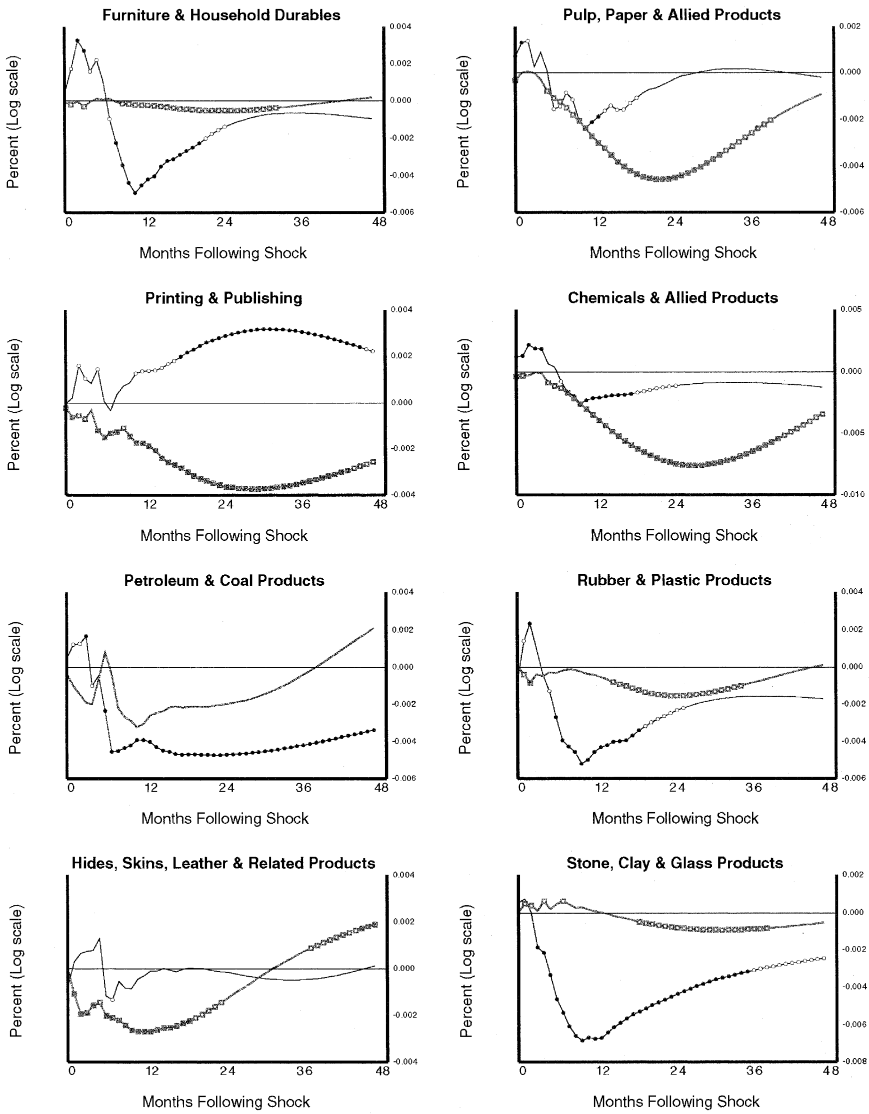
Figure 4 INDUSTRY OUTPUT & RELATIVE PRICE RESPONSES TO A FEDERAL FUNDS RATE SHOCK: ENTIRE SAMPLE PERIOD: JANUARY 1959 TO MARCH 2000



(a)

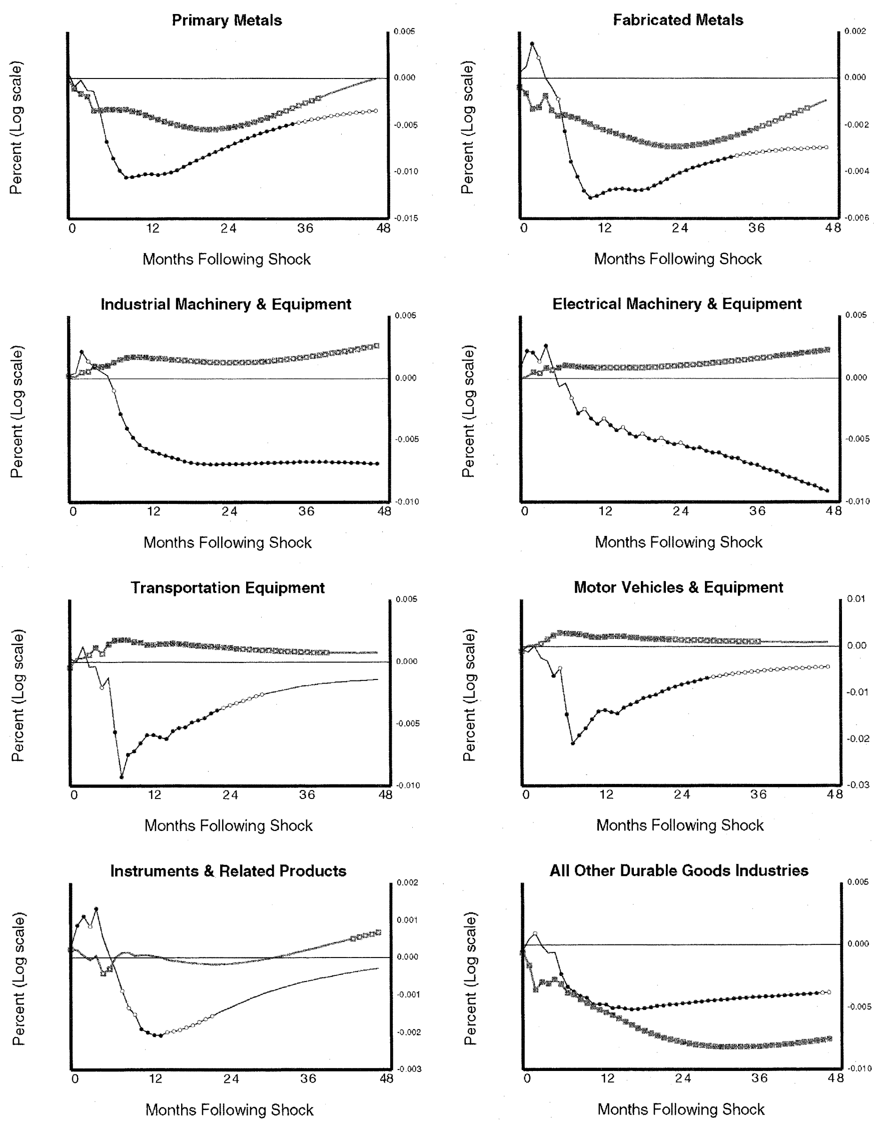
Thin line with circles, output: filled, significant at 10%; open, significant at 25%. Thick line with boxes, price/wage: filled, significant at 10%; open, significant at 25%

Figure 4 CONTINUED



(b)

Figure 4 CONTINUED



(c)

Table 1 NUMBER OF PERIODS IN FIRST TWO YEARS *P/W* RESPONSE IS GREATER THAN ZERO, SIGNIFICANTLY AT 10% LEVEL

	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
Nondurables	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, $n \geq 2$	10	6	19	15	16	3

observe in Figure 4c. Look at the price and output responses of motor vehicles: prices rise steeply and then decay slowly after a peak at 9 months; the output response is nearly the mirror image, falling to a trough at 9 months and slowly increasing from there.

Nor are these unimportant or noninfluential 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.

