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## **RESUMO/ABSTRACT**

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This paper presents evidence on the relationship between cyclical shocks and productivity growth, for 20 2-digit SIC US manufacturing industries and a set of monetary policy, fiscal policy, and oil price shocks. The paper uses as a measure of productivity change a Solow residual corrected for a wide range of non-technological effects due to imperfect-competition, non-constant returns to scale, and cyclical utilization rates of capital and labor services. The empirical framework identifies policy shocks independently of productivity measurement issues via a two-step procedure. While the typical industry shows weak responses of productivity to the shocks considered, in some industries temporary contractionary policy shocks lead to increases in productivity. In addition, the results reveal that there are localized asymmetries, with contractionary policy shocks having larger productivity effects than their expansionary counterparts. The results support the thesis that job reallocation is an important channel linking contractionary policy shocks and productivity growth. These results support the pit-stop view of downturns.

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# Demand Shocks and Productivity Growth

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## Abstract

This paper presents evidence on the relationship between cyclical shocks and productivity growth, for 20 2-digit SIC US manufacturing industries and a set of monetary policy, fiscal policy, and oil price shocks. The paper uses as a measure of productivity change a Solow residual corrected for a wide range of non-technological effects due to imperfect-competition, non-constant returns to scale, and cyclical utilization rates of capital and labor services. The empirical framework identifies policy shocks independently of productivity measurement issues via a two-step procedure. While the typical industry shows weak responses of productivity to the shocks considered, in some industries temporary contractionary policy shocks lead to increases in productivity. In addition, the results reveal that there are localized asymmetries, with contractionary policy shocks having larger productivity effects than their expansionary counterparts. The results support the thesis that job reallocation is an important channel linking contractionary policy shocks and productivity growth. These results support the *pit-stop* view of downturns.

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# 1 Introduction

Macroeconomic theory has traditionally neglected the effects of cycles on productivity growth. Recently, however, several papers in the endogenous growth literature have challenged this stance and have proposed theories on the effects of cycles on productivity growth. To date, the empirical evidence is mixed and on balance inconclusive (Aghion and Howitt (1998, Ch. 8)). A characterization of the literature on cycles and productivity growth as ‘some stories, no facts’, while somewhat harsh, is on the mark. These developments, combined with recent advances in the measurement of productivity, provide the impetus for renewed interest in empirical work on the relationship between cycles and productivity growth. This paper studies the productivity effects of a set of cyclical shocks for 20 2-digit SIC US manufacturing industries, from 1972:2 to 1992:4. The paper focuses on the arguments recently formalized by Aghion and Saint-Paul (1998).

Aghion and Saint-Paul (1998) argue that some productivity improving activities are disruptive, in the sense that firms must sacrifice some output and profits to implement them. Hence, during temporary demand downturns the opportunity cost of investing in such disruptive productivity improving activities is lower and firms invest more in these activities, which results in productivity growth. As a corollary of this reasoning, we follow the literature and use the label "Opportunity Cost View" of recessions henceforth. Examples of such activities may include job reallocation, managerial reorganizations, experimentation with new technologies, and training.

Some authors, namely Gali and Hammour (1992) and Saint-Paul (1993), have found empirical evidence that supports such view of recessions. Gali and Hammour and Saint-Paul study the productivity effects of demand shocks by means of bivariate VARs, with productivity change measured by the Solow residual and a cycle indicator, typically an employment rate. They identify demand shocks as those shocks with no within-period effect on productivity. Gali and Hammour use quarterly and annual data for the US manufacturing sector, while Saint-Paul uses aggregate annual data for a sample of OECD countries. Both studies find that a negative demand shock leads to an increase in productivity. However, these pieces of evidence suffer from important shortcomings that stem from measurement of productivity, identification of the demand shocks, and interpretation issues of the competing stories relating cycles and productivity growth.

On the measurement issues, studies like Basu et al. (1999) demonstrated that the Solow residual is contaminated by non-technological effects, which render it a polluted measure of productivity growth. In addition, these non-technological effects are highly correlated, both contemporaneously and dynamically, with shocks to activity, and hence must be controlled for in studies of the relationship between cyclical demand shocks and productivity growth. On the identification issues,

the identifying restriction that it takes at least one period for the productivity improving activities to have a noticeable impact on productivity is certainly ad-hoc and less defensible for annual data than for quarterly data. More to the point, even if demand shocks have no within-period effect on true productivity, they may have on the Solow residual.

This paper tackles these issues head on. First, it uses as measures of productivity change Solow residuals corrected for all non-technological effects believed to be of empirical importance and investigates the robustness of the results for many alternative specifications of productivity change. Second, the identification of demand shocks is achieved independently of the measurement of productivity. In addition, the demand shocks identified have concrete structural interpretations: they are monetary policy and fiscal policy shocks. To achieve identification of monetary policy shocks, the paper borrows from Christiano, Eichenbaum and Evans (2000) and Romer and Romer (1997), and of fiscal policy shocks from Rotemberg and Woodford (1992) and Perotti and Blanchard (2002).

There are at least three reasons to focus on these shocks. First, for the Opportunity Cost View to be effective, the downturn in the demand that firms face has to be transitory since if permanent then both the costs and benefits of the productivity improving activities change in an equal manner, leaving the optimal investment decision in these activities unchanged. Moreover, what matters is whether firms perceive the downturn to be transitory or permanent. If firms correctly identify the cause of the downturn as temporary and common to the entire economy, they may want to engage in productivity improving activities to take advantage of the temporary slack before the economy picks up again. This motivates us to use economy-wide shocks, such as policy shocks, and avoid sectoral specific shocks, such as to relative prices, since it is more reasonable to argue that firms expect the former to be temporary while the latter may be specific and permanent. Second, by studying different demand shocks we can analyze the responses of the real interest rate and of job reallocation to the different shocks, which according to the Opportunity Cost View, as argued below, have a role in the relationship between cyclical demand shocks and productivity change. Third, it may be of independent interest to analyze the productivity effects of monetary policy and fiscal policy shocks at the sectoral level. In this sense, this paper also provides further insight into whether monetary and fiscal policy shocks have lasting real, productivity effects.

On the interpretation issues, whereas the Opportunity Cost View predicts that temporary contractionary shocks may have positive productivity effects, learning-by-doing (Stadler (1990)) and capital market imperfections (Stiglitz (1993)) theories predict the opposite, which complicates matters, since, ideally, empirical tests of the Opportunity Cost View ought to reveal its absolute empirical relevance in addition to its relative empirical relevance vis à vis the competing theories.

This point motivates the design of thorough and direct tests of the Opportunity Cost View. The paper attempts to do this by looking at the roles of the real interest rate and of job reallocation, and the distinct productivity effects of shocks to demand and to supply conditions. In a companion paper (Menezes (2004)), we extend the Aghion and Saint-Paul (1998) model and show that: (1) supply shocks have no effects on productivity growth; and (2) transitory demand downturns have positive effects only if the real interest rate is not too countercyclical. The first result owes to the fact that supply shocks matter essentially to intra-temporal decisions, and not to inter-temporal decisions, such as the decision to invest in productivity improving activities. The second result holds because if the real interest rate increases enough during transitory demand downturns, then all investment activities decrease, regardless of their temporarily low opportunity cost. These extensions are meaningful since they guide our empirical strategy, as discussed below.

The result that supply shocks have no effects on productivity growth implies that we must separate demand shocks from supply shocks, which, incidentally, we are not guaranteed to obtain from simple VAR identification strategies, as pursued in Gali and Hammour and in Saint-Paul. Also note that this result is in contrast to the competing theories which are silent with respect to the demand vs. supply nature of the shocks. For this purpose, the paper uses as a measure of supply shocks oil price shocks, following Hamilton (1985) and Davis and Haltiwanger (1999).

The second result, that the cyclical nature of the real interest rate has a first-order effect on the main implications of the Opportunity Cost View, motivates us to look at the joint behavior of different demand shocks and of the real interest rate, because the Opportunity Cost View unambiguously predicts that productivity growth is stronger after transitory demand downturns associated with decreases in the real interest rate than after transitory demand downturns associated with increases in the real interest rate. We pursue this line of investigation by considering different demand shocks.

Another novelty in the paper is the consideration that contractionary and expansionary demand shocks may have different productivity effects. In Aghion and Saint-Paul (1991), only contractionary demand shocks have positive productivity effects, while expansionary demand shocks have no effects on productivity at all. Note that this asymmetry is not predicted by the competing theories, and, hence, looking at asymmetries constitutes a more thorough test of the Opportunity Cost View and helps us with the interpretation issues. Finally, the paper investigates the empirical role of job reallocation as a link between demand shocks and productivity growth.

The paper is organized as follows. Section 2 lays out the framework used to measure productivity change. Section 3 spells out the identification of the shocks and the estimation of the Impulse Response Functions (IRFs) of productivity to these shocks. Section 4 documents and interprets the main results. Section 5 offers some final remarks. The Appendix describes the data.

## 2 Empirical Framework

### 2.1 Basic Strategy to Measure Productivity Growth

Under the Solow assumptions of competitive markets, constant returns to scale, proper measurement of the inputs, and homogeneous production function, TFP growth and the Solow residual coincide, with the Solow residual interpreted as a shift in the underlying production function. However, and following the work by Hall (1990), a burgeoning literature vigorously demonstrated that the Solow residual should not be interpreted as a pure measure of productivity change (Basu et al. (1999)), unless proper account is taken of the non-technological effects introduced into the Solow residual by the violation of the Solow assumptions. More to the point, these non-technological effects are highly correlated with shocks to activity and hence cannot be treated as classical measurement error in the context of this paper.

While there is no agreement in the literature on how to take account of these non-technological effects, there is wide agreement on the need to do so since the properties of the Solow residual change in a dramatic fashion after one controls for varying rates of input utilization, non-constant returns to scale, and imperfect competition in product markets. This literature has uncovered the following stylized facts: the corrected Solow residual, when compared to its uncorrected counterpart, displays lower implied probability of technological regress; lower volatility relative to output growth; and lower contemporaneous correlation with input and output growth. In addition, the typical US manufacturing industry exhibits constant or near constant returns to scale and a substantial amount of factor hoarding during the cycle. These characteristics can be thought of as constraints that must be satisfied by candidate measures of productivity change (King and Rebelo (1998), Burnside, Rebelo, and Eichenbaum (1995) and Shapiro (1996)).

It seems desirable then to employ a correction framework that readily accommodates a wide spectrum of non-technological effects in the original Solow residual, regardless of their sources, while leading to a corrected Solow residual in conformity with the findings of other independent studies.

Having the ability to study the effects of the shocks of interest on productivity for each plausible correction scheme allows one to ask: for which range of this spectrum of plausible corrections does a particular result obtain? If the result obtains for the entire spectrum (all plausible corrections) then one should regard this result as independent of the correction procedure. If the answer to a particular question varies over this spectrum, then one has to integrate the different answers over all parts of the spectrum, weighting them according to their empirical plausibility, albeit in an informal manner.

## 2.2 A Framework to Measure Productivity Growth

Each 2-digit SIC manufacturing sector is described by a production function of the form:

$$Y_{it} = A_{it}F_i(\Phi_{it}H_{it}N_{it}, U_{it}K_{it}) \quad (1)$$

where  $Y_{it}$  is real value added,  $A_{it}$  is an index of the state of technology and measures TFP,  $N_{it}$  is labor employees,  $H_{it}$  is hours worked per labor employee,  $K_{it}$  is the capital stock, and  $F_i$  is a homogeneous function of some degree  $\gamma_i$ . Let  $L_{it} \equiv H_{it}N_{it}$  be total labor hours worked. Firms may change the contribution of the inputs in the short run by varying the utilization rates of labor and capital services,  $\Phi_{it}$  and  $U_{it}$ , respectively.

