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Understanding the Effects of a Shock to Government Purchases

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Abstract

This paper investigates the consequences of an exogenous increase in U.S. government purchases. We find that in response to such a shock, employment, output, and nonresidential investment rise, while real wages, residential investment and consumption expenditures fall. The paper argues that a simple variant of the neoclassical growth model which distinguishes between nonresidential and residential investment is consistent with this evidence.

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1. Introduction

This paper investigates the consequences of an exogenous increase in U.S. government purchases. Consistent with results in Ramey and Shapiro (1997) we find that, in response to such a shock, employment, output, and nonresidential investment rise, while real wages, residential investment and consumption expenditures fall. We argue that a simple variant of the neoclassical growth model which distinguishes between nonresidential and residential investment is consistent with this evidence.

There are various reasons to be interested in what happens to the economy after an exogenous increase in government purchases. We focus on this question because the answer to it is useful as part of a particular limited information strategy for assessing the empirical plausibility of competing business cycle models. The essence of this strategy is to compare the predictions of different models for how the economy responds to a particular shock.¹

To be a useful part of such a diagnostic strategy, a shock must satisfy three criteria. First, different models must react differently to the shock. Second, we must understand the nature of the experiment involved. For example, does the candidate shock lead to transitory or persistent changes in the variable that has been shocked? Third, we must know how the actual economy responds to such a shock.

Shocks to government purchases clearly satisfy the first criterion.² It is well known that different models react differently to exogenous changes in government purchases.³ In the neoclassical models analyzed by Aiyagari, Christiano and Eichenbaum (1992), Christiano and Eichenbaum (1992), Baxter and King (1993) and Burnside and Eichenbaum (1996) an exogenous increase in government purchases, financed by lump sum taxes, raises output and the real interest rate but reduces consumption and real wages.⁴ In the multisector models of Phelan and Trejos (1996) and Ramey and Shapiro (1997), an exogenous increase in government purchases can lead to

¹See Christiano, Eichenbaum and Evans (1997) as well as the references therein for a discussion of this strategy as applied to exogenous monetary policy shocks.

²Here and throughout the paper, the term government purchases refers to government consumption, i.e. purchases of goods and services that are not used to augment the stock of nonmilitary capital.

³See Ramey and Shapiro (1997) for a useful summary of the literature.

⁴Aiyagari, Christiano and Eichenbaum (1992) point out that the sign of the response of the interest rate depends on the utility function of the representative consumer.

either a rise or a fall in real wages, depending on how they are measured. In addition, sectoral output may rise or fall depending on the sector in question. Rotemberg and Woodford (1992) study the effects of changes in government purchases in a model which incorporates increasing returns and oligopolistic pricing. In sharp contrast to the one sector models above, their model implies that a positive shock to government purchases raises real wages. Similarly, in Devereux, Head and Lapham's (1996) model, which also assumes the presence of increasing returns and imperfect competition, an exogenous increase in government purchases raises private consumption and real wages.

While shocks to government purchases satisfy the first criterion, it is less clear that they satisfy the second and third criteria. As Ramey and Shapiro (1997) stress, there has been relatively little work done on identifying the effects of exogenous shocks to government purchases on the economy. Three important exceptions are the studies by Blanchard and Perotti (1998), Rotemberg and Woodford (1992) and Ramey and Shapiro (1997). Blanchard and Perotti (1998) use institutional information about the tax and transfer systems in different countries to construct an exactly identified Vector Autoregression (VAR) for real output, taxes and government purchases. This allows them to identify the effects of fiscal shocks on total output. While certainly of interest, their study does not directly help to discriminate between the competing models discussed above. This is because all of those models predict that real output should rise after an exogenous increase in government purchases. Rotemberg and Woodford (1992) identify exogenous movements in government purchases with statistical innovations to defense purchases in a VAR that contains a small list of variables. In contrast, Ramey and Shapiro (1997) use the 'narrative approach' to isolate political events that led to three large military buildups which were arguably unrelated to developments in the domestic U.S. economy. Throughout this paper we refer to their estimates of the dates at which these events began as the Ramey-Shapiro episodes. The basic strategy underlying Ramey and Shapiro's empirical analysis is to examine the behavior of the U.S. economy after the onset of these episodes.

In our view there are at least three reasons for being skeptical of VAR based innovations to real defense purchase as measures of exogenous shocks to government purchases. First, the estimated innovations may reflect shocks to the private sector that cause defense contractors

to optimally rearrange delivery schedules, say because of strikes or other developments in the private sector. Indeed according to Ramey and Shapiro (1997, page 40) “... many of the disturbances in the VAR approach are due solely to timing effects on military contracts and do not represent unanticipated changes in military spending.” Second, private agents and the government may know about a planned increase in defense purchases well before it is recorded in the data. For example, suppose that at time t the fiscal authority receives information that causes it to commit to a stream of defense purchases in the future, say because North Korea attacks South Korea. The space spanned by the variables in a small VAR may not contain this information. Under these circumstances an econometrician will uncover, at best, a polluted measure of exogenous shocks to government purchases. Finally, inference using innovation based measures of shocks to government purchases appears to be quite fragile to perturbations in the sample period used as well as the list of variables included in the VAR (see Christiano (1990)).

For these reasons, we adopt an extended version of the Ramey-Shapiro approach in our empirical work. Our main findings are that in response to an expansionary shock in government purchases:

- defense expenditures as well as total government purchases rise,
- output rises, both in the aggregate and in all sectors that we look at,
- real wages fall,
- nonresidential investment rises sharply,
- residential investment declines sharply,
- after a delay, purchases and production of consumer durables and nondurables fall,
- real interest rates initially fall but then rise.

A novel feature of our analysis is that we attempt to confront uncertainty about the actual dates at which the Ramey-Shapiro episodes began. That there is uncertainty about the dates is evident once we recognize that the key issue is when U.S. economic agents understood that a

military buildup was going to begin. It is one thing to know when the North Koreans attacked South Korea. However, ascertaining when economic agents knew that the U.S. was going to respond is a far more subtle empirical issue. To deal with this issue, we provide evidence that our results are robust to date uncertainty. At the same time we also document that the Ramey-Shapiro dates are unusual relative to other, arbitrarily selected dates in the sample. These findings support the interpretation that we have isolated the response of the U.S. economy to exogenous increases in government purchases per se.

Taking this interpretation as given, we develop a modified version of the one sector neoclassical growth model to interpret our estimated response functions. Our modifications are motivated by the following issues. First, in the standard one sector growth model, a highly persistent shock to government purchases leads to a large fall in consumption. In the data, however, there is only a small fall in purchases of consumer nondurable goods and services after a Ramey-Shapiro episode. Second, the standard one sector model is silent on the question of why residential investment falls while nonresidential investment rises after a positive shock to government purchases.

To understand our strategy for addressing these issues, recall that in the standard neoclassical growth model, a persistent rise in government purchases raises the present value of the representative household's tax burden. The resulting negative wealth effect increases household's labor supply and lowers the demand for private consumption. As a consequence, equilibrium real wages and private consumption fall while employment increases. With capital and labor being complements in production, investment rises.⁵

With this in mind, we modify the basic model to distinguish between two types of capital. The first type is used to produce goods. Investment in nonresidential capital augments this type of capital. Like any durable consumption good, the second type of capital yields consumption services. Investment in residential structures, i.e. housing, augments this type of capital (for the sake of simplicity, we do not distinguish between durable consumption goods and housing). With this modification, the negative income effect associated with a persistent increase in government

⁵If the rise in government purchases induced by the shock is transitory, employment will rise while investment falls. See section 4 below.

purchases, leads to a *rise* in nonresidential investment, and a substantial fall in consumption service flows. The latter is achieved, in part, by lowering the stock of residential capital and a *fall* in residential investment. As in the standard model, total output rises and real wages fall. We conclude that our model can account for the basic *qualitative* response of the U.S. economy to a persistent shock in government purchases.