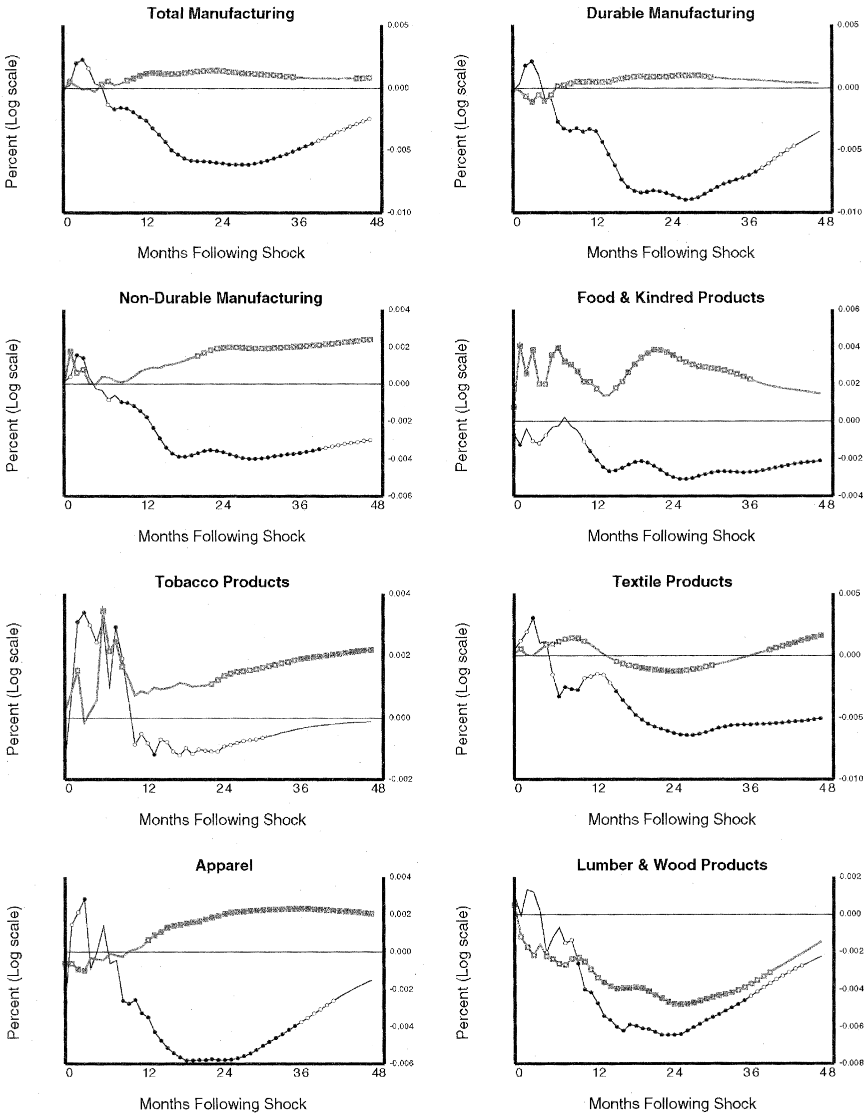
Some of the industries that exhibit strong cost-side effects run counter to our prior expectations. One such example is motor vehicles and parts, which shows a very pronounced increase in the ratio of price to wages. One might think that an industry governed by such large firms would not experience large 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 January 1983 to March 2000 (the Volcker–Greenspan period). We choose these two subsamples based on the works of Faust (1998) and Gordon and 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 subsamples removes the volatility of monetary policy and economic aggregates experienced between late 1979 and 1982 from the data.

Figure 5a through c 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 4 through 7 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

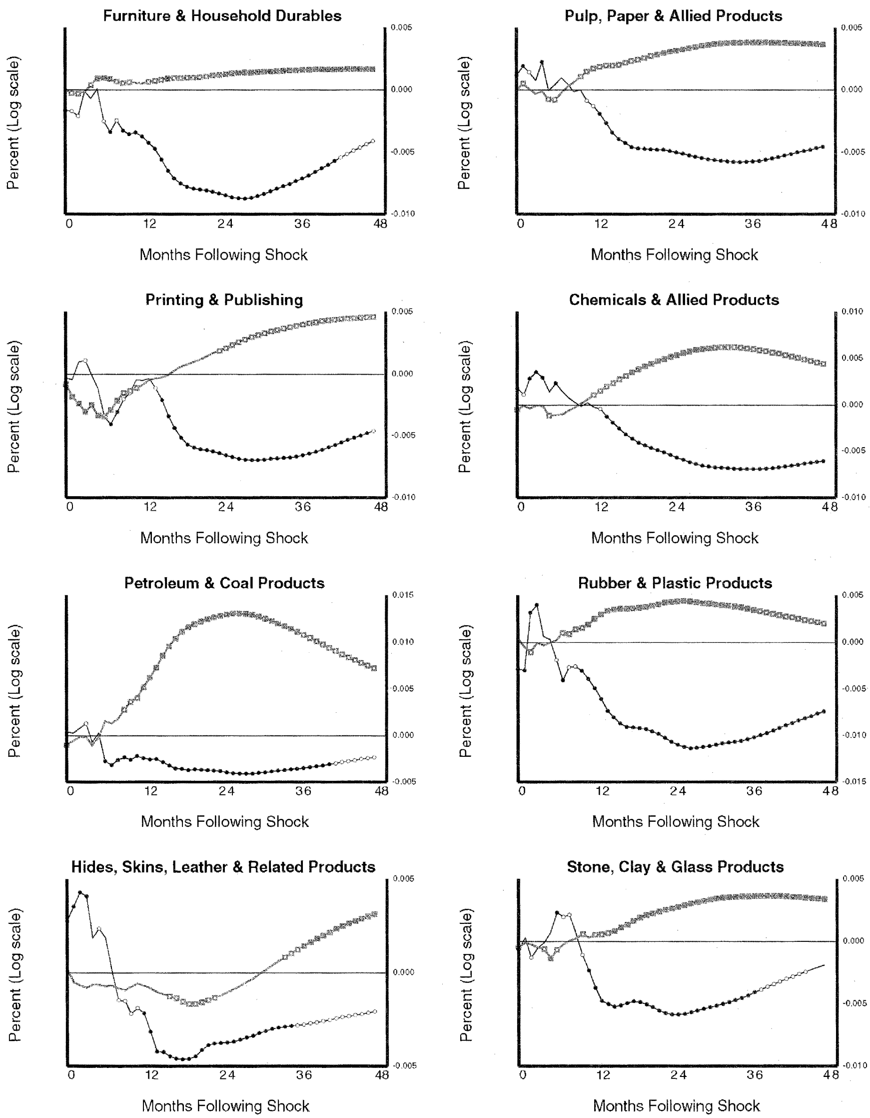
Figure 5 INDUSTRY OUTPUT & RELATIVE PRICE RESPONSES TO A FEDERAL FUNDS RATE SHOCK: EARLY SAMPLE PERIOD: JANUARY 1959 TO SEPTEMBER 1979



(a)

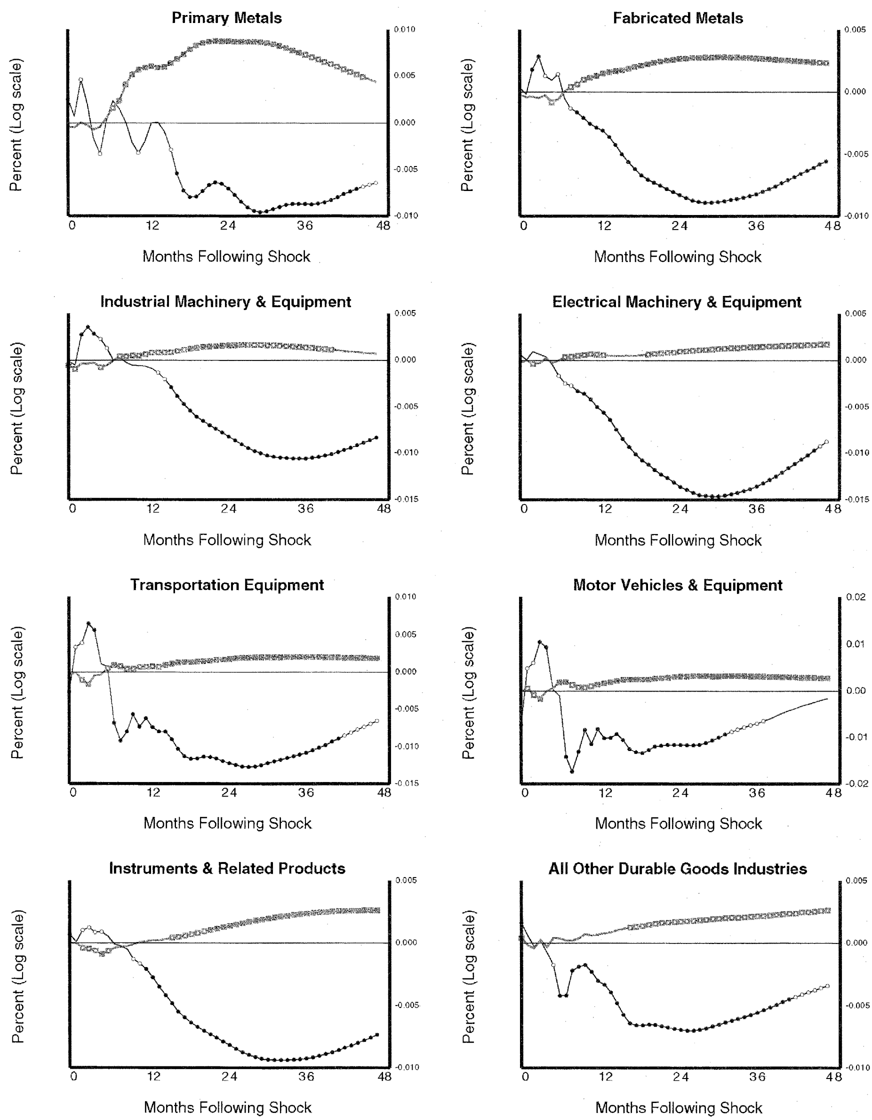
Thin line with circles, output: filled, significant at 10%; open, significant at 25%. Thick line with boxes, price/wage: filled, significant at 10%; open, significant at 25%.