Hall (1990) assumes that the firm solves a cost minimization problem and derives TFP growth rate:

$$da_{it} = dy_{it} - \gamma_i[\alpha_{it}(dl_{it} + d\phi_{it}) + (1 - (\mu_{it}/\gamma_i)\alpha_{it})(dk_{it} + du_{it})] \quad (2)$$

where  $x \equiv \ln X$ ,  $\mu_{it}$  is the markup ratio, and  $\alpha_{it}$  is the share of total revenue that accrues to labor services. Equation (2) involves the unobserved series  $d\phi_{it}$ ,  $du_{it}$ ,  $\mu_{it}$ , and parameter  $\gamma_i$ . To render (2) operational we employ proxies for the series  $d\phi_{it}$  and  $du_{it}$  and allow the parameter  $\gamma_i$  and series  $\mu_{it}$  to vary within a reasonable range (discussed below).

The studies that have used proxies for  $du_{it}$  considered data on electricity consumption (Burnside et al. (1995)), shift work (Shapiro (1996)), workweek of capital (Shapiro (1996)), and functions of labor variables (Evans (1992)). We follow Burnside et al. (1995) and assume  $dk_{it} + du_{it} \equiv de_{it}$ , where  $de_{it}$  is the growth rate of industrial electricity consumption. Note that  $de_{it}$  should capture all intensive margins of adjustment that firms may have at their reach when trying to vary the contribution of capital services; that hoarding of electricity does not pose a problem; that the sectors covered on the empirical exercises presented in this paper are all manufacturing sectors, where this assumption is *a priori* fairly innocuous; and that data on industrial electricity consumption are available at the quarterly frequency.

For  $d\phi_{it}$  we follow Gordon (1990). Define  $L_{it}^* \equiv \Phi_{it}L_{it}$  as effective labor services. Assume that  $\Phi_{it}$  is a variable stationary around one (say, ‘effort’). Let  $l_{it}^{*trend}$  and  $l_{it}^{trend}$  be stationary deviations from a common trend. Gordon assumes that a fraction  $\varphi_i$  of the changes in  $l_{it}^{*trend}$  takes the form of changes in the labor utilization rate:  $\phi_{it} = \varphi_i l_{it}^{*trend}$ . Hence,  $\phi_{it} = (\varphi_i/(1 - \varphi_i)) l_{it}^{trend}$ , and, finally,  $dl_{it}^* = dl_{it} + (\varphi_i/(1 - \varphi_i))dl_{it}^{trend}$ . In practice we use micro evidence on  $\varphi_i$  found in the work of Fay and Medoff (1985) who report an average value of  $\varphi_i$  equal to 0.21 for the US manufacturing sector. However, we allow  $\varphi_i$  to take on values  $\{0, 0.1, 0.2, 0.3\}$ , with the role of effort increasing in  $\varphi_i$ . The trend term is obtained by applying the Hodrick-Prescott filter to measured hours, with

$\lambda = 1600$ .

We let  $(\mu_{it}/\gamma_i)$  vary between 1 and  $1/\alpha_{it}$ , where the lower bound follows from the second-order condition for profit maximization and the upper bound from the imposition of nonnegative returns on effective capital services.<sup>1</sup>

As we try different TFP specifications, we get different IRFs to each shock considered. Section (4) discusses the sensitivity of the IRFs to the alternative specifications of TFP. Here we focus on the differences in widely studied properties of the Solow residual brought about by changing the TFP specification, as illustrated by Table 1 (where  $\rho(x, y)$  is the correlation coefficient between  $x$  and  $y$ , and  $\sigma_x$  is the standard deviation of  $x$ ). For brevity, we focus on the typical industry, reasonably represented by the aggregate manufacturing sector. Many other specifications were also considered, but the specifications presented in Table 1 seem to encompass all the relevant ones.

Table 1

$(\varphi_i; \mu_i/\gamma_i) =$	0; 1	0; 1.2	0.1; 1	0.1; 1.2	0.2; 1	0.2; 1.2	0.3, 1	0.3, 1.2
Prob( $da_{it} < 0$ )	9.6%	9.6%	16.8%	13.2%	19.2%	19.2%	24.1%	25.3%
$\rho(da_{it}, dy_{it})$	0.20	0.15	-0.00	-0.09	-0.23	-0.33	-0.43	-0.52
$\rho(da_{it}, dl_{it}^*)$	-0.12	-0.19	-0.32	-0.43	-0.53	-0.64	-0.70	-0.78
$\sigma_{da}/\sigma_{dy}$	0.17	0.16	0.18	0.18	0.20	0.21	0.24	0.26

The columns on the far right of Table 1 suggest that ‘increasing the correction’ ultimately leads to residuals not in accordance with our priors about technological progress. As we further depart from the original Solow residual case ( $(\varphi_i; \mu_i/\gamma_i) = (0; 1)$ ), the residual becomes highly negatively correlated with both output growth and labor input growth, and relatively more volatile, which, combined with a virtually unchanged mean, explains the increase in the probability of technological regress. Basu et al. (1999) using different data and methods obtain corrected residuals that exhibit properties well in accordance with at least the first four cases (from left to right). Note also that increasing the markup to degree of returns to scale ratio above 1.2 implies shares of pure economic profits in excess of 17%, which is bluntly at odds with Basu et al. (1999). Overall, these

<sup>1</sup>The assumption that  $\mu_{it}$  is constant over time is both needed, since we have no direct data on it, and quantitatively innocuous. Suppose that the true markup ratio  $\mu_{it}^*$  equals  $\mu_i + v_{it}$ . The discrepancy between  $\mu_{it}^*$  and  $\mu_{it}$ ,  $v_{it}$ , is important to the extent that it may be dynamically correlated with the shocks of interest. Moreover, the difference between the true growth rate of TFP and the used one would then be:

$$v_{it}\alpha_{it}(dl_{it}^* - dk_{it}^*)$$

which is likely to be fairly small, since in practice  $(dl_{it}^* - dk_{it}^*)$  is very small and does not cloud our conclusions.

results suggest that when interpreting the TFP responses, little weight should be given to TFP specifications similar to the ones on the far right of Table 1.

### 3 Identifying the Shocks

#### 3.1 Basic Motivation

The empirical strategy used to study the dynamic impact of monetary and fiscal policy shocks on TFP for each of the 20 2-digit SIC manufacturing sectors has the following two steps:

- *First Step*: The policy shocks common to all sectors are identified;
- *Second Step*: The IRF of TFP to these shocks is estimated for each sector.

Note that: 1) the first step involves only economy-wide variables, guaranteeing that the recovered series for each policy shock considered is the same for all sectors; and 2) the different specifications proposed for the sectoral TFP indices are used only in the second step, and, hence, the identified policy shocks are invariant with respect to the exact specification of the sectoral TFP indices.

On reflection, this is clearly as it should be. There are at least two reasons to adopt this two-step procedure. First, if the policy shocks were identified from, say, a VAR that included TFP, as in Gali and Hammour (1992) and Saint-Paul (1992), the policy shocks would then depend on the specification of TFP. We find this property unwelcome. From this VAR one could estimate the IRF of TFP to a policy shock. If this exercise were repeated with a different specification of TFP, and we have already established the need to perform sensitivity analysis to different TFP specifications, then new results would emerge. How should one interpret the new results? They could be caused by the different specification of TFP, the different series of recovered policy shocks, or both. This problem is avoided here since the identification of the policy shocks is decoupled from the estimation of the IRFs of the sectoral TFP indices and from the uncertainty inherent in the correct specification of these latter objects. Second, the two-step procedure allows the second-stage estimation of the IRFs to be asymmetric with respect to positive and negative policy shocks, as suggested by theory (see Section 1).

For the identification of the policy shocks (the proxy for demand shocks), the paper capitalizes on the existing literature. Moreover, and to deal with the multitude of identification schemes put forth in the literature, we employ identification schemes that, on the one hand, do not impose unwelcome restrictions on the estimation of the IRFs, and, on the other hand, are widely viewed in

the literature as well founded and agreed upon. This strategy is also employed in the identification of the oil price shocks (the proxy for supply shocks), as discussed in the final part of this section.

## 3.2 Monetary Policy Shocks

### 3.2.1 The Christiano, Eichenbaum and Evans (2000) Approach

Christiano, Eichenbaum and Evans identify monetary policy shocks with the disturbance term  $\epsilon_t^s$  in the monetary authority's policy function rule:

$$S_t = f(\Omega_t) + \epsilon_t^s$$

The monetary authority's operating instrument,  $S_t$ , is the sum of a reaction to current developments in the economy,  $f(\Omega_t)$ , and a discretionary policy shock,  $\epsilon_t^s$ . By specifying the information set available to the monetary authority at time  $t$ ,  $\Omega_t$ , and imposing linearity of the function rule  $f$ , we recover the policy shock  $\epsilon_t^s$  as the serially uncorrelated residual from an OLS regression of  $S_t$  on the elements of  $\Omega_t$ .

Given these identifying assumptions, the IRF of a variable  $x_t$  to a monetary policy shock ( $\epsilon_t^s$ ) is consistently estimated by regressing  $x_t$  via OLS on current and lagged values of  $\epsilon_t^s$ . More formally:

$$x_t = C(L)\epsilon_t^s + v_t$$

where  $C(L)$  is an infinite order polynomial in non-negative powers of the lag-operator (in practice truncated at the twentieth lag). It is assumed that all non-monetary policy shocks are subsumed in  $v_t$ , which is uncorrelated with  $\epsilon_t^s$  both contemporaneously and at all leads and lags. To investigate the asymmetric effects of contractionary and expansionary monetary policy shocks, the estimating equation (for the IRF) becomes:

$$x_t = C(L)^+\epsilon_t^{s+} + C(L)^-\epsilon_t^{s-} + v_t$$

where  $\epsilon_t^{s+} \equiv \max(\epsilon_t^s, 0)$  is a contractionary or tight shock, when the central bank target instrument is an interest rate policy, and  $\epsilon_t^{s-} \equiv \min(\epsilon_t^s, 0)$ , an expansionary or easy shock.

Christiano, Eichenbaum and Evans suggest the Federal Funds Rate as the monetary authority's operating instrument, or, alternatively, Non-Borrowed Reserves. We consider both operating instruments and the following information set:

$$\Omega_t = \{Q_{t-\tau}, P_{t-\tau}, C_{t-\tau}, FF_{t-\tau-1}, NBR_{t-\tau-1}, TR_{t-\tau-1} : \tau = 0, 1, \dots, 4\}$$

where  $Q$  is the log Real GDP,  $P$  is the log of the GDP deflator,  $C$  is the log of an index of sensitive commodity prices (a leading indicator of inflation),  $FF$  is the Federal Funds Rate,  $NBR$  is the log

of Non-Borrowed Reserves, and  $TR$  is the log of Total Reserves. We compare our shocks with the shocks identified by Garibaldi (1997), who follows Cover (1992) and get a correlation coefficient of 0.82 (see Figure 1). Our results, discussed in the next section, based on  $\epsilon_t^F$  are, in this sense, robust to the identification scheme.

### 3.2.2 Narrative Approach

We follow Romer and Romer (1997) who, from their reading of history, identify dates when the Federal Reserve deliberately pursued a desinflationary course of action.