While our empirical results are consistent with this simple variant of the neoclassical model, they pose a sharp challenge to models like that of Rotemberg and Woodford (1992) and Devreux, Head and Lapham (1996) in which real wages rise after a positive shock to government purchases. One of the key empirical results in our paper is that real wages fall after such a shock. This is true regardless of whether we analyze aggregate or sector specific real wages. It is also true regardless of whether we consider before or after tax real wages. Finally, this result is robust across the different price indices that we use to construct alternative measures of the real wage. Based on this evidence we conclude that models in which real wages rise after a positive shock to government purchases are inconsistent with the data.

The remainder of this paper is organized as follows. In Section 2 we discuss our methodology for identifying the effects of an exogenous increase in government purchases. Section 3 reports the results of implementing this methodology on post World War II U.S. data. Section 4 presents our model and assesses its ability to account for the empirical findings of Section 3. Finally, Section 5 discusses some shortcomings of our model.

2. Identifying the Effects of Shocks to Government Purchases

Since actual government purchases are highly reactive to the state of the economy, we need to make identifying assumptions to isolate exogenous movements in government purchases, G_t . In practice, many analysts focus on a particular component of G_t : defense purchases, whose time t value we denote by g_t . Authors such as Rotemberg and Woodford (1992) identify a shock to g_t with the residual in a simple ordinary least squares regression of the form,

$$g_t = f(\Omega_t) + \varepsilon_t. \tag{1}$$

Here f is a linear function, Ω_t summarizes the information set available to the fiscal authority when setting its desired value for g_t , and ε_t is a serially uncorrelated shock that is orthogonal to the elements of Ω_t . This orthogonality assumption implies that the fiscal authority sees the elements of Ω_t when it chooses g_t , and that the elements of Ω_t do not respond contemporaneously to ε_t . Rotemberg and Woodford assume that Ω_t consists of past observations on g_t , and lagged values of the number of people employed by the military.⁶

Under these identifying assumptions, ε_t can be estimated by the fitted residuals from an OLS regression of g_t on the elements of Ω_t . The response of any particular variable, say z_t , to a shock in g_t can be estimated by the coefficients in an OLS regression of z_t on current and lagged values of ε_t .

In contrast, Ramey and Shapiro (1997) pursue a ‘narrative approach’ to isolate three arguably exogenous events that led to large military buildups: the Korean War, the Vietnam War and the Carter-Reagan Buildup. Based on their reading of history, they date these events at the third quarter of 1950, the first quarter of 1965 and the first quarter of 1980.⁷ Various econometric procedures can be used to exploit the identifying assumption that exogenous shocks to government purchases occurred at these dates. For example, suppose we define the set of dummy variables D_t , where $D_t = 1$ if $t = \{1950:3, 1965:1, 1980:1\}$ and zero otherwise. Suppose we estimate the parameters of $\gamma(L)$ in the regression equation

$$z_t = \gamma(L)D_t + \varepsilon_t. \tag{2}$$

Here $\gamma(L)$ is a finite ordered polynomial in nonnegative powers of the lag operator L . If the Ramey and Shapiro war dummies are truly exogenous, a consistent estimate of the response of z_{t+k} to an exogenous shock in g_t is given by the estimated coefficient on L^k , γ_k .

Ramey and Shapiro use a modified version of this approach in which they estimate the regression

⁶Rotemberg and Woodford assume there is a time trend in both g_t and the number of people employed by the military.

⁷See Ramey and Shapiro (1997) for a detailed discussion of how these dates were chosen.

$$z_t = a_0 + a_1 t + a_2(t \geq 1973 : 2) + \sum_{i=1}^8 \alpha_i z_{t-i} + \sum_{i=0}^8 \beta_i D_{t-i} + \varepsilon_t, \quad (3)$$

To derive the dynamic response function of z_t to a war dummy, they simulate the estimated version of (3).⁸

An alternative procedure for using Ramey and Shapiro's identifying assumptions is to include D_t as an explanatory variable in a VAR. Suppose that z_t is an element of the vector stochastic process X_t which has the representation:

$$X_t = A(L)X_{t-1} + B(L)D_t + u_t. \quad (4)$$

Here, $A(L)$ and $B(L)$ are finite ordered vector polynomials in nonnegative powers of L whose coefficients can be estimated using equation-by-equation least squares. A consistent estimate of the response of z_{t+k} to an exogenous shock in g_t is given by an estimate of the coefficient on L^k in the expansion of $[I - A(L)L]^{-1} B(L)$.⁹

In our analysis we find it convenient to map the first two-step procedure into an asymptotically equivalent VAR-based procedure.¹⁰ There are two reasons for this. First, estimating dynamic response functions via (2) requires losing a number of initial data points equal to the number of dynamic responses that we wish to estimate. With the VAR procedure we only lose a number of observations equal to the lag length of the VAR. Second, the presence of other variables in the VAR allows us to assess the robustness of the assumption that the Ramey and Shapiro dummy variables are exogenous.

⁸If the Ramey and Shapiro war dummies are truly exogenous, the two approaches just discussed yield asymptotically equivalent results.

⁹Blanchard and Perotti (1998) use a similar strategy to investigate the effect of the 1975:2 tax cut in the U.S.

¹⁰See Eichenbaum (1997) for a comparison of some results obtained using this procedure and the one used in Ramey and Shapiro (1997). There it is shown that the point estimates emerging from the two procedures are very similar.

3. Empirical Results

This section reports our results regarding the consequences to the U.S. economy of an exogenous increase in government purchases. Section 3.1 displays results obtained using the Ramey and Shapiro dummy variables. Section 3.2 explores the sensitivity of our main results to perturbations in the timing of the Ramey-Shapiro dates. Section 3.3 assesses how unusual those dates are relative to randomly selected alternatives.

3.1. Results Using the Ramey and Shapiro War Dummies

The results in this subsection were obtained by incorporating the Ramey and Shapiro (1997) dummy variables into the VAR given by (4). Unless otherwise noted, the vector X_t contains the log level of time t real GDP , the net three month Treasury bill rate, the log of the producer price index of crude fuel, the log level of Ramey and Shapiro's measure of real defense purchases, g_t , and the log level of the variable z_t whose response function we are interested in. Except for results pertaining to after tax real wage rates, all estimates are based on quarterly data from 1948:1 to 1996:1. Due to data limitations, the after tax real wage results are based on quarterly data over the sample period 1948:1 to 1993:4. The appendix contains a description of the data used in our analysis.

This subsection is organized in three sections. Subsection 3.1.1 discusses the response of different types of expenditures, output and employment to a Ramey-Shapiro episode. Subsection 3.1.2 summarizes our findings regarding compensation and real wages. Finally, Subsection 3.3 briefly discusses the response of money, prices and interest rates to a Ramey-Shapiro episode.

3.1.1. Output, Employment, Consumption and Investment

In this subsection, we summarize our evidence regarding the way different sectors of the economy respond to the onset of a Ramey-Shapiro episode. Our key results can be summarized as follows. After a positive increase in government purchases, there is a large, hump shaped increase in real defense expenditures, aggregate output and employment. The rise in output is associated with a broad based expansion of nonresidential investment and a delayed fall in consumption.