Figure 5 CONTINUED



(b)

Figure 5 CONTINUED



(c)

price effect. For total manufacturing and for 15 of the individual industries, the price effects are significant at the 10% level. In contrast, only lumber and leather and 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 rising 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.

4.3 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 effect of monetary policy on aggregate variables.

As has been discussed by many observers (e.g., Friedman, 1986), the financial structure of the United States 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. Romer and Romer (1993) use a narrative approach 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 nonprice rationing led to particularly acute credit crunches, which could have led to severe limitations in working capital.

Finally, the switch from fixed to floating exchange rates during the 1970s may also explain the weakening of the cost channel. With floating exchange rates, a monetary contraction causes the exchange rate to appreciate, making imported materials cheaper. Thus, any direct cost-side effects of a monetary contraction may have been counter balanced by the exchange-rate effect in the floating-rate period. Thus, well-documented differences in financial markets, foreign-exchange 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 and 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 subperiod, we might expect that the effects of monetary policy on output would be greater in magnitude and last longer in the earlier period.

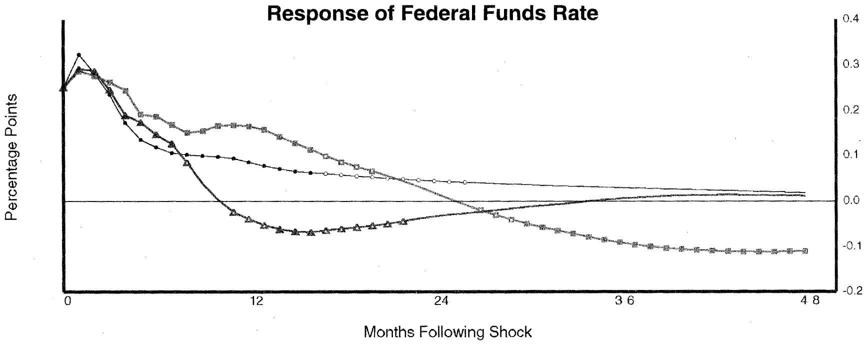
To test this hypothesis, we estimate the basic macro part of the model for the two subperiods [that is, system (3) minus the last two equations]. Because we wish to compare the magnitudes of the response of output to a given shock to monetary policy, we set the innovation for both periods equal to 25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

Figure 6 shows the responses of the FFR, industrial production, and the aggregate price level to a 25-basis-point federal-funds shock for the model estimated over each of the two subsamples (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 FFR, in Figure 6a. The peak responses of the early and the later period are very similar, but their duration is very different. The funds rate takes almost 2 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.

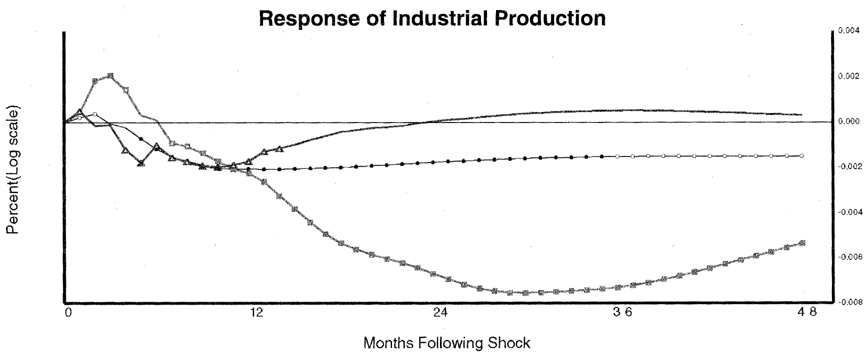
Consider now the impulse responses of output, in Figure 6b. Comparison of the figures shows that the trough of output is almost 4 times as deep during the early period as during the later period. Moreover, the duration of the effect on output appears to be much longer during the early period. The trough occurs more than 2 years after the initial shock during the early period, but less than 1 year after the initial shock during the later period. Furthermore, during the early period output is still well below its previous level even 4 years after the shock. During the later period, output rebounds within 2 years of the shock to the FFR. Thus,

12. The standard deviation of the innovation to the FFR 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.

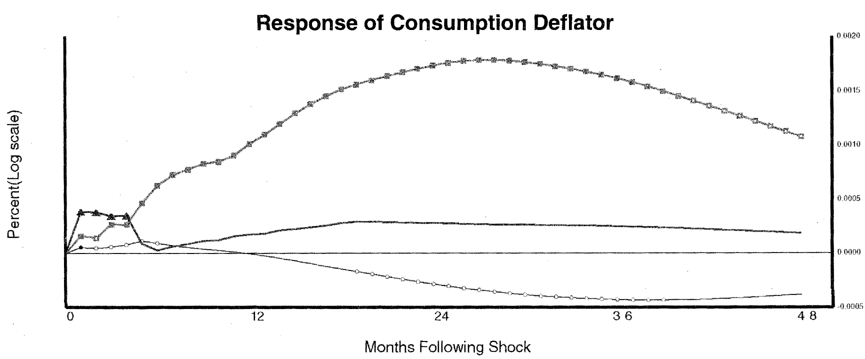
Figure 6 AGGREGATE RESPONSES TO A 25-BASIS-POINT FEDERAL-FUNDS-RATE SHOCK, ACROSS DATA SAMPLES



(a)



(b)



(c)

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%.

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 FFR 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 2 years before beginning to fall. By contrast, during the later sample period, prices are mostly unresponsive after a brief positive spike in the first 5 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's (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 none of these eliminate the price puzzle.

We also explored several alternative specifications of the Federal Reserve's reaction function in search of one that might dissipate the price puzzle in the early sample period.[14] The price-puzzle finding was robust to almost all specifications we tried. The only specification we could find that significantly reduced the price puzzle in the early period was one that satisfied *all* of the following criterion: (1) it included M1 or M2; (2) it included commodity prices in the Federal Reserve's reaction function; (3) it excluded any measure of oil prices, be it dummy variables or a price index; and (4) it used a lag length of 12 or greater. In this specification, the magnitude of the price-level rise was greatly reduced and was no longer statistically different from zero. We felt, however, that this specification did not make economic sense, because it assumed that the Federal Reserve monitored only general commodity prices without observing oil prices specifically. It is also worth noting that even under this anomalous specification, price-to-wage ratios still rise at the industry level.

We believe that, in combination with Hanson's work, this 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 vari-

13. The rise in prices during this period is significant at the 10% level for more than 3 years following the FFR shock.
14. We undertook this exploration at the urging of Christopher Sims.

ables (like the FFR). 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.

4.4 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 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* (QFR) suggests that the rise in the relative prices of these industries may be directly related to financing costs. The QFR 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 subsample 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

Table 2 INDUSTRY *P/W* RESPONSE CORRELATION WITH INTEREST EXPENSE

Sample	*Int. expense quarter*	*Correlation*	
		Peak response	*Integral*
Early	1974:1	0.529	0.519
Late	1990:4	0.434	0.395

presumably stressful periods of financing for manufactures, since the FFR was still high and sales had begun to decline in each industry. The cross-sectional snapshot for the earlier sample period is first quarter 1974, and for the later one, fourth quarter 1990.