To investigate the dynamic productivity effects of contractionary monetary policy shocks identified via the narrative approach we estimate the following equation:

$$tfp_{it} = a_{i,0} + a_{i,1} * t + \sum_{j=1}^8 b_{i,j} rr_{t-j} + \sum_{j=1}^8 c_{i,j} tfp_{i,t-j} + \epsilon_{i,t}$$

where  $tfp_{it}$  is the log of  $TFP_{it}$ , and  $rr_t$  is a 0/1 dummy variable that equals 1 when  $t$  equals: 1966:2, 1968:4, 1974:2, 1978:3, 1979:4, 1988:3 (Romer dates, taken from Christiano, Eichenbaum and Evans (2000), p. 60). The vertical lines in Figure 1 mark the Romer dates. Under the identifying assumption that  $rr_t$  is strictly exogenous, the OLS estimates of  $a_i$ ,  $b_i$  and  $c_i$  consistently estimate the IRF of TFP to a Romer shock. Eight lags (quarters) of  $tfp_{it}$  and  $rr_t$  are included to capture the dynamics of the processes.

### 3.3 Fiscal Policy Shocks

The extent to which movements in fiscal variables reflect current developments in the domestic US economy depends on the definitions of the fiscal variables. For instance, while some transfer expenditures are highly reactive to the state of the economy, innovations to defense spending are generally thought of as exogenous shocks. This observation motivates treating defense related variables separately from non-defense variables. Hence, we offer two methods to identify fiscal policy shocks: the first focuses on innovations to defense spending, and draws on Rotemberg and Woodford (1992); the second addresses shocks to a broader measure of government spending (defense and non-defense) and to a revenue variable, and follows Blanchard and Perotti (2002). While focusing on military variables is certainly less demanding in terms of identifying restrictions, by using broader spending measures we are likely to uncover fiscal policy shocks with larger real effects. Nevertheless, each of these two approaches provides an assessment of the robustness of the results obtained under the other.

### 3.3.1 Defense Spending

Rotemberg and Woodford (1992) identify a policy shock to their defense spending policy variable as the residual in a regression of the form:

$$g_t = z(\Phi_t) + \epsilon_t^g$$

where  $\Phi_t$  is the information set available to the fiscal authority when it sets its operating instrument  $g_t$ , and  $z$  is a linear policy rule.  $\epsilon_t^g$  is the policy shock, a serially uncorrelated residual, orthogonal to the elements of  $\Phi_t$ . Under these identifying assumptions, the IRF of a variable  $x_t$  to a fiscal policy shock  $\epsilon_t^g$  is consistently estimated by regressing  $x_t$  via OLS on current and lagged values of  $\epsilon_t^g$ .

### 3.3.2 Total Government Spending and Taxes

Blanchard and Perotti (2002) study the dynamic effects of shocks to government spending and taxes on output by means of a structural VAR that relies on institutional information about the tax and transfer systems. The policy variables consist in one expenditure variable, total purchases of goods and services (spending), and one revenue variable, total tax revenues minus transfers (taxes). In the first step we estimate the structural VAR and recover the policy shocks  $\epsilon_t^g$  (spending) and  $\epsilon_t^t$  (tax). Then, we consistently estimate the IRF of a variable  $x_t$  to the fiscal policy shock  $\epsilon_t^y$ ,  $y = g, t$ , by regressing  $x_t$  via OLS on current and lagged values of  $\epsilon_t^y$ . We also consider that contractionary fiscal shocks may have different effects from expansionary fiscal shocks.

## 3.4 Oil Shocks

Davis (1987) claims that allocative disturbances, such as oil price shocks, have more powerful real effects when they reinforce, rather than reverse, the direction of past disturbances. Davis and Haltiwanger (1999) offer a specific oil price shock designed along these lines, and define an oil price shock index as the log of the following ratio: the current real oil price divided by a weighted average of its observations in the prior 20 quarters, with weights that sum to one and decline linearly to zero. Interestingly, the authors report that their result is especially important for samples that extend beyond 1985, which further supports results found in Hamilton (1996). Since the TFP series used in this paper start in 1972:2 and end in 1992:4, the concerns about the appropriate oil price shock measure expressed in the above studies are of practical importance here, leading us to adopt the Davis and Haltiwanger oil price shock index (oil index) as a measure of oil price shocks.

A complementary strategy to identify oil price shocks has been followed by Hamilton (1985), who adopts a narrative approach. Hamilton isolates a set of episodes (dates) marked by sharp exogenous oil price increases. Hoover and Perez (1994) update Hamilton’s work and identify ten oil price shocks in total: {1947:4, 1953:2, 1956:2, 1957:1, 1969:1, 1970:4, 1974:1, 1978:1, 1979:3, 1981:1}. We use these dates and 1991:3 (to mark the Iraqi invasion of Kuwait) to construct a dummy variable that signals an oil price shock identified via the narrative approach (oil dummy or Hamilton dates). The vertical lines in Figure 2 correspond to the Hamilton dates. Not surprisingly, the Hamilton dates tend to coincide with the onset of prolonged increases in the oil price index.

**Oil Price Index** We estimate the IRFs of sectoral TFPs to an innovation to the oil price index as follows: first, we fit an autoregressive process to the oil price index ( $op_t$ ), whose residuals are defined as the innovations to the oil price index ( $e_t^o$ ); second, we regress the log of sectoral TFP on its own lagged values, current and lagged values of the oil index, and a deterministic trend. Finally, we simulate the regressions to compute the IRFs of TFP to  $e_t^o$ . To be specific, we estimate the following equations via OLS equation by equation:

$$op_t = a_{p,0} + \sum_{j=1}^8 a_{p,j} op_{t-j} + e_t^o$$

$$tfp_{it} = a_{i,0} + a_{i,1} * t + \sum_{j=1}^8 b_{i,j} tfp_{i,t-j} + \sum_{j=0}^8 c_{i,j} op_{t-j} + e_{i,t}$$

**Oil Dummy** We estimate the following equation:

$$tfp_{it} = \alpha_{i,0} + \alpha_{i,1} * t + \sum_{j=1}^8 \beta_{i,j} od_{t-j} + \sum_{j=1}^8 \gamma_{i,j} tfp_{i,t-j} + \epsilon_{i,t}$$

where  $od_t$  is the oil dummy. Under the identifying assumption that  $od_t$  is strictly exogenous, the OLS estimates of the parameters  $\beta$  and  $\gamma$  consistently estimate the IRF of TFP to an oil dummy shock.

## 4 Results and Interpretations

### 4.1 Results

This section documents the effects of the monetary, fiscal, and oil shocks on TFP for the 20 2-digit US manufacturing industries considered. As we saw in sections 3 and 4, this study considers several specifications of TFP for each industry. To achieve a balance between ease of interpretation and reflection of the true importance of trying several TFP specifications we focus on the following eight

parameterizations of TFP:  $\varphi_i$ , which relates to the importance of a procyclical labor utilization rate, taking on values  $\{0, 0.1, 0.2, 0.3\}$ , and  $\mu_i/\gamma_i$ , the markup-returns to scale ratio, which indexes for imperfect competition-returns to scale, taking on values  $\{1, 1.2\}$ . In practice, and as a general result, the greater  $\varphi_i$  and/or  $\mu_i/\gamma_i$  (loosely speaking, the greater the correction), the further away from the unshocked path is the IRF of TFP for any shock. The discussion that follows is organized by type of shock. For brevity, we focus on the typical industry and interesting exceptions. Finally, and whenever appropriate, the IRFs correspond to shocks with a size of one standard deviation and are measured as percentage deviations from the unshocked path.

**Monetary Policy Shocks** Part A.1 of Figure 3 displays selected IRFs of TFP and two standard-errors-bands to a contractionary federal funds rate shock, when tight and easy shocks are assumed to have symmetric effects. Let's first look at the typical industry, represented by the aggregate manufacturing industry. The lines with circles are the IRFs of the different TFP specifications tried, and the solid lines the associated two standard-errors-bands. The clustering of the lines indicates that the typical response of TFP is fairly small and insensitive to changes in  $\varphi_i$  or in  $\mu_i/\gamma_i$ . There is a single noteworthy exception to this permissive pattern, displayed in Part A.2 of Figure 3: in Industry Machinery (SIC 35), TFP rises to level off at the tenth quarter after the shock (in the 2%-3% range, depending on the specification), and is accompanied by a transitory decline in output (not reported), as predicted by the Opportunity Cost View. We get the same results for a contractionary nonborrowed-reserves shock. Quite interestingly, Industry Machinery (SIC 35) was again the only industry with a significant, positive TFP response at longer horizons. Note that in no industry does TFP decline after a contractionary shock, unlike learning-by-doing or capital market imperfections theories suggest.

Part A of Figure 4 presents selected responses of TFP to tight and easy federal funds rate shocks. Allowing for asymmetric effects makes little difference overall; responses to both tight and easy shocks tend to be statistically insignificant (16-20 quarters). Interestingly, the responses to tight shocks tend to be positive. The only flagrant cases of asymmetries occur in Industry Machinery and Equipment (SIC 35), where a tight shock leads to an increase in TFP, and an easy shock has no noticeable effect; and in Food and Kindred Products (SIC 20), where an easy shock has negative productivity effects, and a tight shock has no noticeable effects. These asymmetries are confirmed when we use F-tests for the presence of asymmetries in the TFP responses. Figure 7 displays the p-values of these tests. Each TFP specification has an associated p-value. A simple way to summarize the multitude of tests per industry is to report the maximum and minimum p-values over all specifications. If both extremes are greater than  $\alpha$  we fail to reject the null of

symmetry at the  $\alpha$  confidence level for all specifications considered. If the interval between the maximum and minimum p-values contains the desired confidence level, then we need to look deeper at which specifications led to which results before reaching a conclusion. Fortunately, the latter situation occurred only twice, in Printing and Publishing (SIC 27) and Rubber Products (SIC 30). Clearly, the picture that emerges from these tests is one of symmetry, with the above mentioned exceptions of Industry Machinery and Equipment (SIC 35) and Food and Kindred Products (SIC 20). Finally, we obtain the same qualitative results with tight and easy non-borrowed reserves shocks.

Part B of Figure 4 displays the typical response of TFP and output (the line with crosses) to a Romer shock (estimation in log-levels). Now there are no signs of significant productivity effects. The same results emerge with estimation in growth rates.

**Fiscal Policy Shocks** Part A of Figure 5 displays the IRFs of military spending and military employment to an expansionary shock to military spending ( $\epsilon_t^m$ ). Part B of Figure 5 presents selected IRFs of TFP and output. Clearly, the TFP responses barely change across specifications. Most industries exhibit weak responses of TFP, regardless of the output response. However, in Industry Petroleum and Coal Products (SIC 29) output (temporarily) decreases and TFP increases, and in Instruments and Related Products (SIC 38), both output and TFP decrease.

Part C of Figure 5 looks at the effects of an expansionary total spending shock, when tight and easy shocks are assumed to have symmetric effects. Food and Kindred Products (SIC 20) is the only industry where the TFP response at 20 quarters after the shock is greater in absolute value than two standard-errors, with an expansionary spending shock leading to a decline of TFP of about -1.5%. Once more, changing the parametrization of TFP does not change the results in any substantive way. Turning to the tax shock ( $\epsilon_t^t$ ), there is no evidence of significant productivity effects in any industry.

Part D of Figure 5 presents the results for tight and easy spending shocks. In many industries, a tight shock leads to an increase in TFP (16-20 quarters), although not greater than two standard-errors. Again, tax shocks have no sizable effects on TFP. The two bottom panels of Figure 7 document the ubiquitous absence of asymmetries for fiscal shocks. Chemicals and Allied Products (SIC 28) and Rubber and Plastics (SIC 30) for spending shocks are the exceptions, as expected, in light of their IRFs.