As background to our analysis, the upper panel of Figure 1 reports the log of real defense expenditures with the vertical lines at the Ramey-Shapiro episodes. The lower panel of Figure 1 reports the share of defense spending in GDP. Note that the time series on real defense expenditures are dominated by three events: the large increase in real defense expenditures associated with the Korean war, the Vietnam war and the Carter-Reagan defense buildup. The Ramey-Shapiro dummy variables essentially mark the beginning of these episodes.

The four panels of Figure 2 report the responses of real defense spending, real government purchases, real GDP and real private GDP to a Ramey-Shapiro episode. Here government purchases refers to defense spending plus local, state and federal government purchases of consumption goods. In Figures 2-11 the solid lines display point estimates of the coefficients of the dynamic response functions.¹¹ Also, the dashed lines correspond to sixty-eight percent confidence interval bands.¹²

Consistent with results in Ramey and Shapiro (1997), the onset of a Ramey-Shapiro episode leads to a large, persistent, hump shaped rise in defense expenditures: g_t initially rises by about 1%, with a peak response of 30% roughly six quarters after the shock. The response of real government purchases is similar to that of real defense purchases. While the response is smaller, it is still substantial: total government purchases rise in a hump shaped pattern with a peak response of 14% roughly 6 quarters after the shock. Paralleling the response of defense expenditures, there is a delayed, hump shaped response in real GDP, with a peak response of about 3.5% four quarters after the shock. The rise in private real GDP (GDP minus government purchases) is much smaller, with a peak response of about 1.8%.

¹¹With one exception, the impulse response functions are reported in units of percentage point deviations from a variable's unshocked path. The exception is that impulse response functions of interest rates are reported in percentage points (see subsection 3.1.3).

¹²These were computed using a bootstrap Monte Carlo procedure. Specifically, we constructed 500 time series on the vector Z_t as follows. Let $\{\hat{u}_t\}_{t=1}^T$ denote the vector of residuals from the estimated VAR. We constructed 500 sets of new time series of residuals, $\{\hat{u}_t(j)\}_{t=1}^T$, $j = 1, \dots, 500$. The t^{th} element of $\{\hat{u}_t(j)\}_{t=1}^T$ was selected by drawing randomly, with replacement, from the set of fitted residual vectors, $\{\hat{u}_t\}_{t=1}^T$. For each $\{\hat{u}_t(j)\}_{t=1}^T$, we constructed a synthetic time series of Z_t , denoted $\{Z_t(j)\}_{t=1}^T$, using the estimated VAR and the historical initial conditions on Z_t . We then re-estimated the VAR using $\{Z_t(j)\}_{t=1}^T$ and the historical initial conditions, and calculated the implied impulse response functions for $j = 1, \dots, 500$. For each fixed lag, we calculated the 80th lowest and 420th highest values of the corresponding impulse response coefficients across all 500 synthetic impulse response functions. The boundaries of the confidence intervals in the figures correspond to a graph of these coefficients.

Figure 3 displays the responses of various measures of employment to Ramey-Shapiro episode. Notice that private employment rises in a hump shaped pattern which parallels the hump shaped rise in defense and government purchases. The response of employment in the manufacturing sector is qualitatively similar to the response of total private employment, but is larger with a peak rise of roughly 5%. Employment in the durables and nondurables manufacturing sectors both rise, with the rise in the first sector exceeding the rise in the second sector. Finally, Figure 3 indicates that employment in the construction sector and employment by the federal government rises.

Figure 4 displays the response of real expenditures on different categories of consumption and investment to a Ramey-Shapiro episode. A number of important results emerge here. First, consumption expenditures on nondurable goods and services fall after a brief delay. However, the response at all horizons is quite small. Second, there is an initial 6% rise in consumption expenditures on durable goods. However, these expenditures quickly fall below their preshock levels. After 2 years, they are roughly 5% below their preshock level. The combined response of total real consumption expenditures on nondurables, services and durables, depicted in the panel labelled ‘Total Consumption’, is small.

To fully understand the response of consumption, we now consider how investment responds to a Ramey-Shapiro episode. Figure 4 shows that a positive shock to government purchases is followed by a sharp *decline* in residential investment. The peak response occurs roughly 6 quarters after the shock, at which point residential investment is 15% below its preshock level. Since residential investment and durable consumption purchases both represent investments in stocks of capital which yield consumption services, it is natural to consider the combined response of these types of expenditures. From the panel labeled ‘Durables + Residential’, we see that this combination of expenditures initially rises but within two quarters falls below its preshock level. The peak response occurs roughly 2 years after the shock, with expenditures falling roughly 6% relative to their preshock level. Evidently, once we treat investment in housing symmetrically with investment in other consumer durables, there is substantial evidence of a decline in consumption related expenditures.

In sharp contrast to residential investment, Figure 4 shows that a Ramey-Shapiro episode

leads to a persistent *rise* in nonresidential investment. The peak response occurs roughly 6 quarters after the shock, at which point nonresidential investment expenditures are approximately 8% above their preshock level. Given the stark difference in the response paths of residential and nonresidential investment, it is important to understand which components of the latter rise. Figure 5 indicates that *all* types of nonresidential investment - information processing equipment, structures, industrial equipment, producer durable equipment and transportation equipment - rise in response to a Ramey-Shapiro episode.¹³

We conclude from studying Figures 4 and 5 that a positive shock to government purchases induces a broad based expansion in nonresidential investment along with a delayed fall in consumption expenditures. The latter occurs mostly via a reduction in durable consumer good expenditures, defined to include investment in housing. Figure 6, which displays the response of different measures of industrial production (IP) to a Ramey-Shapiro episode, provides corroborating evidence for this view. First, the shock leads to a persistent rise in manufacturing IP. The rise is concentrated in durable manufacturing goods which increases more sharply than output of nondurables manufacturing goods. Consistent with the expenditure data, we see an initial rise in the output of both durable and nondurable consumer goods. However, the increase is small and short lived relative to the rise in total manufacturing and durable goods manufacturing output. Both durable and nondurable consumer goods fall after about 3 quarters, with the peak decline in the former exceeding that of the latter.

3.1.2. Compensation and Real Wages

In this subsection we summarize our evidence regarding the response of compensation and real wages to a Ramey-Shapiro episode. As discussed in the introduction, these results are particularly useful for assessing the empirical plausibility of alternative business cycle models. The key result in this subsection is that every measure of compensation and real wages that we consider *falls* in response to a positive shock to government purchases. This constitutes a strong challenge to claims in the literature that real wages rise in response to an exogenous increase in government purchases (see, for example, Rotemberg and Woodford (1992)). In contrast, this

¹³ After roughly six quarters investment in transportation equipment begins to decline significantly.

result is consistent with neoclassical models which predict that real wages should go down after such a shock because of the negative income effects associated with increases in government purchases.

Figure 7 reports the estimated response functions for six measures of real compensation: compensation per hour in private business (deflated by the CPI, a deflator for private business output and the GDP deflator), and manufacturing (deflated by the CPI, the PPI for manufacturing and the GDP deflator). Note that all six measures of compensation decline. In all cases, the fall in manufacturing compensation exceeds the corresponding fall in private business sector compensation.

Next we consider the response of real wages to a Ramey-Shapiro episode. We do so using both before tax and after tax versions of various real wage measures. Our data on average marginal tax rates are based on the annual tax rates for all sources of income reported in Fairlie and Meyer (1996). These are displayed in Figure 8. In using this data, we assume that tax rates are constant within the year and that they apply to labor income. Note that the tax rate rises around each of the Ramey-Shapiro episodes. Consequently, working with before tax real wages could in principle give misleading results regarding firms' and households' incentives to vary employment in the aftermath of a shock to government purchases.