Table 2 presents the correlation between the two summary measures of the price–wage response and interest expense as a fraction 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.[15] Thus, there appears to be a strong link between the response of industry prices and a key balance-sheet variable.

5. *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*

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

markups, has been the subject of intense research in recent years by several authors. We discuss each of these possible explanations.

5.1 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 will fall relative to prices.

We consider this explanation to be implausible. Christiano, Eichenbaum, and Evans (1997) show that the 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 found direct evidence that this type of model cannot explain our results. We investigated the separate responses of nominal prices and wages by industry for the period 1959 to 1979, which had the strongest rises in the price-to-wage ratio.[16] We found 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.

5.2 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 FFR because it is forecasting future inflation that is not anticipated by a parsimonious VAR, then the incorrectly specified reaction function will make it look as if shocks to the funds rate raised prices. It may be that industrial production, consumer prices, and commodity prices are not sufficient to capture all of the information used by 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.

16. The graphs showing these results are omitted for space reasons. They are available upon request from the authors.

Romer and Romer (2000) have compiled a series of past forecasts from the Green Books 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 FFR 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 FFR:

$$\mathrm{FFR}_t = \sum_{i=0}^{1} \left(\alpha_i \,\mathrm{GB}\, \Delta Y_t^{t+i} + \beta_i \,\mathrm{GB}\, \Delta P_t^{t+i}\right) + f_5' \,\mathrm{SD}_t + \sum_{j=0}^{12} g_{5,j}' \mathrm{HP}_{t-j} + \sum_{k=1}^{7} a_{5,k} Y_{t-k} + \epsilon_{5,t}, \tag{4}$$

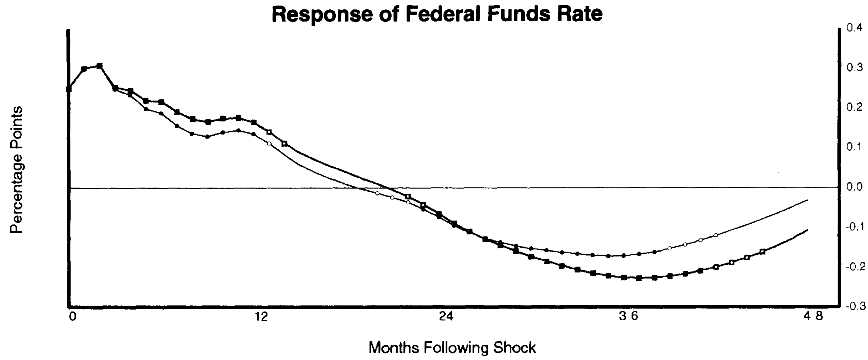
where GB ΔY_t^{t+i} + is the Fed Green Book Forecast for output growth for quarter $t + i$ made in month t, and similarly, GB ΔP_t^{t+i} is the forecast of inflation.

Figure 7 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 FFR. Thus, it seems unlikely to us that our results could be explained by a misspecified reaction function.

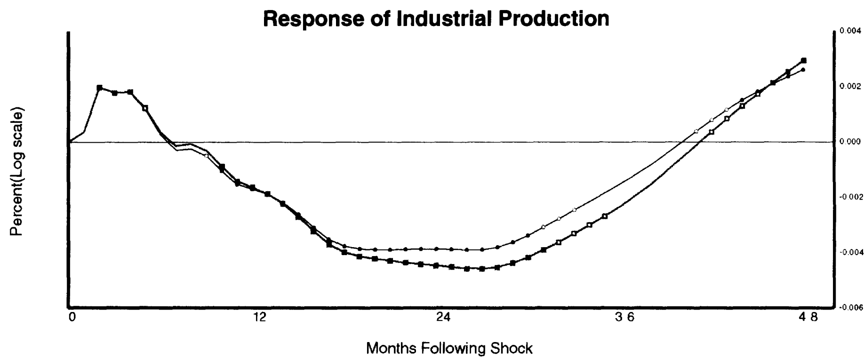
5.3 COUNTERCYCLICAL MARKUPS

Countercyclical markups have been offered as a possible factor in cyclical fluctuations in recent years by Rotemberg and Woodford (1991, 1992) and Chevalier and 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

Figure 7 AGGREGATE RESPONSES TO A 25-BASIS-POINT FEDERAL FUNDS RATE SHOCK, USING GREEN BOOK FORECASTS



(a)



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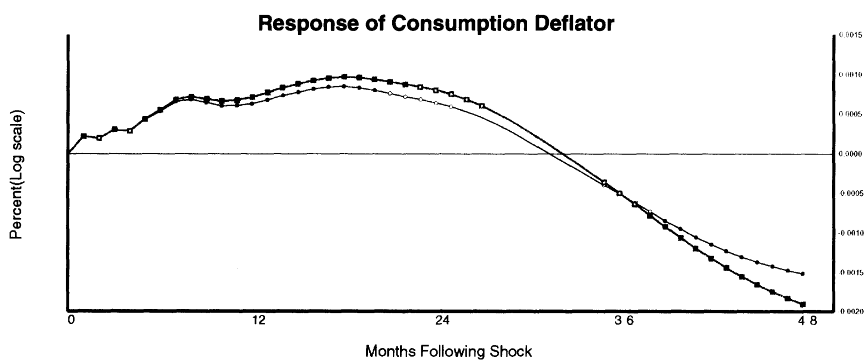

(c)

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, Green book specification: filled, significant at 10%; open, significant at 25%.

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 and 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 and Shapiro (1998), also confirmed in Section 2 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 and 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 and Scharfstein find that leveraged firms do indeed lower their nominal prices less (or raise them more) during recessions than do 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.

6. *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

Almost all data used in this paper come from one of the following sources: the Bureau of Economic Analysis (BEA) at the Department of Commerce; the Bureau of Labor Statistics (BLS) at the Department of Labor; the 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; the 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 and Perez (1994) and are supplemented by this paper's authors with 1998:12 (see footnote 9); Romer dates (quarterly, 1947;4, 1955:3, 1968:4, 1974:2, 1978:3, 1979:4, 1988:4), which come from Romer and Romer (1994); and Ramey–Shapiro dates (quarterly, 1950:3, 1965:1, 1980:1) which come from Ramey and Shapiro (1998).

SECTION 2

Figure 1 productivity: *index of output per hour in business*, BLS; private hours: *index of total hours in business*, BLS; real wages: *nominal hourly compensation in business* divided by *deflator for private business*, BLS; price level: *deflator for private business*, BLS; money: *M2*, FRB; *federal funds rate*, FRB. All data are quarterly series and in logarithms, except the FFR, which is the quarterly average level.

Figure 2a *defense purchases of aircraft and equipment, billions 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 2b output: *GDP in chained 1996 dollars,* BEA; real wages: *nominal hourly compensation in business* divided by *deflator for private business,* BLS; both quarterly logarithms. Romer dates and Ramey–Shapiro dates are given above.

SECTION 3

Figure 3 The first five variables in the VAR are the same as those for Figures 4–6, described below. The hours variable is defined as the log of the product of average weekly hours and the number of production workers, BLS. Inventories are the log of chain-weighted manufacturing inventories by stage of processing from the BEA. The ratios are created by taking the difference between the log of inventories and the log of hours.

SECTION 4

Figures 4–6 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 nondurable manufacturing, FRB; prices: for total, durable, and nondurable 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 FFR, 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 and 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 interquarter volatility, we smoothed the data using a Hodrick–Prescott filter before taking cross-sectional correlations.

Figure 7 Macroeconomic variables as above. Green Book data on Federal Reserve Board staff forecasts for coming inflation and output growth were kindly supplied from David and 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.

CALCULATION OF STANDARD ERROR BANDS FOR IMPULSE RESPONSE FUNCTIONS:

In all figures significance levels refer to one-tailed hypothesis tests.