**Oil Shocks** The first panel of Figure 6 displays the response of the oil price index to an own shock. The other panels display selected responses of output and TFP (estimation in log-levels).

The typical TFP response is one of virtually no impact response, followed by very mild changes and quick reversion to zero. There is a single exception to this pattern: in Food Products (SIC 20), TFP steadily rises up to 2%-3%, and is associated with a transitory decrease in output.

The results using the oil dummy are remarkably similar. In particular, the effect in Food Products (SIC 20) is again 2%-3%, and is accompanied by a transitory decline in output. However, now Petroleum and Coal Products (SIC 29) shows a decline in TFP. On balance, the typical industry shows virtually no response of TFP, with the clear exception being a positive effect in Food Products (SIC 20).

## 4.2 Interpretations

**Summary of Results and Interpretations** The variation in the results brought about by the different specifications of TFP is small. Ditto, the evidence speaks in favor of very small productivity effects of monetary, fiscal, and oil shocks. Table 2 contains the pairs of industries and shocks where significant TFP effects (20 quarters after the shock) were found. The large majority of the cells (read industries-shocks pairs) show contractionary shocks having positive productivity effects, in accordance with the Opportunity Cost View. Furthermore, in two other instances, expansionary shocks have negative effects, as predicted by a symmetric version of the Opportunity Cost View. When do contractionary (expansionary) shocks have negative (positive) productivity effects, as predicted by learning-by-doing and capital market imperfections theories? Only Petroleum and Coal Products (SIC 29) and Chemicals and Allied Products (SIC 28) show such a pattern (for military spending and oil shocks, and total spending shocks, respectively). Table 2 also reveals the presence of asymmetries, although in a localized manner. Note also that contractionary oil shocks cause TFP to decline only in Petroleum and Coal Products (SIC 29).

Note that the identified shocks do help explain activity and hence are suitable for the quantification of the importance of the Opportunity Cost View and competing theories. Figure 8 displays p-values of F-tests of exclusion of military purchases, oil price index, oil dummy, and Romer dummy in univariate regressions models of sectoral industrial output, job creation, and job destruction (with the last two series taken from Davis et al. (1996)). The variation in the results does not blur the main point taken from Figure 8: the signal extracted with the identified shocks is in most cases strong enough for our purposes. In addition, Figure 9 shows that in many instances the shocks help explain the TFP indices.

**The Role of Job Reallocation** Aghion and Howitt (1998, Ch. 8) and Aghion and Saint-Paul (1998) allude to the work by Hall (1991) as the first formalization of the ideas embodied in the

Opportunity Cost View. According to Hall: “Measured output may be low during (downturn) periods, but the time spent reorganizing pays off in its contribution to future productivity.” Hall claims that there is relatively more reorganization going on during downturns than in upturns, based on the fact job reallocation for the US manufacturing sector is countercyclical (Davis and Haltiwanger (1992)). The countercyclicity of job reallocation is also mentioned by Aghion and Saint-Paul (1998), and Aghion and Howitt (1998, Ch. 8) as evidence supportive of the Opportunity Cost View. By the same token, Hall and Taylor (1996, p. 136) note in their macroeconomics textbook that the large amount of job reallocation typical of downturns may be the “silver lining to the storm clouds of recessions.”

Based on the above mentioned studies, we investigate the role of job reallocation as a channel linking the considered shocks and productivity growth. If the contractionary shocks lead to higher productivity growth but not to higher job reallocation, we interpret the evidence as speaking against the empirical importance of job reallocation as a productivity improving activity. Conversely, if the contractionary shocks lead to higher productivity and to higher job reallocation, we do not dismiss the thesis that job reallocation may play a significant role in the relationship between the shocks and productivity change.

We use data described in Davis et al. (1996) to construct sectoral measures of job reallocation and estimate the impact that the monetary, fiscal, and oil shocks have on job reallocation using the methods employed in the estimation of the IRFs. Table 3 presents the cumulative responses of job reallocation to contractionary monetary, fiscal, and oil shocks. In all six cases where Opportunity Cost View effects were found (see Table 2) the cumulative response of job reallocation is positive at the twelfth period after the shock. Furthermore, the responses are substantially higher than the response of the average industry. Taken at face value, these results suggest that job reallocation may be at play and may help explain the observed Opportunity Cost View effects.

**The Role of the Real Interest Rate** As discussed in the introduction, the smaller the increase in the real interest rate, the more productivity should increase for a given transitory decline in demand. Turning to an empirical application of this result, what is the evidence for the several shocks considered? While it is agreed that transitory contractionary monetary shocks lead to a transitory increase in the real interest rate (Christiano, Eichenbaum and Evans (2000)), the empirical evidence on transitory contractionary spending shocks supports both temporary declines in the real interest rate and no significant effects (Karayalçin (1999)). Now recall that four out of the six Opportunity Cost View cases were found for contractionary spending shocks, which seems to agree with the Opportunity Cost View. Of course, in light of the reduced number of significant

TFP responses, we should interpret these results as suggestive, but hardly definitive.

## 5 Final Remarks

The typical 2-digit SIC US manufacturing industry shows small productivity effects in response to monetary policy, fiscal policy, and oil shocks. However, there are exceptions to this pattern. Interestingly, the exceptions are generally characterized by temporary contractionary policy shocks having positive productivity effects (16-20 quarters), suggesting that there is significant investment in productivity going on during transitory downturns. In addition, there are signs of asymmetries in the responses of productivity, with productivity responses to contractionary policy shocks being, in general, positive and larger than their counterparts to expansionary shocks. Overall, the evidence lends very little support to learning-by-doing and capital market imperfections theories. These results are robust to the alternative specifications of TFP and identifying strategies employed in the empirical framework, that take stock on the state-of-art in the relevant literature. The data do not dismiss the thesis that job reallocation and the real interest rate may be important channels linking the considered shocks and productivity growth. As for policy implications, the data reveal that contractionary policy shocks do not lead to declines in productivity both at the industry level and at the aggregate manufacturing level.

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## 6 Appendix - Data

Unless otherwise mentioned, the data come from FRED. All data mentioned in this section, with the exception of the labor shares series, are seasonally adjusted, and quarterly values correspond to averages of underlying monthly data. The labor input series are the product of two (Citibase) series: total hours worked by production workers (LPHR) and total number of production workers (LPP). Growth rates of effective capital services are assumed to equal growth rates of industrial electricity consumption, measured as the kilowatts of electricity used at the 2-digit SIC level, obtained from the Board of Governors. Manufacturing measures of output at the 2-digit SIC level were constructed from the Board of Governors industrial production indices. Labor shares series were taken from an updated version of the Jorgenson et al. (1987) dataset maintained by John Fernald. Since the original labor shares are available at annual frequency, it is assumed that there is no variation in these series within the year in order to obtain quarterly values. The values corresponding to the years 1990-1992 are assumed to equal the values of the year 1989.

### Industry Codes

<b>SIC Code</b>	<b>Industry</b>	<b>Group</b>
20	Food and Kindred Products	Nondurable
21	Tobacco Products	Nondurable
22	Textile Mill Production	Nondurable
23	Apparel and Other Textiles	Nondurable
24	Lumber and Wood Products	Durable
25	Furniture and Fixtures	Durable
26	Paper and Allied Products	Nondurable
27	Printing and Publishing	Nondurable
28	Chemicals and Allied Products	Nondurable
29	Petroleum and Coal Products	Nondurable
30	Rubber and Plastic Products	Durable
31	Leather and Leather Products	Nondurable
32	Stone, Clay, and Glass Products	Durable
33	Primary Metals	Durable
34	Fabricated Metals	Durable
35	Industry Machinery and Equipment	Durable
36	Electronics and Other Electrical Equipment	Durable
37	Transportation Equipment	Durable
38	Instruments and Related Products	Durable
39	Miscellaneous Manufacturing Industries	Durable

**Table 3**

## Cumulative Responses of Job Reallocation to (Contractionary) Shocks

Industry	FFR Monetary Shock		Total Spending Shock		Military Spending Shock		Oil Dummy	
	Period 8	Period 12	Period 8	Period 12	Period 8	Period 12	Period 8	Period 12
20	-1.95	-2.91	-1.95	3.67	0.36	0.63	2.83	2.75
21	-1.28	-3.13	-1.28	3.40	2.48	2.52	-4.83	-5.22
22	0.04	-0.62	0.04	0.28	0.00	0.12	-1.17	-1.31
23	-0.34	-0.90	-0.34	-0.20	1.93	2.33	-2.75	-2.00
24	-0.32	-0.80	-0.32	2.18	0.02	0.49	5.51	6.36
25	-0.17	-0.68	-0.17	0.26	0.82	0.84	-0.76	0.69
26	-0.09	-0.78	-0.09	0.77	0.64	1.00	0.69	-0.18
27	0.08	-0.46	0.08	-0.15	0.65	0.77	-2.20	-1.99
28	-0.55	-0.83	-0.55	0.62	0.46	0.64	0.31	0.36
29	2.41	1.95	2.41	0.63	-1.42	-0.83	11.73	13.00
30	-0.02	-0.39	-0.02	1.77	0.03	0.52	3.22	3.12
31	-0.07	-1.08	-0.07	-1.25	-0.04	0.07	-0.48	-0.64
32	0.46	0.17	0.46	0.38	-0.94	-0.59	2.49	3.56
33	1.28	1.55	1.28	0.66	-1.84	-0.89	7.30	8.68
34	0.19	0.07	0.19	1.75	-0.18	0.24	4.94	5.62
35	0.51	0.72	0.51	0.12	-0.46	0.24	3.36	5.47
36	0.17	-0.31	0.17	0.44	0.04	0.22	0.06	1.03
37	1.27	1.20	1.27	4.08	0.28	1.37	15.29	12.88
38	-0.33	-0.81	-0.33	0.31	1.06	1.53	-0.71	0.02
39	-0.87	-2.00	-0.87	0.75	1.32	1.39	-3.14	-3.33
<b>Average</b>	0.02	-0.50	0.02	1.02	0.26	0.63	2.08	2.45

Comments:

Cells contain the cumulative response of job reallocation eight and twelve periods after the shocks.

Values are percentage deviations from unshocked path.

Except the Oil Dummy, shocks are of a size of one standard deviation.