Figure 9 displays the response of eight measures of real wages to a Ramey-Shapiro episode: before and after tax real wages in the durables goods manufacturing, nondurable goods manufacturing, wholesale trade and construction sectors. Nominal wages are deflated using the CPI.¹⁴ The key result here is that every measure of the real wage falls after a positive shock to government purchases. As expected, the fall in after tax wages is larger than the fall in before tax wages.

Figure 10 displays additional evidence regarding the response of real wages to a Ramey-Shapiro episode. Here we display the response functions of before and after tax real wage rates in the manufacturing sector, calculated using the CPI, the PPI for manufacturing and the GDP deflator. Consistent with Figure 9 each measure of the real wage falls after a positive shock to

¹⁴Our results are very similar if we deflate using the GDP deflator. We could not obtain separate PPI deflators for all these industries.

government purchases. Again the fall is larger for after tax real wages.

Viewed overall, the evidence presented in this subsection strongly supports the view that real wages fall in response to a positive shock to government purchases.

3.1.3. Prices, Money and Interest Rates

In this subsection, we summarize our evidence regarding the behavior of real interest rates following a Ramey-Shapiro episode. As background for our discussion, column 1 of Figure 11 presents the response functions for the GDP deflator, the CPI and M1. Note that after a positive shock to government purchases, there is a persistent increase in all three variables. The peak response in M1 occurs roughly a year after the initial shock, while the peak responses in the GDP deflator and the CPI occur one or two quarters earlier. Additional background is provided by column 2 of Figure 11, which displays the responses of three nominal interest rates: the yield on three month, one year and two year Treasury bills. In all three cases, the interest rate initially falls but then rises.¹⁵

To examine the behavior of the real interest we proceeded as follows. Define the j period ahead real interest rate, $r_{t,j}$, at time t , as

$$r_{t,j} = R_{t,j} - E_t(P_{t+j} - P_t). \quad (5)$$

Here $R_{t,j}$ is the log of the nominal yield on a j quarter bond purchased at time t , P_{t+j} is the log of the *CPI* at time period $t + j$, and E_t denotes the time t conditional expectation operator, which we compute using the estimated *VAR*.

Column 3 of Figure 11 displays the dynamic response functions of this measure of the real interest rate for the 1 quarter rate, the one year rate ($j = 4$), and the two year rate ($j = 8$). Note that the real 1 quarter rate falls sharply for about one year before rising above its preshock level. The real one year interest rate's response is similar to that of the 1 quarter rate except for a smaller initial decline. The two year rate rises more quickly than the one year rate and

¹⁵These response functions were computed substituting the relevant interest rate into the VAR in place of the net three month Treasury bill rate used in the rest of our analysis.

the rise is larger.

Viewed overall, our results provide mixed evidence on the response of the real interest rate to an increase in government purchases. With about a one year delay, all of our real interest rate measures rise after the onset of a Ramey-Shapiro episode. However, substantial care must be taken in interpreting this result. The k period ahead response of $r_{t,j}$ depends on the expected rate of inflation from k periods after the shock to $k + j$ periods after the shock. In considering the response of the two year interest rate one year after the shock, inference depends critically on the ability to reliably estimate the change in the price level between one year after the shock and 3 years after the shock. To the extent that there is bias in the VAR coefficients that push us away from units roots in the price level, this would seriously affect inferences about the response of the price level many periods after the shock. In light of this, we view our interest rate results as suggestive, but hardly definitive.

3.2. Assessing the Robustness of Our Results

In the previous subsection we displayed estimates of the dynamic response of the U.S. economy to an exogenous change in government purchases. There are at least two sources of uncertainty regarding these results. The first is due to sampling uncertainty in the estimated impulse response functions. This source of uncertainty is summarized by the confidence interval bands displayed in the figures discussed above. The second, which we investigate here, is due to uncertainty about the actual dates at which the Ramey-Shapiro episodes began.

The Monte Carlo methods that we used to quantify the importance of sampling uncertainty do not convey any information about ‘date’ uncertainty. This is because they take as given the Ramey and Shapiro dates. One simple way to assess the importance of date uncertainty is to redo our analysis perturbing the Ramey and Shapiro dates. We say that date uncertainty is not important if qualitative inference is robust to small perturbations in the Ramey and Shapiro dates. At the same time, if we obtained the same results regardless of which dates we use in the analysis, we would lose confidence in our interpretation of the results. After all, if it does not matter which dates we use, there would be no reason to interpret the estimated response functions as capturing the effects of an exogenous increase in government purchases per se.

To assess the robustness of inference to perturbations in the Ramey and Shapiro dates, {1950:3, 1965:1, 1980:1}, we conducted the following three experiments.

- *Experiment 1:* Hold the last two Ramey and Shapiro dates fixed. Then redo the analysis of Section 3.1 assuming the actual date of the first episode was $1950:3 + j$, $j = -1, -2, -3, +1, +2, +3$.
- *Experiment 2:* Redo experiment 1 but hold the first and third Ramey and Shapiro dates fixed and perturb the second date.
- *Experiment 3:* Redo experiment 1 but hold the first two dates fixed and perturb the third date.

Figures 12 and 13 report the results of experiment 1 for a subset of the aggregates discussed in the previous section: real GDP, residential investment, nonresidential investment, after tax manufacturing wages (calculated using the CPI), nondurables and services consumption, and total government purchases. As can be seen the effect of date uncertainty regarding the first episode is quite small. Figure 12 reports estimated impulse response functions for nonnegative values of j . The only sensitivities that emerge are as follows. First, if we assume that the Korean war episode actually began in 1951:2, after tax manufacturing real wages fall, but with a three quarter lag. Second, the delayed small decline in nondurables and services that occurs when $j = 0$ becomes a small rise for the other values of j . Still, the basic result regarding nondurables and services is robust: the estimated response is small, regardless of which value of j is used. Figure 13 reports estimated impulse response functions for nonpositive values of j . Again two sensitivities emerge. First, if we assume that the Korean war episode actually began in 1949:4, residential investment rises in response to the military buildup. Second, when j is not equal to zero, there is a small rise in nondurables and services after the increase in government purchases.

Based on this evidence, we conclude that qualitative inference is robust up to misdating of the Korean War episode by one half year in either direction of the Ramey and Shapiro date. In the interests of space we do not report analogs to Figures 12 and 13 for experiments 2 and 3. This is because the estimated impulse response functions were extremely robust to variations in j . In part this reflects the importance of the Korean War episode in generating our results.

3.3. Are the Ramey and Shapiro Episodes Special?

This subsection provides evidence on the response of the economy to Ramey-Shapiro episodes relative to other, arbitrarily selected, time periods.¹⁶ For the sake of concreteness we focus on the response of real GDP, residential investment, nonresidential investment, after tax manufacturing wages, and residential investment plus durable expenditures. We consider the responses of these variables relative to government purchases to emphasize the conditional comovements with government purchases that are induced by the onset of a Ramey-Shapiro episode. In addition, we find it of interest to consider the response of residential minus nonresidential investment.

We proceeded as follows. First, we randomly chose three dates in our sample period, which we refer to as synthetic episode dates. Second, we estimated the dynamic response of the variable in question to the onset of a synthetic episode date using the same methods that were used to estimate the response to a Ramey-Shapiro episode (see Section 2). We repeated this procedure 500 times (sampling dates with replacement) and calculated the 25th lowest and 475th highest values of the corresponding impulse response coefficients across the 500 impulse response functions. These are reported as dashed lines in Figure 14 along with our point estimate of the dynamic response function of the relevant variable obtained using the original Ramey and Shapiro dates. If there was nothing special about the pattern of comovements associated with the Ramey-Shapiro dates, then the estimated impulse responses to those dates ought to lie within the dashed lines.