Figure 1 The model with long-run restrictions was estimated via Generalized Method of Moments (GMM), using the IV method suggested by Shapiro and Watson. To calculate standard error bands, we used the estimated mean and variance–covariance matrix of coefficients to generate 500 draws from a normal distribution with the same mean and variance–covariance matrix. We then computed impulse response functions from each of those draws. For each horizon, we sorted the responses and chose the ones corresponding to the percentage bands given in the figure.

Figures 2–7 VARs were estimated using ordinary least squares (OLS). We calculated confidence bands for the impulse responses using Kilian's (1998) bootstrap-after-bootstrap bias correction method. Using the OLS-estimated errors and coefficient matrix, we created 1000 bootstrapped realizations of the endogenous time-series data, with which we re-estimated the coefficient matrix for each realization. We then used the bootstrapped coefficient matrices to estimate and correct the asymptotic bias of the OLS coefficient matrix. The bias-adjusted coefficient matrix was then used to create 1000 bootstrapped estimates of the impulse response functions to approximate their asymptotic distribution. For each iteration of both bootstraps, the initial conditions were assumed to be those of the original regression.

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Comment[1]

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1. *Introduction*

The cost channel presented by Barth and Ramey is a potentially important component of the monetary transmission mechanism. Casual evidence of this phenomenon often appears in economic discussions between central bankers and the public. For example, Federal Reserve staff regularly collect anecdotal survey information about regional and national economic developments from businesses. During a time of rising short-term interest rates, it is not unusual to hear about rising inventory costs and the increasing likelihood that these higher costs will be passed along to consumers in the form of higher prices. If these high short-term interest rates reflect an attempt to fight inflationary pressures through contractionary monetary policy, these anecdotes suggest that more inflation will be forthcoming, not less. This is the essence of the Wright Patman effect described by Barth and Ramey. Of course, the significance of anecdotes alone is usually unclear. Consequently, Barth and Ramey's empirical analysis of this issue provides useful evidence on the importance of the cost channel for the U.S. economy.

This is an ambitious and useful paper. Barth and Ramey use a variety of identification restrictions to identify technology, aggregate-demand, and monetary-policy shocks. They find that monetary policy shocks induce economic responses that are more like the responses following technology shocks than like those following demand shocks. They interpret the aggregate and industry results as providing support for a cost channel in the monetary transmission mechanism. Their paper is ambitious in trying to identify the effects of this important economic mecha-

1. This paper represents the views of the author and should not be interpreted as reflecting the views of the Federal Reserve Bank of Chicago or the Federal Reserve System.

nism without an explicit dynamic general equilibrium model. It is very useful to understand how far the evidence can be pushed to argue for the role of a cost channel over other channels.

Although I think the cost channel is probably important, my comments focus primarily on the potential contributions of other endogenous mechanisms for explaining the estimated impulse responses. In particular, Barth and Ramey do not spend much time discussing the role of systematic monetary policy or variations in factor utilization. When these features are considered, their empirical results are sometimes more favorable to the cost-channel explanation and other times less favorable. In the absence of a dynamic economic model, it is difficult to quantify each channel's contribution.

2. *Sources of Propagation and Multiple Shocks*

In dynamic general equilibrium models, exogenous impulses can generate persistent responses in endogenous variables through a variety of propagation and amplification mechanisms. Uniquely identifying the economic mechanisms from a small number of first and second moments of the data is challenging. For example, Sargent (1978) presents a dynamic equilibrium analysis of the labor market in which fluctuations are driven by exogenous impulses to productivity and real wages. There are three sources of propagation in the model: persistence in the exogenous wage process, persistence in the exogenous productivity processes, and costs of adjusting labor hours. Although the model is formally econometrically identified, Sargent displays two sets of parameter estimates which have approximately the same likelihood owing to the finite sample length. The economic differences between these parameter estimates center on the sources of propagation. In one case, persistence comes chiefly from the productivity shocks. In the other, persistence is due mainly to more costly adjustment in labor hours. In the context of Sargent's model, the real-wage and labor-hours data alone do not provide convincing information on the sources of propagation.

A more recent example of this identification problem comes from research by Galí (1999), Basu, Fernald, and Kimball (1998), Dotsey (1999), and Francis and Ramey (2001). Galí (1999) and Basu, Fernald, and Kimball (1998) have found empirically that a positive technology shock leads to a muted response of output initially and a fall in employment. If firms have predetermined prices and are committed to satisfying demand at those prices, then an exogenous increase in productivity will not lead to an increase in output unless demand increases at the predetermined price. This result depends on the way in which monetary policy systematically responds to the state of the economy. If an exogenous money growth rule is assumed, then aggregate demand will not systematically increase following a positive productivity shock. Within the framework of Galí's model, however, Dotsey (1999) demonstrates that empirically plausible Taylor rules (estimated in Clarida, Galí, and Gertler, 2000) lead the monetary authority to reduce short-term interest rates in this situation. The Taylor rule's endogenous response to the state of the economy stimulates aggregate demand enough so that output and employment rise. Dotsey's result highlights the importance of realistically capturing the systematic component of monetary policy in dynamic economies. Conditional on the validity of Galí, Basu, Fernald, and Kimball's empirical facts and of Clarida, Galí, and Gertler's Taylor-rule estimates, Galí's model with sticky prices is incomplete.

In a very different dynamic general equilibrium model, Francis and Ramey (2001) show that a flexible-price economy with habit persistence in consumption preferences and costs of adjusting investment can generate essentially no initial response of aggregate demand following a technology shock. With aggregate demand and output effectively predetermined relative to technology shocks, this leads to a fall in employment following a positive technology shock. With no nominal rigidities in the model, the specification of the monetary policy rule is not necessary to determine real allocations. Francis and Ramey's analysis highlights two alternative propagation mechanisms in order to match the empirical facts. Clearly, more information from additional data sources is required to sort these issues out.

Barth and Ramey's empirical investigation of multiple economic shocks generates two types of information that are not available from a single-shock analysis and that may discriminate among different explanations. The first type of new information is the key insight of their analysis. If different economic shocks have *similar* effects on a subset of macroeconomic data, the similarities can imply that a common economic mechanism is responsible. Barth and Ramey focus on the empirical responses of macroeconomic data following three identified shocks: technology, aggregate demand, and monetary policy. Their Figure 1 shows that contractionary monetary policy and technology shocks separately lead to reductions in productivity. Identified contractionary aggregate-demand shocks increase productivity. The similarity between technology and monetary policy shock responses leads to a theoretical discussion of the importance of a supply channel—namely, working-capital costs—in the monetary transmission mechanism.

The second type of new information is more subtle and difficult to disentangle qualitatively. If different economic shocks have *different* effects on a subset of macroeconomic data, the differences may imply that a common economic mechanism is at work in each case. For example, assume the cost channel is important. Barth and Ramey and Christiano, Eichenbaum, and Evans (1997) capture this by assuming firms must finance their wage bill by borrowing working capital. This feature of the economy is active following all realizations of the economic shocks. Barth and Ramey's Figure 1 shows that contractionary demand shocks lead to higher real wages, while contractionary technology and monetary policy shocks lead to lower real wages. If interest rates respond endogenously to the contractionary demand shock, the cost channel may be responsible for the magnitude of the real-wage response, which can be either larger or smaller depending on the direction of the interest-rate response. I discuss this in a more specific context below. From the perspective of a qualitative analysis, different signs in these responses are probably easiest to interpret. But different magnitudes of responses can be enough to identify alternative propagation and amplification mechanisms in the context of a tightly parametrized theoretical analysis.