Fig. 1--Monetary Policy Shocks and Romer Dates  
o: Cover Approach FFR Shock, +:CEE Approach FFR Shock

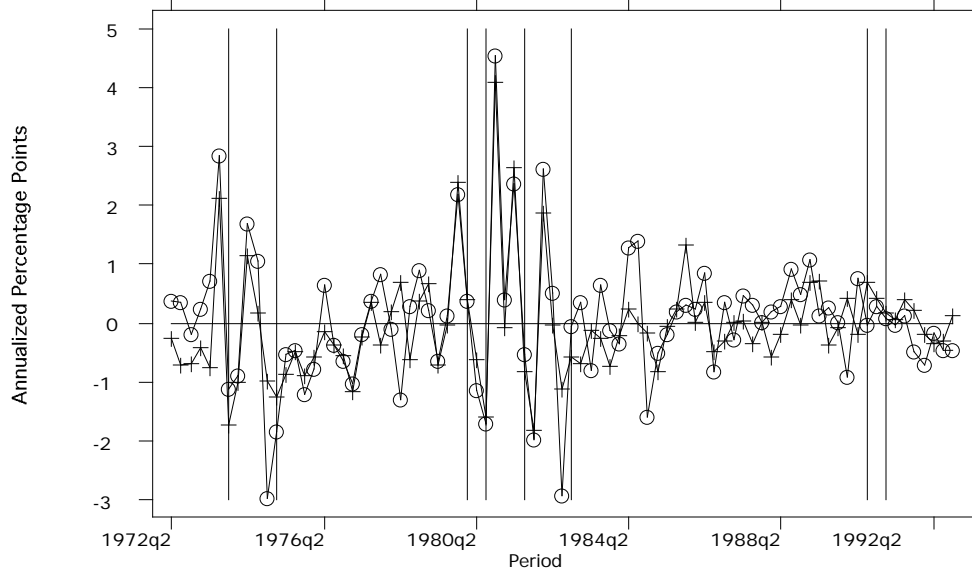
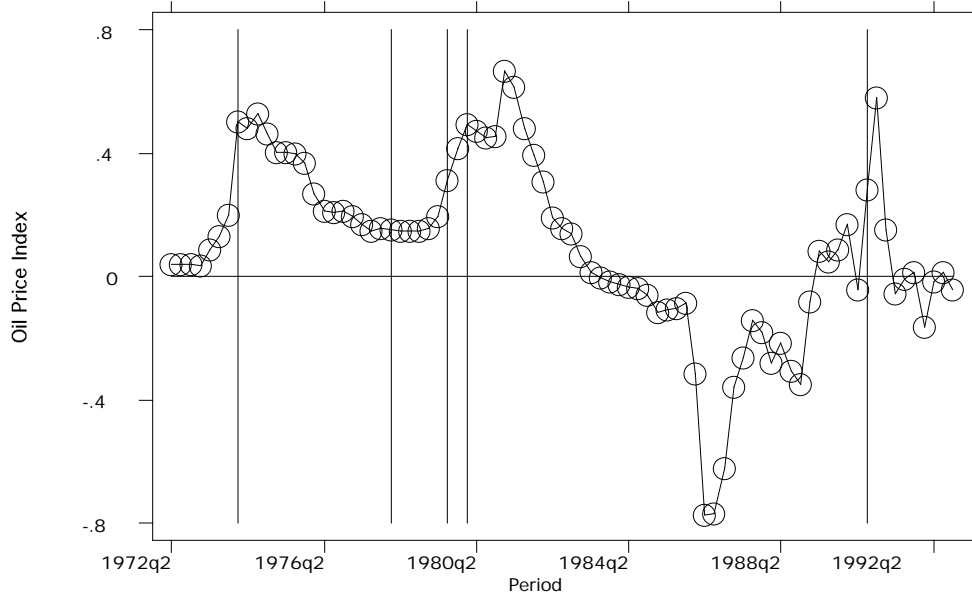