Notice that for every variable, the estimated response function lies outside the confidence intervals for a subset of the horizons considered. Because this result was marginal in the case of nonresidential investment, we redid the analysis focusing on residential minus nonresidential investment. As can be seen, the estimated response function of this variable lies well outside the confidence intervals for a broad subset of the horizons considered. We conclude that the behavior of residential investment relative to nonresidential investment after the onset of a Ramey-Shapiro episode is unusual relative to other dates in the sample.

¹⁶The Ramey and Shapiro dates enter the VAR's in a statistically significant manner. In particular the null hypothesis that the coefficient on the dummy variable associated with these dates is zero can be rejected at the 1% significance level. However, this result does not bear directly on whether impulse response functions associated with the Ramey and Shapiro dates are unusual relative to those associated with other dates.

Based on this evidence we reject the view that the estimated response functions discussed in Section 3.1 could have plausibly arisen using arbitrarily selected dates for the time dummy variables. There is something special about the Ramey and Shapiro dates. In our view what is special is that they coincide with the onset of exogenous increases in government purchases.

4. Accounting for the Facts

In the previous section we attempted to document the response of the economy to an exogenous increase in government purchases. In this section we interpret our findings using a simple modified version of the one sector neoclassical growth model. The section is divided into three parts. The first subsection describes our theoretical framework, the second subsection describes the way we calibrated the model's parameters and the third subsection discusses the quantitative properties of our model.

4.1. Theoretical Framework

The model which we consider is a variant of the neoclassical growth model modified to allow for both nondurable and durable consumption goods. A representative household ranks alternative streams of consumption services and hours worked according to

$$E_0 \sum_{t=0}^{\infty} \beta^t [\log C_t^* + \eta \log (1 - n_t)]. \quad (6)$$

Here E_0 is the time 0 conditional expectations operator, β is a subjective discount factor between 0 and 1, while C_t^* and n_t denote time t consumption services and the fraction of the household's time endowment devoted to work, respectively.

Consumption services are produced according to the technology:

$$C_t^* = \begin{cases} [\theta C_t^\psi + (1 - \theta) D_t^\psi]^{1/\psi}, & \psi \leq 1, \psi \neq 0 \\ C_t^\theta D_t^{1-\theta}, & \psi = 0 \end{cases} \quad (7)$$

where $0 \leq \theta \leq 1$. The variable C_t denotes time t units of the nondurable consumption good and D_t is the stock of durable consumption goods, which includes the stock of housing. Our

decision to model housing together with other durable consumption goods is motivated by three considerations. First, housing is a durable consumption good. Second, as Figure 4 shows, both residential investment and durable consumption good expenditures fall after the onset of a Ramey-Shapiro episode, although the latter does so with a delay. Finally, for simplicity we thought it worthwhile to assume that the service flows from different durable goods are perfect substitutes in consumption.

The aggregate resource constraint for the economy is given by

$$C_t + I_{D,t} + I_{K,t} + G_t \leq K_t^\alpha [X_t n_t]^{1-\alpha}, \quad 0 < \alpha < 1. \quad (8)$$

Here K_t denotes the beginning of time t stock of market capital, G_t denotes time t government purchases, $I_{K,t}$ denotes time t investment in market capital, $I_{D,t}$ denotes time t investment in household durable goods, and X_t represents the time t state of technology. Throughout we assume that government purchases are financed by lump sum taxes.

The stocks of market capital and durable consumption goods evolve according to:

$$\begin{aligned} K_{t+1} &= (1 - \delta_K)K_t + I_{K,t}, \quad 0 < \delta_K < 1, \\ D_{t+1} &= (1 - \delta_D)D_t + I_{D,t}, \quad 0 < \delta_D < 1. \end{aligned} \quad (9)$$

Relation (8) and the second equation in (9) embeds the assumption, made for simplicity, that the technology for producing housing stocks and other consumer durable goods are identical.

Technology evolves in the following deterministic fashion,

$$X_t = \gamma^t, \gamma \geq 1, \quad (10)$$

while government purchases evolves according to

$$G_t = X_t g_t. \quad (11)$$

We assume that $\log(g_t)$ has a finite ordered $ARMA(p, q)$ representation:

$$A(L)\log(g_t) = B(L)\epsilon_t, \quad (12)$$

where $A(L)$ and $B(L)$ are finite ordered polynomials in nonnegative powers of the lag operator L . The roots of $A(L)$ are all assumed to lie outside the unit circle and ϵ_t is an iid shock that is orthogonal to all model variables dated time $t - 1$ and earlier.

It is convenient to define:

$$c_t = \frac{C_t}{X_t}, \quad d_t = \frac{D_t}{X_t}, \quad k_t = \frac{K_t}{X_t}, \quad (13)$$

as well as

$$u(c_t, d_t, 1 - n_t) = \log \left[\theta c_t^\psi + (1 - \theta) d_t^\psi \right]^{1/\psi} + \eta \log(1 - n_t). \quad (14)$$

Under the assumption of perfect competition and complete markets, the competitive equilibrium allocation for our model economy is given by the solution to the planning problem:

Maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, d_t, 1 - n_t) \quad (15)$$

subject to

$$c_t + \gamma d_{t+1} - (1 - \delta_D) d_t + \gamma k_{t+1} - (1 - \delta_K) k_t + g_t = k_t^\alpha n_t^{1-\alpha}, \quad (16)$$

(12) and (14). The maximization is by choice of contingency plans for $\{c_t, d_t, k_{t+1}, n_t\}$ over the elements of the planner's time t information set which we assume includes all model variables dated time t and earlier. Given the solution to this problem, we can obtain the competitive equilibrium allocation for C_t , D_t , and K_t using (10) and (13).

We solve the model using the log linear approximation discussed in Christiano (1998). Given the competitive equilibrium quantity allocation, the equilibrium real wage rate and one period ahead ex post interest rate are given by

$$w_t = (1 - \alpha) X_t (k_t/n_t)^\alpha, \quad \text{and} \quad (17)$$

$$r_{t,1} = \alpha (n_{t+1}/k_{t+1})^{1-\alpha} + (1 - \delta_K)$$

respectively.

4.2. Model Calibration

In this subsection we briefly describe the way we calibrated the model's parameters. Following Fisher (1997) we set $\beta = 1.03^{-1/4}$, $\gamma = 1.004$, $\alpha = 0.237$, $\delta_K = 0.021$ and $\delta_D = 0.022$. The parameter η was set to imply that in nonstochastic steady state the representative consumer spends 30% of his time endowment working. This yielded a value of η equal to 2.74. To assess the robustness of our results, we considered three values of the parameter ψ , which controls the degree of substitutability between C_t and D_t in the production of C_t^* . For each value of ψ , we chose θ so that the nonstochastic steady state value of D/K equals 0.78. This is the sample average of the corresponding number in the postwar U.S. data (see Fisher (1997)).¹⁷ We report results for three values of ψ and corresponding values of θ :

| ψ | θ |
|--------|----------|
| 0 | 0.71 |
| 0.5 | 0.89 |
| -1.0 | 0.16 |

The unconditional mean of the process $\log(g_t)$ was set to 0.117, which implies a nonstochastic steady state value of G/Y equal to 0.21. This is equal to the average value of G/Y over our sample period, where G is defined as total real defense purchases plus total real government (federal, state and local) non defense consumption expenditures and Y equals real GDP. Given our parameter values, the nonstochastic steady state values of the key stationary model variables are

| C/Y | I_K/Y | I_D/Y | G/Y | n |
|-------|---------|---------|-------|------|
| 0.46 | 0.18 | 0.15 | 0.21 | 0.30 |

¹⁷The analog number reported in Greenwood and Hercowitz (1991) is 1.13. The numbers differ because Greenwood and Hercowitz (1991) ignore government capital in their analysis.