3. *Systematic Monetary-Policy Responses*

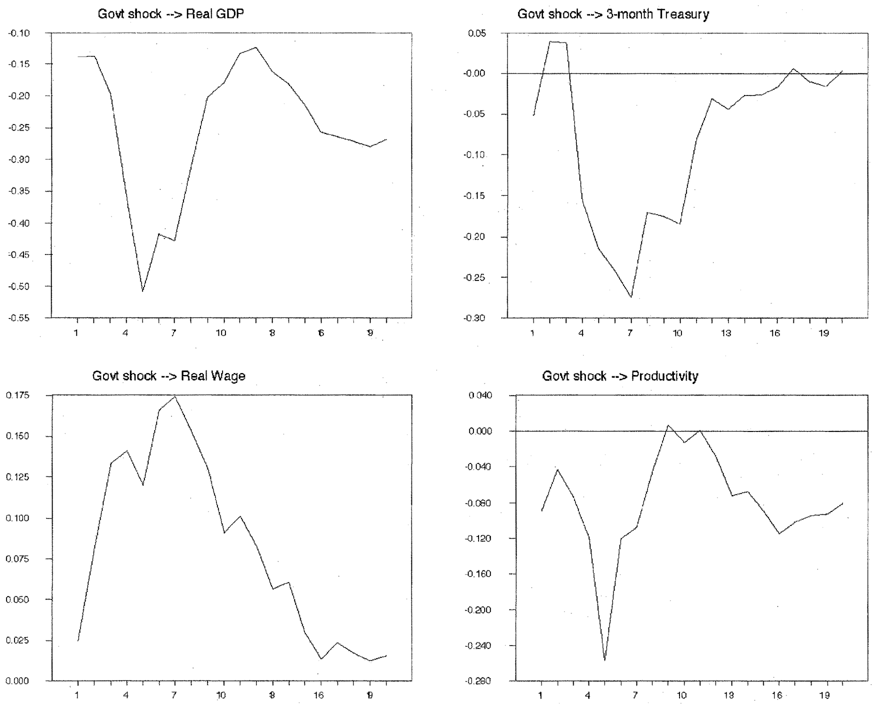
There is much recent evidence on the systematic response of monetary policy to the state of the economy (e.g., Taylor, 1993; Clarida, Galí, and Gertler, 2000; Christiano, Eichenbaum, and Evans, 1999). Barth and Ramey's VAR impulse response functions seem to be quite consistent with the evidence that U.S. monetary-policy actions are well approximated by Taylor rules. This is not at all surprising. A forward-looking Taylor rule without interest-rate smoothing can have the following form:

$$FF_t = \mu + \alpha E\,[y_t - y_t^* \mid \Omega_t] + \gamma E\,[p_{t+s} - p_t - \pi_t^* \mid \Omega_t] + \epsilon_t,$$

where FF is the federal funds rate, $y_t - y_t^*$ is an output gap, $p_{t+s} - p_t - \pi_t^*$ is an s-period-ahead inflation gap, and Ω_t is the Fed's information set for forming conditional expectations of future variables, as well as possibly latent variables like an output gap. In implementing these rules, policymakers must evaluate these expectations. The resulting policy reaction function is a dynamic feedback rule which has the same form as an interest-rate equation in a VAR. Allowing for interest-rate smoothing enhances the similarities further.

In these reaction functions, policy responds systematically to all economic shocks. Focusing on the contractionary aggregate demand shock in Figure 1, output falls while future inflation is essentially unchanged for about two years. The significant fall in the federal funds rate captures

Figure 1 IMPULSE RESPONSES FOLLOWING A RAMEY–SHAPIRO SHOCK



a Taylor-like response to a negative output gap. The subsequent modest rise in inflation is consistent with the expansionary monetary policy. So there appears to be a substantial systematic response of monetary policy following the identified aggregate-demand shock in Barth and Ramey's Figure 1. Given the inherent uncertainty in defining and identifying a shock as aggregate-demand, Barth and Ramey investigate additional sources of exogenous variation in aggregate demand using Ramey–Shapiro government shocks. Their Figure 2b does not display the interest-rate response. I estimated similar response functions for real GDP, real wages, 3-month Treasury bill rates, and labor productivity following a contractionary Ramey–Shapiro shock. Each equation included eight lags of all four endogenous variables plus the contemporaneous value and eight lags of the Ramey–Shapiro shocks. The sample period is 1949–2000, and Figure 1 of this Comment displays the estimated responses. In response to these contractionary demand shocks, the Taylor-rule responses continue to be evident: the fall in short-term nominal interest rates follows the steep reductions in real GDP. Interestingly, productivity falls procyclically with output following these military shocks. The demand shock in Barth and Ramey's Figure 1 displayed a countercyclical response of productivity, although the statistical significance was not strong. The differences in sign and magnitudes may be suggesting the role of other endogenous propagation mechanisms that lead to procyclical productivity (or less countercyclical responses). The recent literature has assigned an important role to labor hoarding and variations in factor utilization (e.g., Burnside and Eichenbaum, 1996, and Braun and Evans, 1998).

In order to find an important role for the cost channel of monetary transmission, it is important to allow for the influences of endogenous monetary policy and the endogenous responses of private agents. Barth and Ramey's theoretical discussion provides a simple framework for thinking about these issues.

4. *Theoretical Discussion*

The thrust of Barth and Ramey's economic analysis is that contractionary monetary-policy shocks induce economic responses that look more like contractionary technology responses than like contractionary demand responses. The basic insights can be understood from a textbook discussion of a competitive spot labor market. Production depends upon capital K, labor N, and an exogenous technology variable z. We have $Y = zF(K, N)$ with F possessing the usual diminishing marginal products. Labor is elastically supplied and increasing in the real wage. A contractionary technology shock increases marginal costs directly by lowering the marginal productivities of labor and capital. The demand for labor falls at all real wages. With z lower, labor productivity and the real wage fall. To consider what happens following a contractionary aggregate-demand shock requires a bit more definition. If we equate this shock with an exogenous fall in unproductive government purchases, then a contraction represents a reduction in current or future taxes. This positive wealth effect leads to a reduction in labor supply at all wage rates. Since the production technology F is unaffected, real wages and labor productivity rise.

In arguing that monetary-policy shocks induce economic responses that look like technology shocks, some thought must be given to the source of nominal non-neutralities. Three candidate rigidities are (a) sticky prices, (b) sticky wages, and (c) limited participation with a working-capital channel.

(a) when prices are predetermined, output is determined by aggregate demand and an unanticipated monetary contraction reduces aggregate demand. Firms' reduced labor requirements can be filled at lower real wages (dictated by the labor-supply schedule). Real wages fall, but labor productivity rises due to the diminishing marginal product of labor. Christiano, Eichenbaum, and Evans (1997) provide a quantitative analysis of these effects.

(b) When nominal wages are predetermined, an unanticipated monetary contraction reduces the price level and increases real wages. The resulting fall in labor input again leads to a rise in labor productivity. See Bordo, Erceg, and Evans (2000) for a quantitative analysis of these effects.

(c) In a limited-participation model with a cost channel, an unanticipated monetary contraction increases nominal interest rates. The higher interest costs of financing the wage bill lead to a fall in labor demand at all wage rates. This leads to a fall in the labor input and real wages, and an increase in labor productivity. In this model, real wages fall but productivity rises. Christiano, Eichenbaum, and Evans (1997) provide a quantitative analysis of these effects.

Table 1 of this comment qualitatively summarizes the theoretical implications of these shocks. The key differences among the shock implications are the responses of real wages and labor productivity. The limited-participation analysis embodies the cost-channel mechanism stressed by Barth and Ramey. As the paper discusses and my earlier discussion of propagation mechanisms emphasized, however, we must keep in mind that the simple textbook discussions omit many model features that the literature has stressed.

5. *Interpreting the Empirical Results*

Table 2 summarizes the qualitative findings of the estimated impulse responses following the identified technology, demand, and monetary pol-

Table 1 THEORETICAL IMPLICATIONS OF CONTRACTIONARY SHOCKS

	Y	N	W/P	Y/N
Technology	↓	↓	↓	↓
Demand	↓	↓	↑	↑
Monetary policy:				
Sticky prices	↓	↓	↓	↑
Sticky wages	↓	↓	↑	↑
Limited participation	↓	↓	↓	↑

Table 2 ESTIMATED RESPONSES FOLLOWING CONTRACTIONARY SHOCKS

	$\hat{Y}$	$\hat{N}$	$\hat{W}/P$	$\hat{Y}/N$	$\hat{R}$
Technology	↓	↓	↓	↓	↑
Demand	↓	↓	↑	?	↓
Federal funds	↓	↓	↓	↓	↑

icy shocks. In the aggregate analysis, as Barth and Ramey emphasize, the federal funds rate and technology shocks have similar responses. To conclude that the cost channel is an important component of the monetary transmission mechanism, we should also consider (1) the way in which systematic monetary policy influences the economy, and (2) whether other important endogenous mechanisms are missing from the analysis.