Fig. 2--Oil Price Index and Hamilton Dates



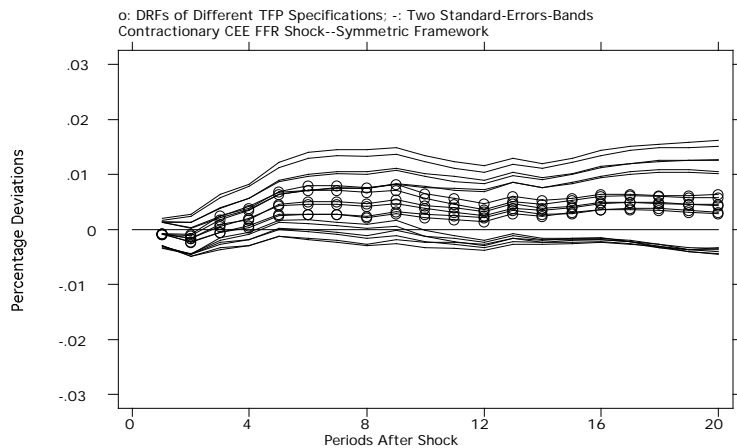


Figure 3 Part A.1--Manufacturing Industry, Contractionary FFR Shock

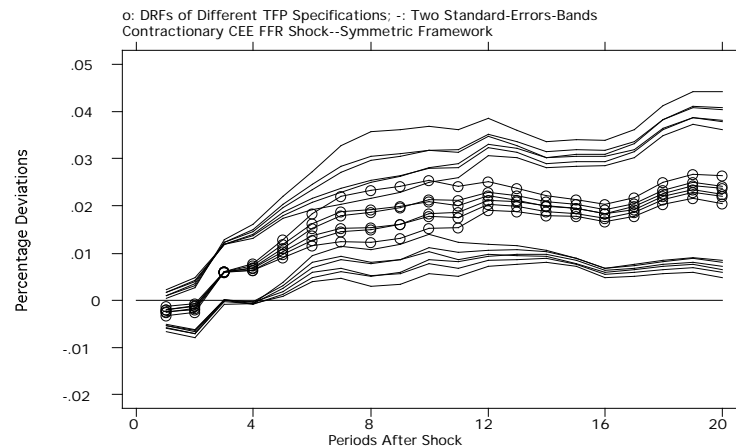


Figure 3 Part A.2--Industry Machinery, Contractionary FFR Shock

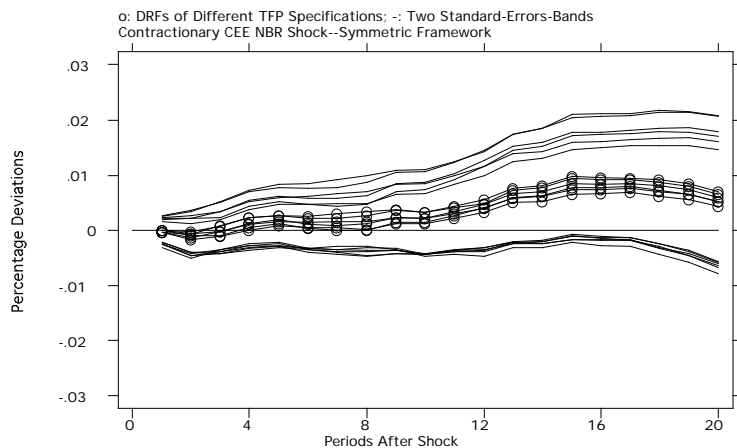


Figure 3 Part B.1--Manufacturing Industry, Contractionary NBR Shock

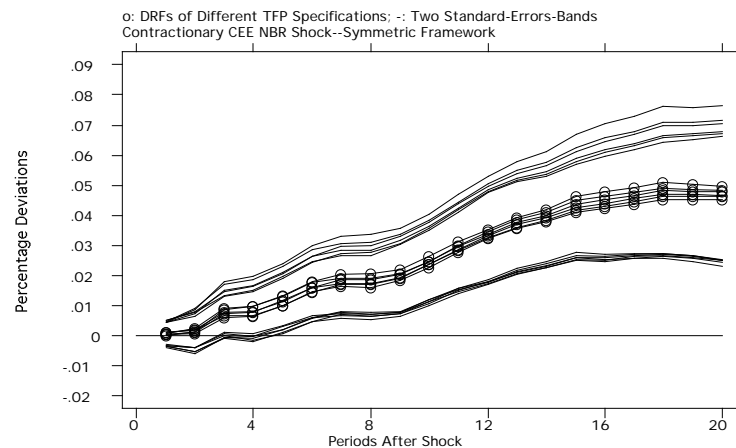


Figure 3 Part B.2--Industry Machinery, Contractionary NBR Shock

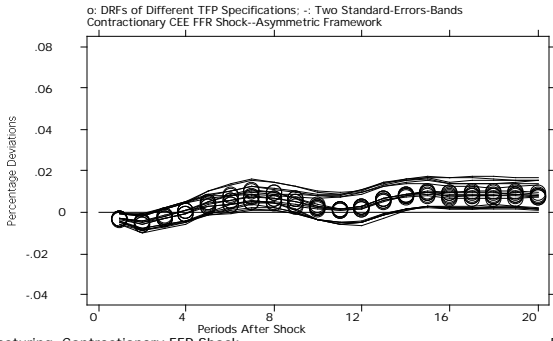


Fig. 4.A--Manufacturing, Contractionary FFR Shock

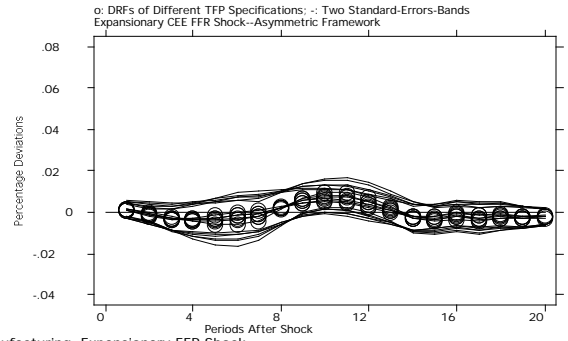


Fig. 4.A--Manufacturing, Expansionary FFR Shock

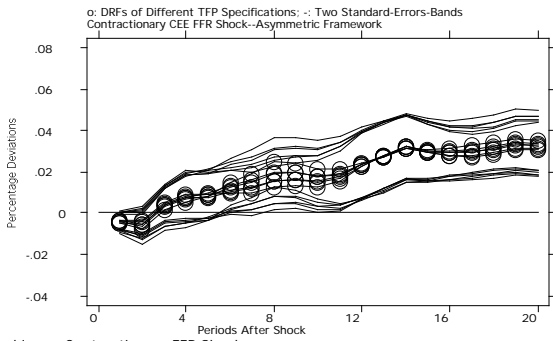


Fig. 4.A--Machinery, Contractionary FFR Shock

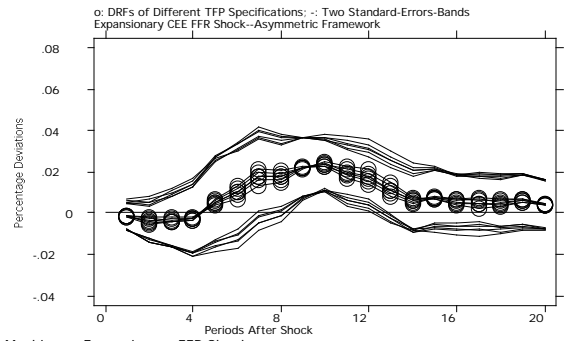


Fig. 4.A--Machinery, Expansionary FFR Shock

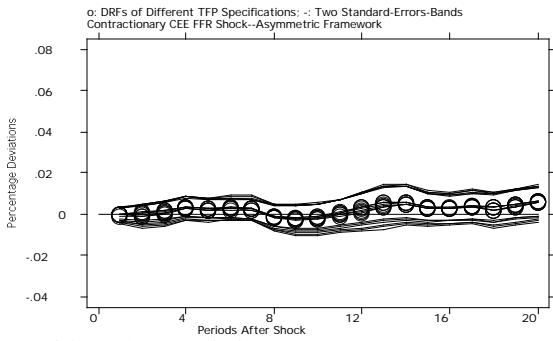


Fig. 4.A--Food, Contractionary FFR Shock

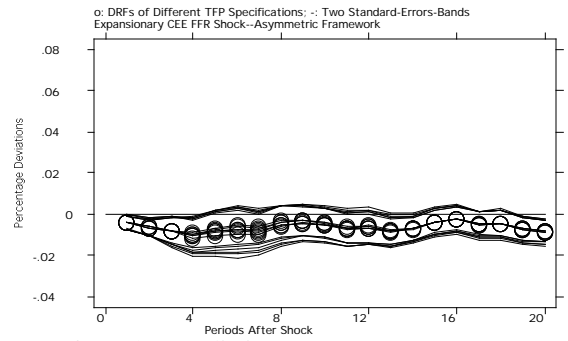


Fig. 4.A--Food, Expansionary FFR Shock

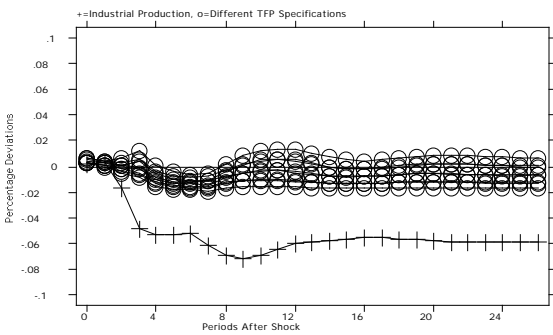


Figure 4 Part B--Manufacturing Industry, Romer Dummy

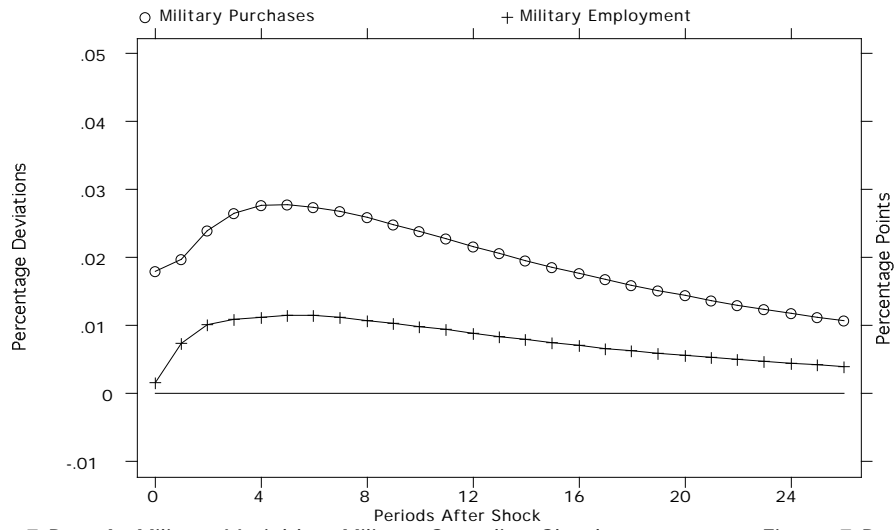


Figure 5 Part A--Military Variables, Military Spending Shock

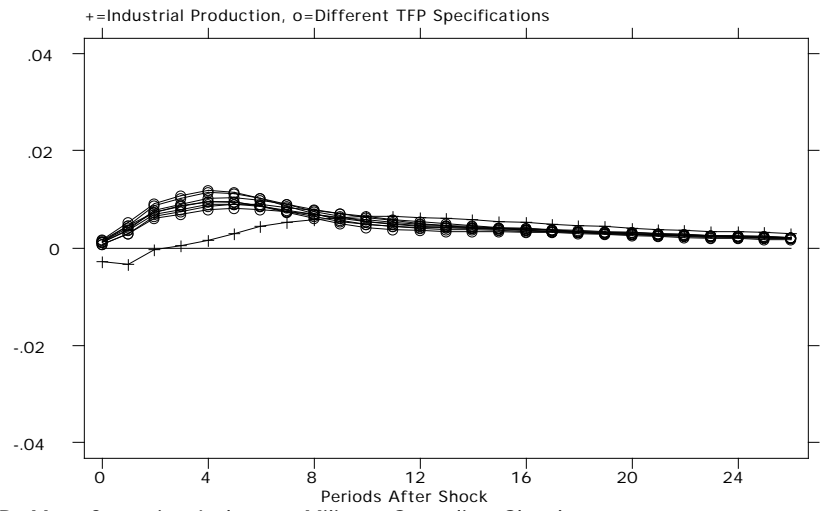