To assess the empirical plausibility of our model, we compare its response to an exogenous shock in G_t to the analog response functions discussed in Section 3. To this end, we consider three parameterizations of $A(L)$ and $B(L)$, the first two of which are useful primarily for pedagogical purposes.

Parameterization 1

Here $\log(g_t)$ is assumed to be iid:

$$A(L) = 1, \quad B(L) = 1. \tag{18}$$

Parameterization 2

Here we suppose that $\log(g_t)$ is an AR(1) process:

$$A(L) = 1 - 0.9L, \quad B(L) = 1. \tag{19}$$

Parameterization 3

While parameterizations 1 and 2 are useful for understanding the dynamic properties of our model, they are not useful for assessing its empirical plausibility. This is because the actual response path of G_t induced by a shock to government purchases is inconsistent with the paths implied by (18) and (19). One way to ensure such consistency is to assume that $\log(g_t)$ evolves according to a univariate moving average representation whose coefficients are given by the estimated dynamic response function to a Ramey-Shapiro episode.¹⁸ Note that this representation is valid *only* for assessing the ability of the model to account for the response of the economy to an exogenous shock to government purchases. In particular, it would be inappropriate to compare the unconditional second moment properties of the model under this representation for $\log(g_t)$ to the unconditional second moments of the data.

¹⁸This claim can be established using arguments identical to those made in Christiano, Eichenbaum and Evans (1998) with reference to monetary policy shocks.

With the previous considerations in mind we adopt as our third parameterization

$$A(L) = 1, \tag{20}$$

B_j : estimated response of real government purchases
at $t + j$ to the onset of a Ramey-Shapiro episode at time t .

The first 16 B_j coefficients that we used are depicted in the top row of the second column of Figure 2. In solving the model, we actually used the first 50 coefficients of the estimated impulse response of real government purchases to the onset of a Ramey-Shapiro episode. Subject to the specification error entailed in approximating an infinite ordered polynomial with a finite number of lags, this ensures that the experiment being conducted in the model coincides with the experiment which we claim to have isolated in the data. Consequently, if our model has been specified correctly, the dynamic consequences of a shock to government purchases should be the same (aside from sampling uncertainty) in our model as in the data.

4.3. Quantitative Results

Figures 15, 16 and 17 summarize the dynamic response of our model economy to a shock to government purchases when $A(L)$ and $B(L)$ are given by (18)-(20), respectively.¹⁹ In the first two cases, we consider a shock equal to a one percent positive deviation of G_t from its nonstochastic steady state growth path. For the third case, the shock is equal to unity. In each case we present results for $\psi = (0, 0.5, -1.0)$. To understand these results, recall that the key effect, in our model, of an increase in government purchases, is a decline in the representative household's permanent income.

In the case of the iid shock to government purchases displayed in Figure 15, this effect is very small. As a consequence, the shock has a very small effect on hours worked, the real wage rate and the interest rate. The household wishes to smooth the flow of consumption services that it enjoys over time. Consistent with the results displayed in figure 15, the optimal way to

¹⁹Note that the response labelled 'Consumption' corresponds to purchases of nondurable consumption goods, C_t , not consumption services, C_t^* .

do this in the face of a small, transitory shock in income is to reduce market investment ($I_{K,t}$) and investment in household durable goods ($I_{D,t}$). By doing this the household can free up resources to minimize the fall in nondurable consumption purchases. Since the flow of services from durables is determined by the stock of durables, it too falls by a relatively small amount. It follows that total consumption services (not displayed in Figure 15) falls by a relatively small amount. The optimal ratio of the decline in nondurable and durable consumption services is determined by the value of ψ . Nevertheless, the qualitative features of the response functions are very similar across the three values of ψ which we considered. Finally, it is worth emphasizing that a key feature of these response functions is that, in the case of a small transitory positive shock to government purchases, *both* $I_{K,t}$ and $I_{D,t}$ decline.

Consider next Figure 16, which corresponds to the case in which $\log(g_t)$ is an AR(1) process with AR coefficient equal to 0.9. Here the initial positive shock to g_t is associated with a non-trivial decline in the household's permanent income. Since leisure is a normal good, equilibrium employment rises. In the impact period of the shock, the stock of market capital is fixed. With employment up, the marginal product of labor falls and hence real wages do also. Consistent with results in Aiyagari, Christiano and Eichenbaum (1992), the household finds it optimal to reduce consumption and increase market investment. The easiest way to see the reason for the latter is to consider the case of a permanent rise in government purchases. In this case the steady state value of hours worked rises. Given our other assumptions, the steady state value of (k/n) does not change, so that k must rise. To build up the higher steady state stock of k , actual investment must initially exceed its new, higher steady state value. The same basic forces apply in the face of a persistent, but not permanent, increase in government purchases. The household must work harder for a number of time periods to pay its larger tax bill. Since hours worked and market capital are complements, the household initially increases $I_{K,t}$ in response to the shock. To reduce the flow of consumption services it enjoys, the household reduces consumption of nondurables and the service flow from durables goods. To accomplish the latter it reduces $I_{D,t}$. So, in response to a persistent increase in government purchases, $I_{K,t}$ rises while $I_{D,t}$ falls. Recall that this was a key feature of our empirical results.

It is interesting to note that the shock leads to a hump shaped response in hours worked as

well as output. This reflects the fact that market capital and hours worked are complements in production. The maximal rise in hours worked occurs after the extra capital induced by the rise in $I_{K,t}$ becomes available. The hump shaped pattern in hours worked and market capital generates a hump shape pattern in output. Finally, consistent with results in Aiyagari, Christiano and Eichenbaum (1992), the real interest rate rises, but by a very small amount.

Figure 17 depicts the response of the economy to a shock to government purchases given by our third parametrization of $A(L)$ and $B(L)$. Notice that Figures 16 and 17 have very similar qualitative features. This is because, in our model, what is important about a shock to g_t is its impact on the present value of household's tax burden. This impact is larger for the third parameterization, and its effects are correspondingly larger. The qualitative effects on the model economy are very similar however. So again the model can account for the fact that, in response to a persistent shock to g_t , consumption, real wages, and $I_{D,t}$ decline, while hours worked, output, $I_{K,t}$ and the real interest rate rise.

5. Conclusion

This paper analyzed the effect of a positive shock to real government purchases on the U.S. economy. Consistent with results in Ramey and Shapiro, (1997) we find that in response to such a shock, total government purchases, employment, output and nonresidential investment rise, while real wages, residential investment and, after a slight delay, consumption expenditures on nondurable goods and services and durable goods fall. The negative response of real wages is particularly useful for discriminating between alternative business cycle models. Models which stress the importance of increasing returns to scale and imperfect competition predict that a positive shock to government purchases drives real wages up. In contrast, simple neoclassical growth models predict that real wages should fall in response to such a shock. Our findings cast doubt on the empirical plausibility of the first class of models and provide support for the second class of models.

We also argued that a simple variant of the neoclassical growth model can account for the finding that residential investment falls while nonresidential investment rises in response to an

increase in government purchases. The key modification was to model residential investment as a form of investment in the stock of durable consumption goods.