In the first case, Barth and Ramey view the rise in the real wage following a contractionary demand shock as indicating the absence of a cost channel. Such a broad-brush dichotomy of demand and supply mechanisms tries to abstract from the complexities of how the cost channel works after various demand shocks. In fact, the role of systematic monetary policy may very well lead to larger increases in real wages following a demand contraction. As I mentioned above, the demand contraction may initially reduce labor supply, output, and labor input, leading to a rise in real wages. A Taylor-rule response of monetary policy may very well lead to a monetary expansion and lower interest rates. In this context, the cost channel stimulates labor demand at all wage rates due to more favorable financing conditions, and *real wages rise further.* Thus, a relatively large increase in real wages may signal an especially large role for the cost channel. Or, put another way, the fact that certain aggregate-demand shocks lead to different real wage implications than technology shocks may signal a large role for the cost channel.

In the second case, the negative response of labor productivity following a monetary policy contraction deserves additional investigation. In light of the diminishing returns to labor, this procyclical response indicates that something has been omitted from the theoretical discussion. There is a large literature that emphasizes the role of variable factor utilization at business and seasonal cycle frequencies (for example, Burnside and Eichenbaum, 1996; Braun and Evans, 1998). Following a monetary contraction, the presence of variable factor utilization would likely reduce the marginal productivity of labor at all wage rates. In equilibrium, real wages and labor productivity would fall. It is important to note that this story does not need to invoke the cost channel in order to account for the responses in the data. Consequently, variable factor utilization is a competing explanation. The industry evidence in Barth and Ramey's Table 1 and Figures 4 and 5 is capable of shedding further light on these competing explanations. The larger responses of *P/W* in selected industries during the 1959–1979 period could be due to a greater dependence on limited working-capital technologies or greater variations in factor utilization rates. The analysis of QFR data begins to get at one side of this issue, but much more should be possible.

Does the factor-utilization story square with the aggregate-demand responses? Here the evidence is mixed. Recall that following a contractionary aggregate demand shock, labor supply falls. A fall in labor input and output should reduce endogenous utilization rates. This reduces labor demand at all wage rates, and intensifies the reductions in output and labor. The qualitative predictions for real wages and labor productivity, however, are ambiguous. The empirical results from the identified VAR shocks and Ramey–Shapiro shocks indicate that real wages rise, but the productivity response may not be robust (comparing their Figure 1 and my Figure 1). Barth and Ramey discount the variable-factor-utilization story in favor of an omitted factor of production such as working capital. A quantitative, dynamic general-equilibrium analysis seems necessary to shed further light here. It is not obvious how an important endogenous mechanism plays a strong role for some shocks, but is presumably rendered mute following other shocks. Stark differences like these have the potential to provide strong identifying power in constructing models of the economy.

Finally, Christiano, Eichenbaum, and Evans (2001) present a model in which variable capacity utilization, the cost channel, and other endogenous propagation mechanisms combine to produce a Wright Patman effect following a monetary policy shock. In a dynamic general equilibrium model with Calvo price and wage contracts, we introduce habit persistence in consumption preferences, investment adjustment costs, variable capacity utilization, and a cost channel. There are large literatures arguing that each of these features is important for understanding aggregate fluctuations. Including all of these endogenous mechanisms allows the model to capture the hump-shaped responses of output, consumption, investment, and productivity following a monetary policy shock. Introducing additional shocks in a model like this may allow for a fuller assessment of each mechanism's contribution to economic fluctuations.

To conclude, Barth and Ramey's analysis of alternative economic shocks in a variety of settings is an important ingredient in the research program to find useful dynamic general equilibrium models for evaluating alternative economic policies. Empirical analyses like this flesh out the broad features of the data which all useful models should capture.

While success along limited dimensions of the data's likelihood surface continues to be relatively easy to attain, this paper helps to open the curtain on the larger challenges facing macroeconomists.

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Comment

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The authors have written an excellent empirical paper arguing in favor of a cost channel for monetary policy. The paper provides extensive evidence from a variety of data sources and experiments in support of this view. In my comment, I will provide some discussion of what exactly I think the cost channel is. I will then discuss their evidence and identification, and provide some additional discussion of evidence from the inventory literature, some of which is complementary to their findings, some of which is not. Finally, I will ask what can we expect to obtain by adding a cost channel to a calibrated model.

The basic cost channel is easily understood by examining the first-order condition for labor demand in a model where firms borrow to hire labor inputs. In this case we have $R(W/P) = \mathrm{MPL}$, where R is the real interest rate, W/P is the real wage, and MPL is the marginal product of labor. If firms borrow to hire inputs such as labor, then as interest rates rise, labor costs rise and labor demand and real wages fall. Assuming that the marginal product of labor is determined by technology and the capital–labor ratio [e.g. $\mathrm{MPL} = A(K/L)^{\alpha}$], labor productivity will rise in response to a tightening of monetary policy as firms move up their labor demand curve in response to increased hiring costs. In contrast, real wages will fall. The implication here is that although real wages move in opposite directions for monetary policy shocks and for other demand shocks, labor productivity moves in the same direction. The author's evidence suggests, to the contrary, that both real wages and labor productivity fall in response to a tightening of monetary policy.

To explain this result, the authors appeal to the notion that there is another input in the production process, such as working capital or inventories. If firms also borrow to hire this additional factor, demand for this input falls as interest rates rise. If labor productivity is decreasing in this input, one could then rationalize a decline in labor productivity in response to monetary policy shocks but not other demand shocks. In this case, monetary policy shocks will have effects more like supply shocks than like demand shocks. For this to be true, it must be the case that the labor productivity decline owing to the decline in this additional input is large enough to offset the fact that, in the absence of any movements in this other input, labor productivity would rise rather than fall.

This raises the question, what is this additional input? As the authors suggest, a natural candidate is inventories in the production function. The aggregate evidence that inventory–sales ratios are strongly and persistently countercyclical is both good news and bad news here. On the one hand, borrowing for inventories is more plausible than borrowing for labor inputs, though working capital is undoubtedly used to finance some component of labor as well as other input costs. The fact that inventories rise relative to sales during a downturn suggests that borrowing costs do indeed rise in response to tight monetary policy. Additional evidence is provided by the work of Gertler and Gilchrist, who document that short-term debt for large manufacturing firms also rises in response to monetary policy. Thus both inventory input movements and movements in short-term debt in response to monetary policy are consistent with the notion that costs rise as interest rates increase.

These movements are not necessarily consistent with the notion that labor productivity should fall in response to a tightening of monetary policy, however. In particular, because inventory inputs are rising—this is true of all types: final goods, materials, and work in progress—relative to sales following tight monetary policy, we would expect inventories to be a poor candidate for explaining the procyclicality of productivity in response to monetary-policy shocks but not other demand shocks. The authors counter this point by providing evidence that the inventory–hours ratio falls rather than rises in response to monetary-policy shocks, this being true during the early part of the sample period but not the later part, consistent with their argument that the cost channel has diminished over time. While this evidence is intriguing, the movements in the inventory–hours ratio only measure the movement of one input relative to another, and not the direct effect of inventories on labor productivity. We need further work to fully assess whether or not inventories, and working capital more generally, provide an argument for procyclical rather than countercyclical productivity in response to monetary policy shocks. (A step along these lines would be to analyze the dynamics of the inventory–sales ratio in response to monetary vs. other demand shocks.)