Figure 5 Part B--Manufacturing Industry, Military Spending Shock

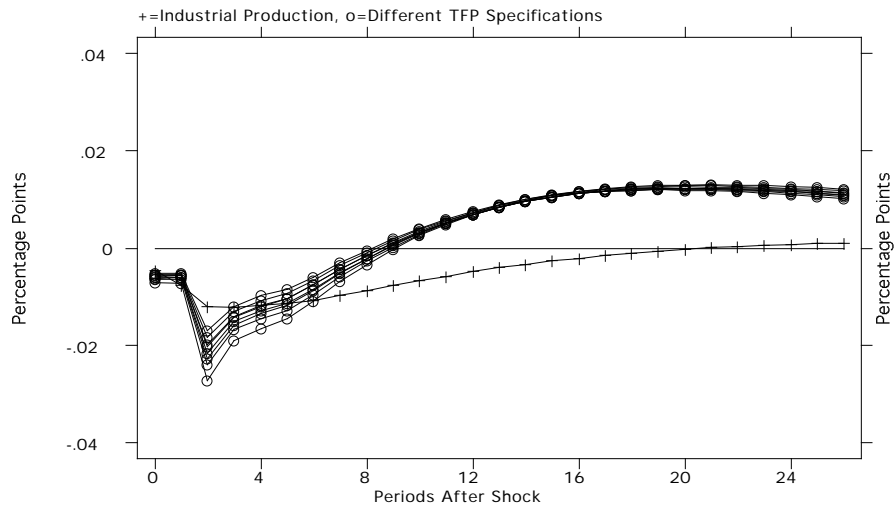


Figure 5 Part B--Petroleum and Coal, Military Spending Shock

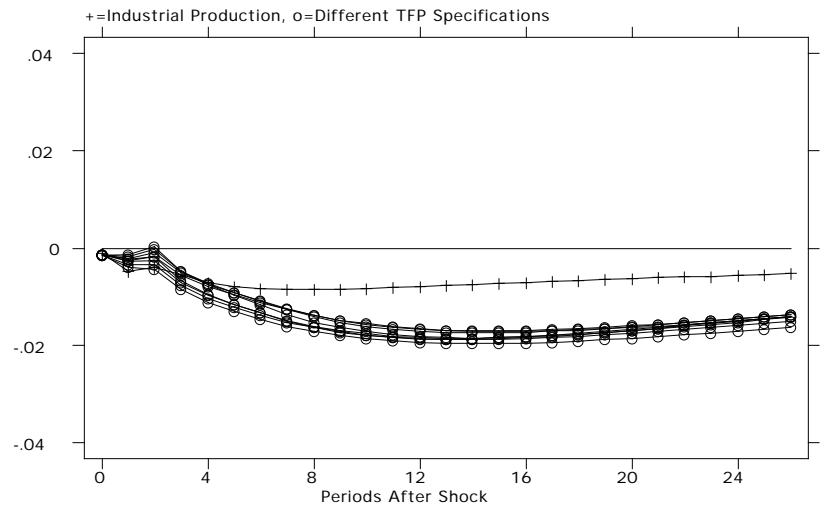


Figure 5 Part B--Instruments, Military Spending Shock

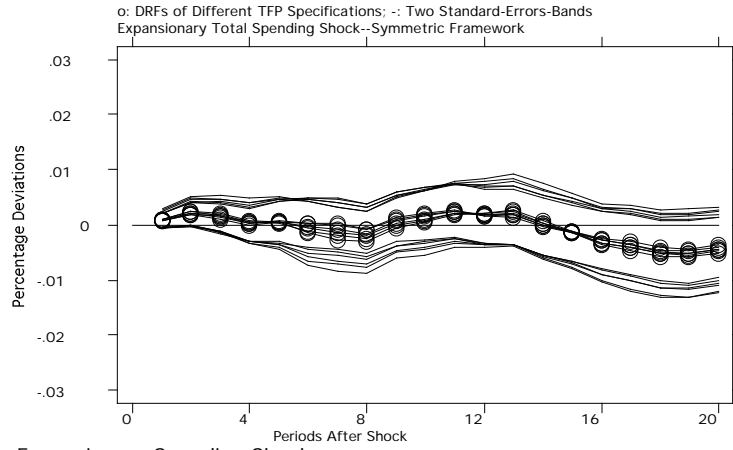


Fig. 5.C--Manufacturing, Expansionary Spending Shock

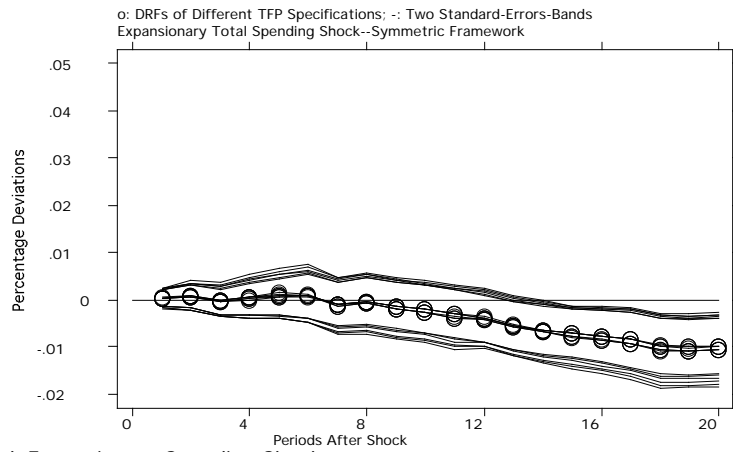


Fig. 5.C--Food, Expansionary Spending Shock

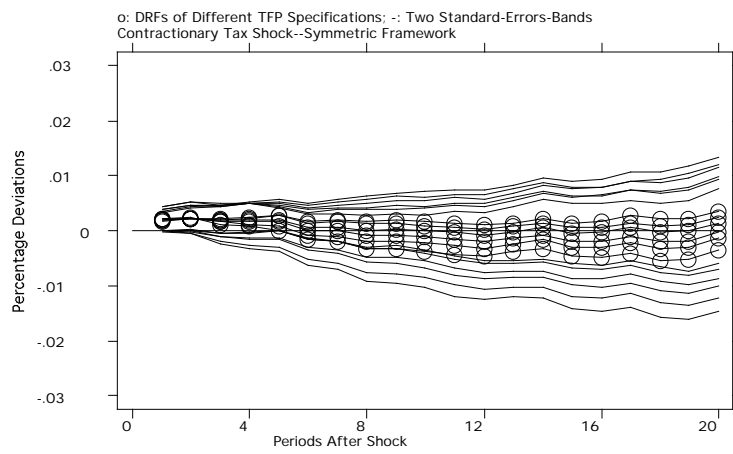


Fig. 5.C--Manufacturing, Contractionary Tax Shock

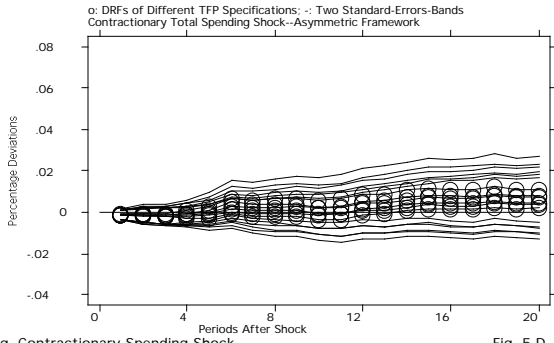


Fig. 5.D--Manufacturing, Contractionary Spending Shock

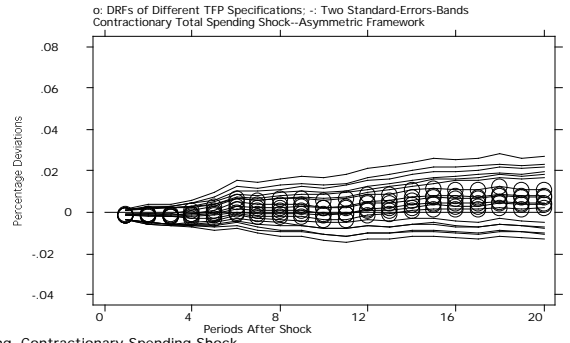


Fig. 5.D--Manufacturing, Contractionary Spending Shock

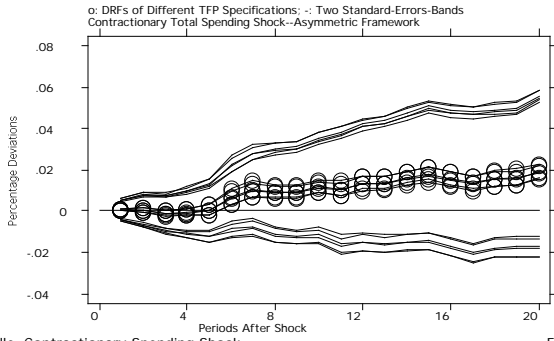


Fig. 5.D--Textile, Contractionary Spending Shock

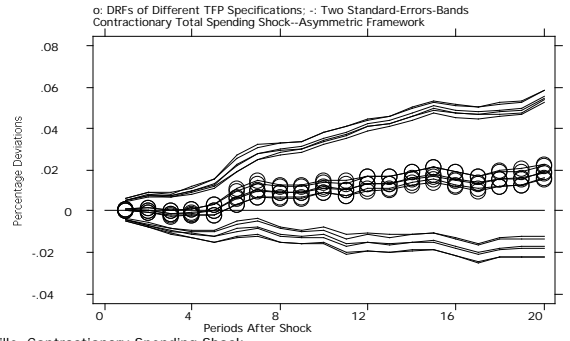


Fig. 5.D--Textile, Contractionary Spending Shock

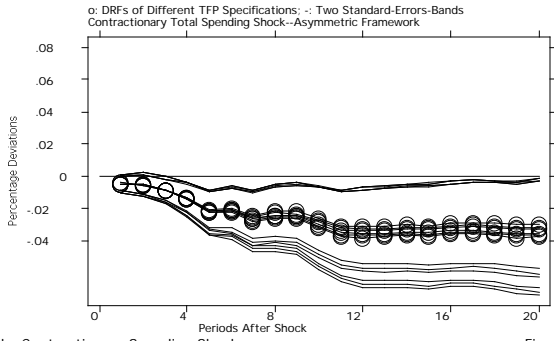


Fig. 5.D--Chemicals, Contractionary Spending Shock

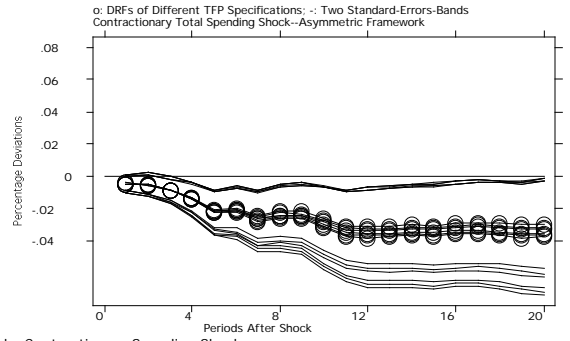


Fig. 5.D--Chemicals, Contractionary Spending Shock

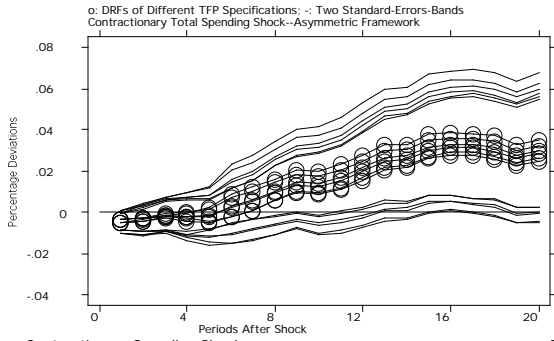


Fig. 5.D--Rubber, Contractionary Spending Shock

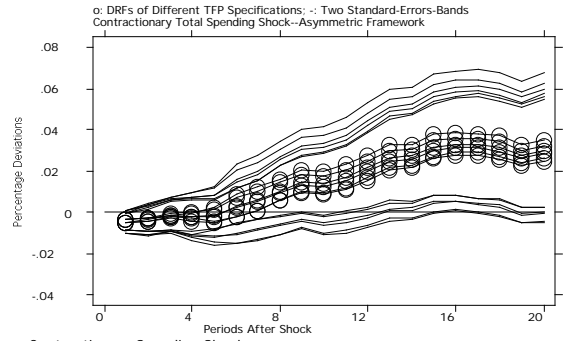
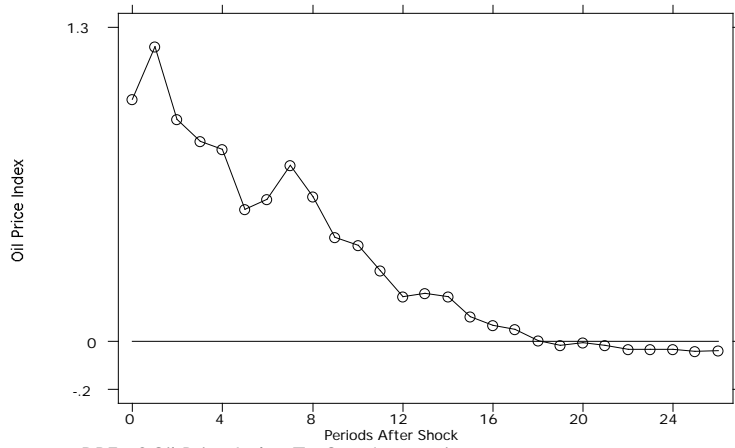