While successful on a variety of dimensions, our model suffers from important shortcomings. First, the model inherits the well known inability of simple complete market representative consumer models to account for the observed time series behavior of asset returns. These failures manifest themselves here in the response of the real interest rate to a shock to government purchases. Roughly speaking, the model predicts that the real interest rate is unaffected by a shock to government purchases. Second, the model based dynamic response functions of residential and non residential investment do not exhibit the persistent, hump shaped patterns that characterize our estimated response functions. The second shortcoming is reminiscent of Greenwood and Hercowitz's (1991) finding that Real Business Cycle models cannot account for some key features of the dynamic paths of household and business capital in response to an aggregate technology shock. It would be interesting to enrich our model by allowing for differential costs of adjusting residential and nonresidential investment. It is possible, but far from certain, that plausible adjustment costs could remedy this aspect of the model's shortcomings.

We conclude by noting a potentially important limitation of our analysis. There is clear evidence that average marginal tax rates on income rose after the onset of the Ramey-Shapiro episodes (see Figure 8). However we evaluated our model under the assumption that taxes are lump sum in nature. Allowing for a rise in marginal tax rates could very well affect the empirical performance of our model. This is because higher tax rates would dampen the positive response of employment and output associated with increases in government purchases (see for example Baxter and King (1993)). An important set of tasks that we leave to future research are (i) finding out which taxes, e.g. labor versus capital income taxes, rose after the Ramey-Shapiro episodes, (ii) incorporating these into our model, and (iii) assessing the net effect of an increase in government purchases when offsetting tax changes are taken into account.

Data Appendix

Our data are from four main sources. Below we list the series which correspond to each of these sources. All series are seasonally adjusted except for interest rates. Most of these series were obtained by us from the Federal Reserve Board's macroeconomic database. Where possible we provide the mnemonic for the same series from the commercially available DRI BASIC Economics Database.

1. Bureau of Economic Analysis. GDP (GDPQ), Defense spending (GGFEQ), Government purchases (Defense spending plus Federal, State and Local consumption expenditures) (GGFEQ+GGOCEQ+GGSCPQ), Private GDP (GDP–Government purchases), Nondurable goods and services consumption expenditures (GCNQ+GCSQ), Durable goods consumption expenditures (GCDQ), Total consumption (the sum of nondurables, services and durables expenditures) (GCQ), Residential investment (GIRQ), Nonresidential investment (GIRQ), Nonresidential structures investment, Producer durable equipment investment, Information processing equipment investment, Industrial equipment investment, Transportation equipment investment, GDP deflator (GDP/GDPQ). The quantity series are all in units of 1992 chain-weighted dollars with the exception of the components of nonresidential investment which are the chain-weighted quantity indexes. The latter were downloaded directly from www.stat-usa.gov.
2. Bureau of Labor Statistics (BLS).
 - Employment – Total private (LP), Manufacturing (LPEM), Construction (LPCC), Durable manufacturing (LPED), Nondurable manufacturing (LPEN), Federal government (LPGOVF)
 - Compensation – Real compensation per hour in business sector (LBCP7), Real compensation per hour in manufacturing sector (LCPM7). Note that these compensation series are the nominal compensation series deflated by the BLS using the consumer price index for all urban consumers. We obtained the alternative real compensation series used in our analysis by inflating the BLS compensation series by the CPI and then deflating by the indicated price series.

- Wages – Manufacturing (LEHM), Durable goods manufacturing (LE6HMD, seasonally adjusted using the Census X-11 procedure), Nondurable goods manufacturing (LE6HMN, seasonally adjusted using the Census X-11 procedure), Wholesale Trade (LEHTW), Construction (LEHCC)
 - Prices – Consumer price index for all urban consumers (PUNEW), Producer price index for the manufacturing sector (PWM), Private business deflator (LBGDP), Producer price index for crude fuel in manufacturing industries (PW1310).
3. Board of Governors of the Federal Reserve System. Net 3 month Treasury Bill secondary market interest rate (FYGM3), M1 (FM1), Industrial Production – Manufacturing (IPMFG), Consumer Goods (IPC), Durable Manufacturing (IPD), Durable Consumer Goods (IPCD), Nondurable Manufacturing (IPN), Nondurable Consumer Goods (IPCN).
 4. Robert Bliss, Federal Reserve Bank of Atlanta. Zero coupon yields on 3 month, 1 year and 2 year treasury securities.

References

- Aiyagari, R., Christiano, L. and M. Eichenbaum, “The Output, Employment and Interest Rate Effects of Government Consumption”, *Journal of Monetary Economics* **30** (1992), 73-86.
- Baxter, M. and R.G. King, “Fiscal Policy in General Equilibrium”, *American Economic Review* **83** (1993), 315-334.
- Blanchard, O. and R. Perotti, “An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output”, manuscript, MIT, 1998.
- Burnside, C. and M. Eichenbaum, “Factor Hoarding and the Propagation of Business Cycle Shocks”, *American Economic Review* **86** (1996), 1154-1174.
- Christiano, L. J., Handout for Comment on “Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity” by J. Rotemberg and M. Woodford, NBER Economic Fluctuations Meetings, Palo Alto, California, 1990.
- Christiano, L.J., “Solving Dynamic Equilibrium Models by a Method of Undetermined Coefficients”, NBER Technical Working Paper, No. 225, 1998
- Christiano, L.J. and M. Eichenbaum, “Current Real Business Cycle Theories and Aggregate Labor Market Fluctuations,” *American Economic Review* **82** (1992), 430-450.
- Christiano, L.J., Eichenbaum, M. and C. Evans, “Monetary Policy Shocks: What Have We Learned and to What End?”, forthcoming, *Handbook of Monetary Economics*, Michael Woodford and John Taylor eds, 1997.
- Christiano, L.J., Eichenbaum, M. and C. Evans, “Modelling Money”, NBER Working Paper No. 6371, 1998.
- Devereux, M.B., Head, A.C. and M. Lapham, “Monopolistic Competition, Increasing Returns, and the Effects of Government Spending”, *Journal of Money, Credit and Banking* **28** (1996), 233 - 254.

- Eichenbaum, M., “Comment on ‘Costly Capital Reallocation and the Effects of Government Spending’ by Valerie A. Ramey and Matthew D. Shapiro”, forthcoming *Carnegie Rochester Conference on Public Policy*, 1997.
- Fairlie, R.W., and B.D. Meyer, “Trends in Self-Employment Among White and Black Men: 1910-1990”, manuscript, Northwestern University, 1996.
- Fisher, J.D.M. “Relative Prices, Complementarities and Comovement Among Components of Aggregate Expenditures”, *Journal of Monetary Economics* **39** (1997), 449-474.
- Greenwood, J. and Z. Hercowitz , “The Allocation of Capital and Time Over the Business Cycle”, *Journal of Political Economy* **99** (1991), 1188 - 1214.
- Ramey, V. and M. Shapiro, “Costly Capital Reallocation and the Effects of Government Spending”, forthcoming *Carnegie Rochester Conference on Public Policy*, 1997.
- Phelan, C. and A. Trejos, “The Aggregate Effects of Sectoral Reallocation”, manuscript, Northwestern University, 1996.
- Rotemberg, J. and M. Woodford, “Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity”, *Journal of Political Economy* **100** (1992), 1153-1297.