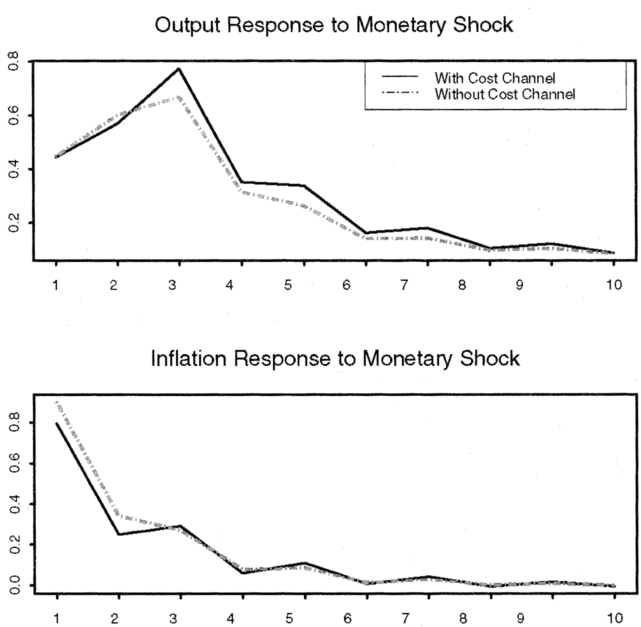
If the labor-productivity movements cannot be rationalized through a cost channel, then we are left with the puzzling result that labor productivity moves in one direction in response to monetary policy shocks and in another direction in response to other demand shocks. One may be tempted to blame this on faulty identification. For example, Romer episodes of tight money are highly correlated with large oil price shocks, confounding supply and demand effects. In addition, military buildups, to the extent that they are more likely to provide anticipated movements in demand than do monetary policy shocks, provide dynamics more like those of a government spending shock in a neoclassical model, even in a setting where prices are sticky and markups are otherwise countercylical. In other words, firms that anticipate demand increases adjust their prices accordingly and are less likely to engage in labor hoarding, which would result in strongly procyclical labor productivity. This seems quite likely to be the case with the aircraft industry example discussed in the paper. Whether or not the military buildups of the Korean and Vietnam wars provide examples of anticipated buildups is more debatable (note it is not the initial increase that needs to be anticipated, but the future spending path). Countering this argument, however, is the fact that the demand shocks in the Gali decomposition are not particularly persistent and hence not likely to be anticipated. Also, the fact that all of the evidence goes in the same direction makes a more persuasive case for the productivity arguments set forth in the paper.

Setting this issue aside, it is possible that the basic cost channel is in place, i.e., monetary policy is transmitted through the supply side as well as the demand side, without their being the additional productivity mechanism discussed above. In this case, the cost channel still serves as an additional source of amplification and propagation to monetary policy shocks, and can help explain the well-known price puzzle. I find both of these arguments plausible. There is ample evidence in the literature that financial factors impinge on both input choices and output, particularly for credit-constrained firms. Increasing marginal costs of borrowing in the downturn are a natural consequence of credit-market frictions. We would therefore expect firms that face severe frictions in credit markets to be most susceptible to a cost channel. Indeed, as the paper discusses, the evidence on small vs. large firms provided by Gertler and Gilchrist is highly consistent with the notion that small firms face rising borrowing costs, which cause a reduction in their output relative to that of large firms in the wake of tight monetary policy. Somewhat surprisingly, the industry decomposition in the paper does not provide strong support for this notion, unless we truly believe that industries such as motor vehicles are likely to face significant credit frictions. On the other hand, the fact that the effect of monetary policy on the wage–price markup is correlated with the amount of interest expense is consistent with a cost channel. The fact that the correlation remains unchanged in both the pre- and the post-1980 period contradicts the notion that the cost channel has declined in importance over time, however.

Finally, it is worth asking under what conditions a cost channel will be a quantitatively important component of the monetary transmission mechanism. Because the cost channel depends on monetary-induced movements in real interest rates, it must be considered in conjunction with other nominal rigidities which give the monetary authority leverage over real as well as nominal interest rates. A basic experiment analyzing the effect of a monetary policy shock in a dynamic New Keynesian model with sticky output prices augmented to include a cost channel suggests to me that the direct effect of the cost channel may not be particularly strong. In this experiment (details are available on request), I assume that aggregate output is produced by two intermediate input sectors of equal size. Both sectors use capital and labor as inputs and face capital adjustment costs. One sector plans labor one period ahead and borrows to pay the wage bill, which is financed over the next year. The other sector hires labor contemporaneously and faces no interest expense in its hiring decision. The monetary authority sets nominal interest rates as a function of past interest rates and current inflation.

The impulse responses to an innovation in monetary policy for output and inflation are plotted in Figure 1. Consistent with the arguments in the paper, the cost channel adds amplification and reduces the inflation response to monetary policy. The amplification is not particularly large, however, relative to the baseline model, and the inflation dynamics are not appreciably altered. In particular, the model does not rationalize the price dynamics seen in the data. The explanation here is quite simple: countercyclical markups owing to sticky prices are still the dominant mechanism by which policy is transmitted, whereas the real effects of interest rates on labor costs are relatively small. It is quite possible that a richer model would provide better results. Adding sticky wages will help match wage–output–inflation dynamics and will come closer to rationalizing the price puzzle. Adding a financial accelerator mechanism will provide more amplification for the cost channel. In particular, coun-

Figure 1 IMPULSE RESPONSE TO A MONETARY SHOCK



tercyclical borrowing for factor inputs implies a worsening of balance sheets during a downturn, which could suppress economic activity.

In this paper, the authors make a strong case that a cost channel is worthy of serious consideration as an important component in the monetary transmission mechanism. Although not all of the evidence is fully rationalized within existing model structures, there is certainly enough evidence here to tempt model builders to incorporate supply as well as demand effects of monetary policy. Whether that can be done in a manner that is consistent with the results in this paper is an interesting topic for future research.

Discussion

In his response, Marvin Barth stressed the point that the paper could explain several empirical puzzles with one simple idea. With respect to the behavior of the inventory–sales ratio, he argued that, at a disaggregated level, the response to a monetary shock is what one would expect to see in response to a cost shock. In particular, inventories of raw materials respond first to the monetary policy shock, then to work in progress; final-goods inventories exhibit a hump shape, reflecting the falloff in final demand. On the VAR identification scheme, it reassured him that the industry-level evidence pointed in the same direction. Ben Bernanke found the evidence on raw-materials inventories quite strong, as it could explain why productivity seemed to fall in response to a monetary shock and could help to distinguish between shocks to demand and money shocks. Barth explained that the authors had not emphasized this evidence, as they did not have disaggregated inventories by stage of process at the industry level.

Chris Sims suggested an alternative explanation for the pattern of impulse responses to monetary policy shocks. He remarked that the VAR literature found a strong correlation between real effects of monetary policy and the price puzzle, which suggested that there was some confounding of technology and monetary policy shocks. He said that with different identification assumptions that allowed for some simultaneity, the price puzzle in the early part of the sample disappeared. He also claimed that putting money into the policy reaction function eliminated the price puzzle. Barth and Ramey replied that they already had money in the policy reaction function, although they had not tried to deal with the simultaneity issue.

Greg Mankiw asked whether monetary policy shocks have permanent effects on hours and output when Romer dates are used to identify the shocks. He wondered whether the permanent effect could be due to hysteresis, or whether instead it was an indication of the confounding of monetary and real shocks.

Philip Lane suggested that if monetary contraction leads to currency appreciation, there could be a cost effect opposite to that examined by the authors, working through the price of imported intermediates. This effect could be tested by examining individual sectors. Valerie Ramey agreed and noted that the cost channel was stronger in the earlier period when exchange rates were fixed.

Daron Acemoglu wanted to know whether sticky prices or sticky wages were necessary to generate the observed pattern of results by industry. He also asked whether the pattern of industry results correlated with specific industry features, such as the ratio of small to large firms, that could bear on the importance of the cost channel. Kristin Forbes suggested using firm-level data to examine the cost channel.

Olivier Blanchard was interested in the correlation of the inverse real-wage response with interest expense. He suggested looking at the response of the inverse real wage to Ramey–Shapiro dates and Romer dates, to get an idea of the heterogeneity of responses to government spending and monetary shocks.

Susanto Basu suggested another explanation for the finding that responses to monetary policy shocks look like responses to productivity shocks. He raised the possibility that innovations in labor supply, such as those driven by low-frequency demographic movements, could be a fourth structural shock missing from the story.

Mark Gertler said that he had simulated models incorporating the cost channel. In these models, the cost channel did a good job of explaining the sluggish response of prices. But price rigidity cannot be the only friction. Otherwise, when interest expense rises, real wages fall and reduce marginal cost. He suggested that the reduced-form responses to shocks could depend on the monetary policy reaction function. A change in the policy reaction function in 1979 could explain the differences in the results between the earlier and later periods.

Ramey commented that the authors do not believe that the cost channel is the only mechanism through which monetary policy shocks have an effect on the economy. But the cost channel is something that might be a useful component in a parsimonious model, and one that is more important than, for example, variable factor utilization.