Fig. 5.D--Rubber, Contractionary Spending Shock



DRF of Oil Price Index To Own Innovation

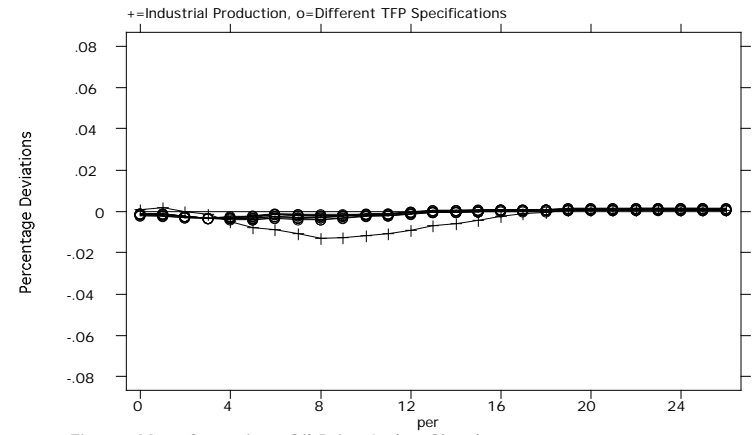


Fig. 6--Manufacturing, Oil Price Index Shock

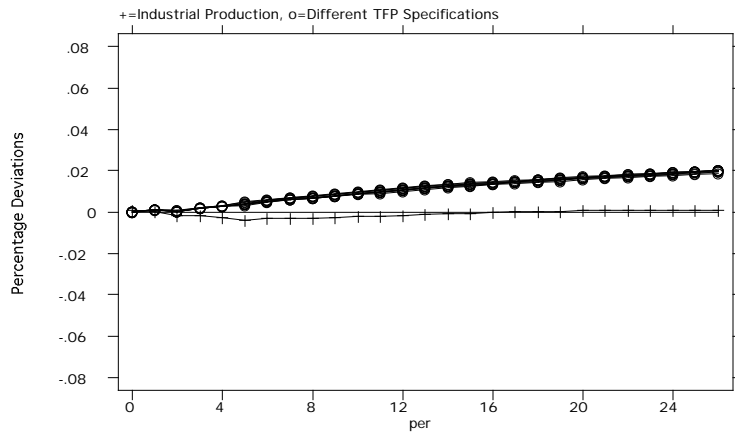


Fig. 6--Food, Oil Price Index Shock

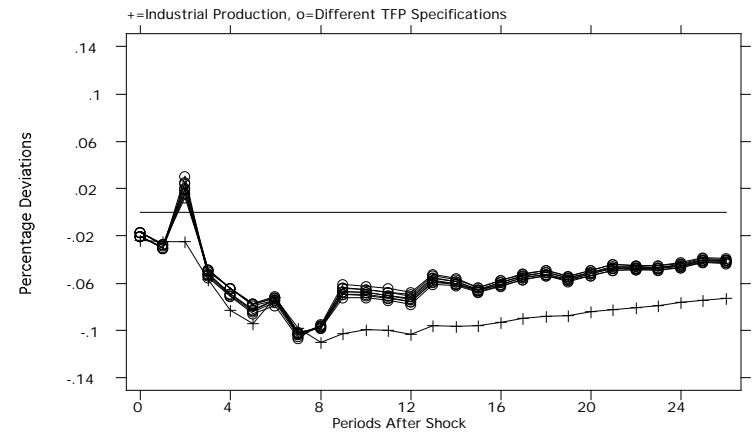


Fig. 6--Petroleum, Oil Dummy Shock

Figure 7 -- Monetary FFR Shock

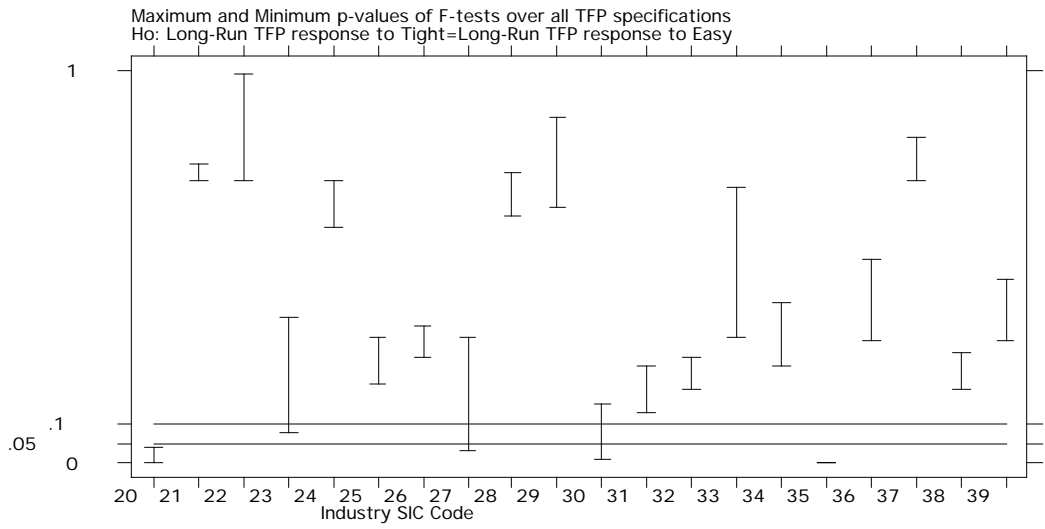


Figure 7 -- Total Spending Shock

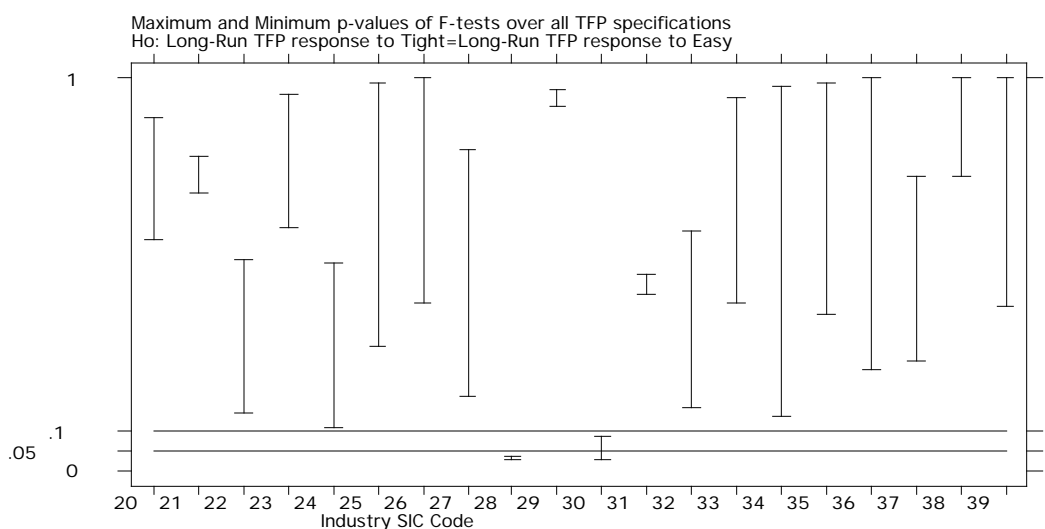


Figure 7 -- Tax Shock

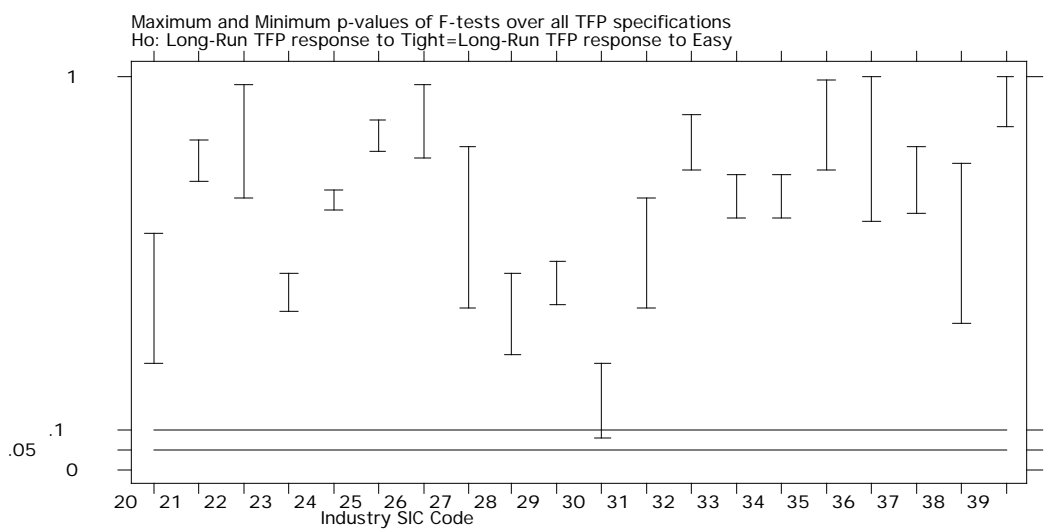


Fig. 8--Industrial Production

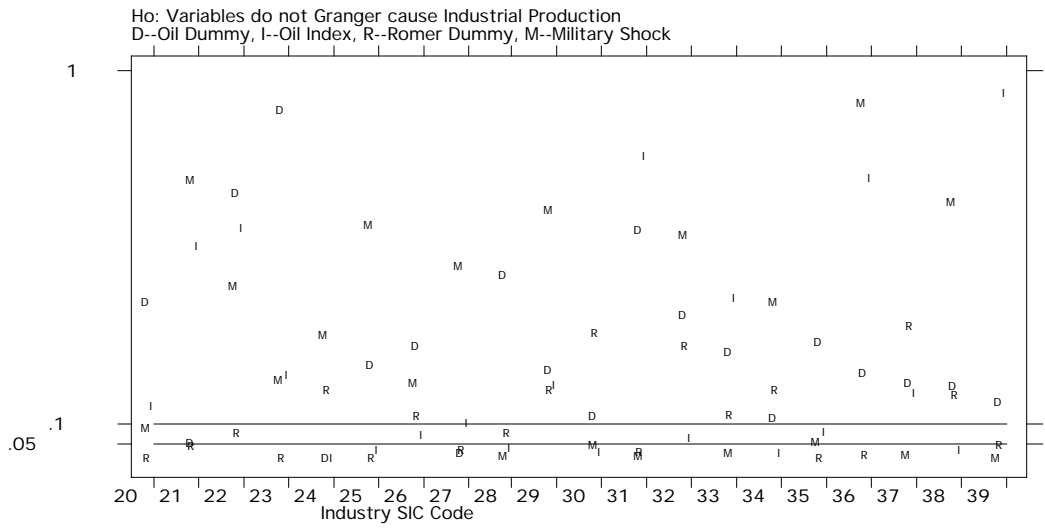


Fig. 8--Job Creation

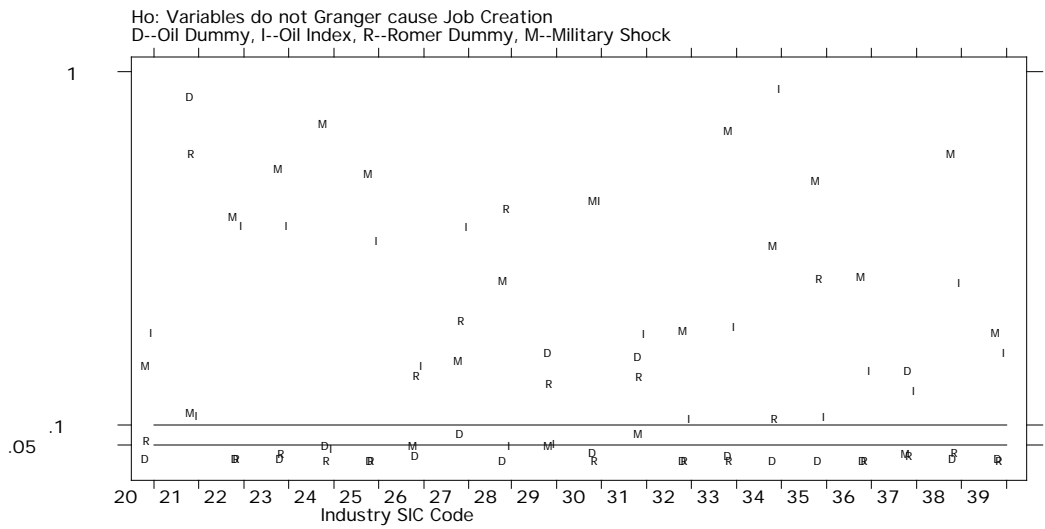


Fig. 8--Job Destruction

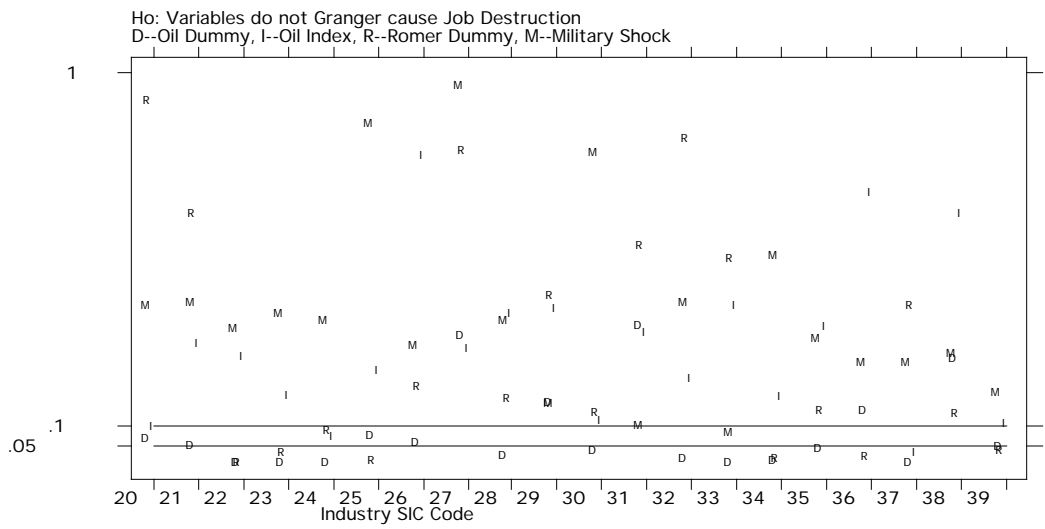


Figure 9--Romer Dummy  
p-values

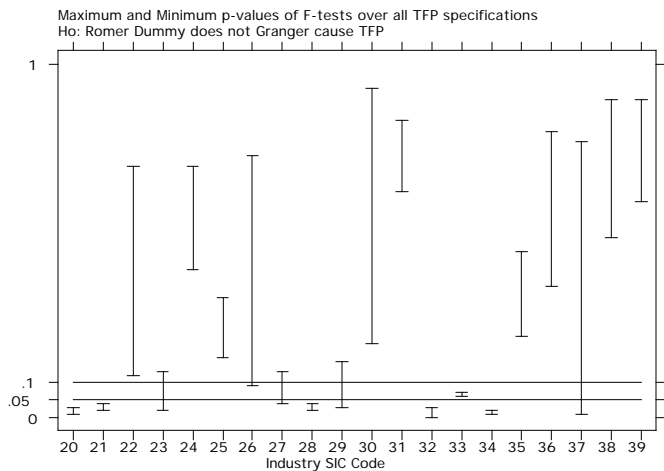


Figure 9--Military Spending  
p-values

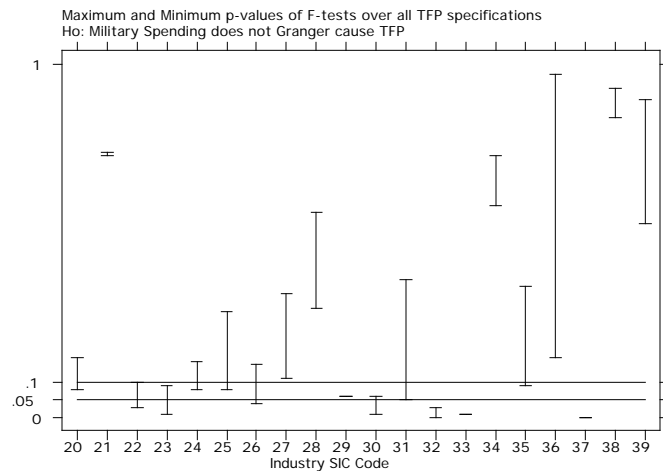


Figure 9--Oil Price Index  
p-values

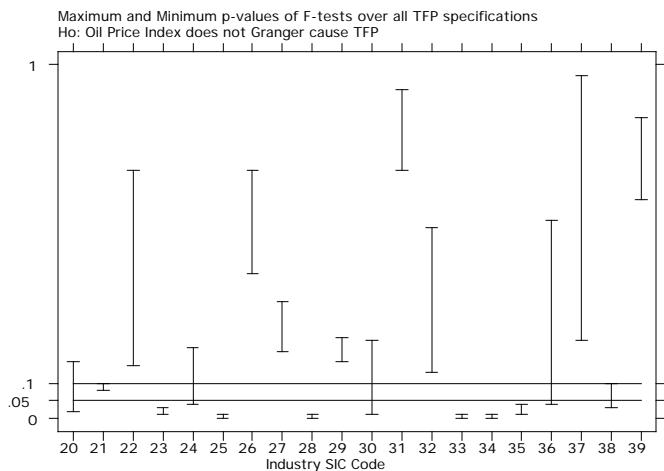


Figure 9--Oil Dummy  
p-values