Figure 1: Post World War II U.S. Defense Purchases

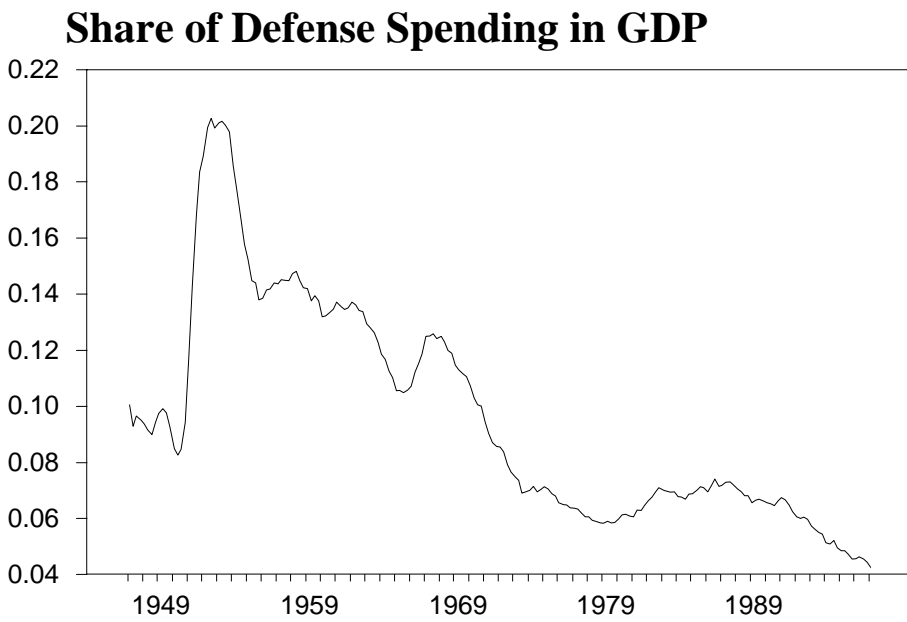
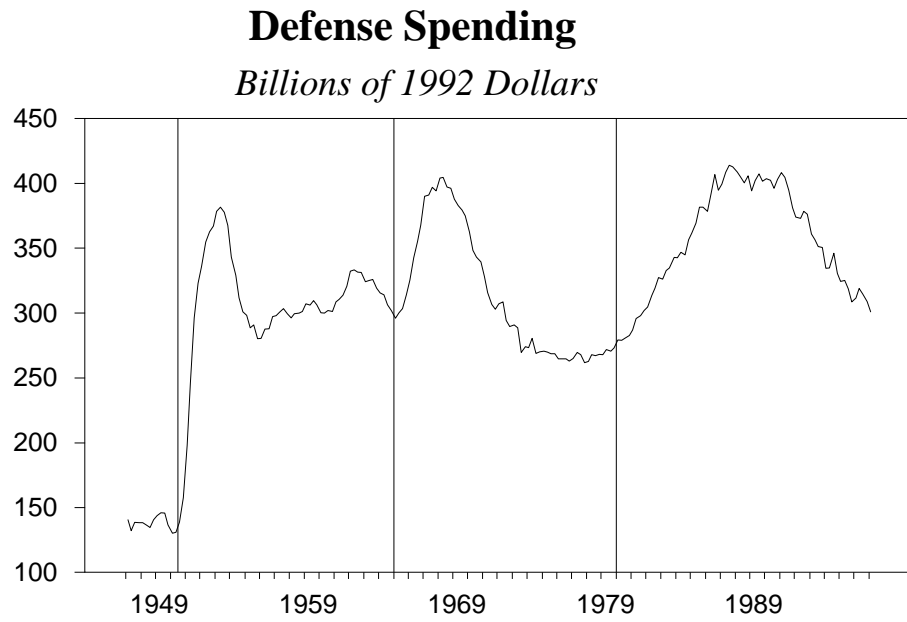


Figure 2: Responses of Government Purchases and Output

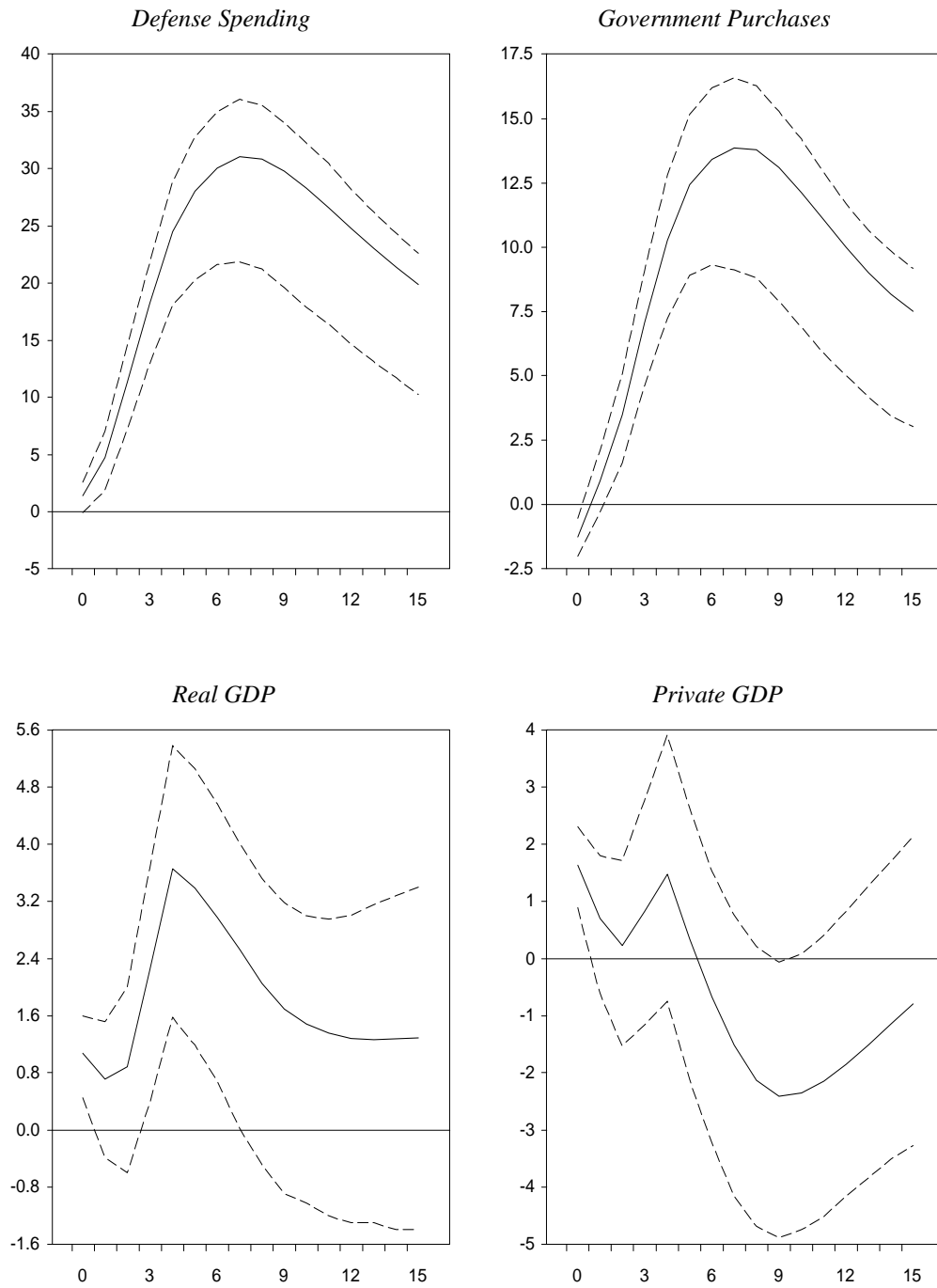


Figure 3: Responses of Employment

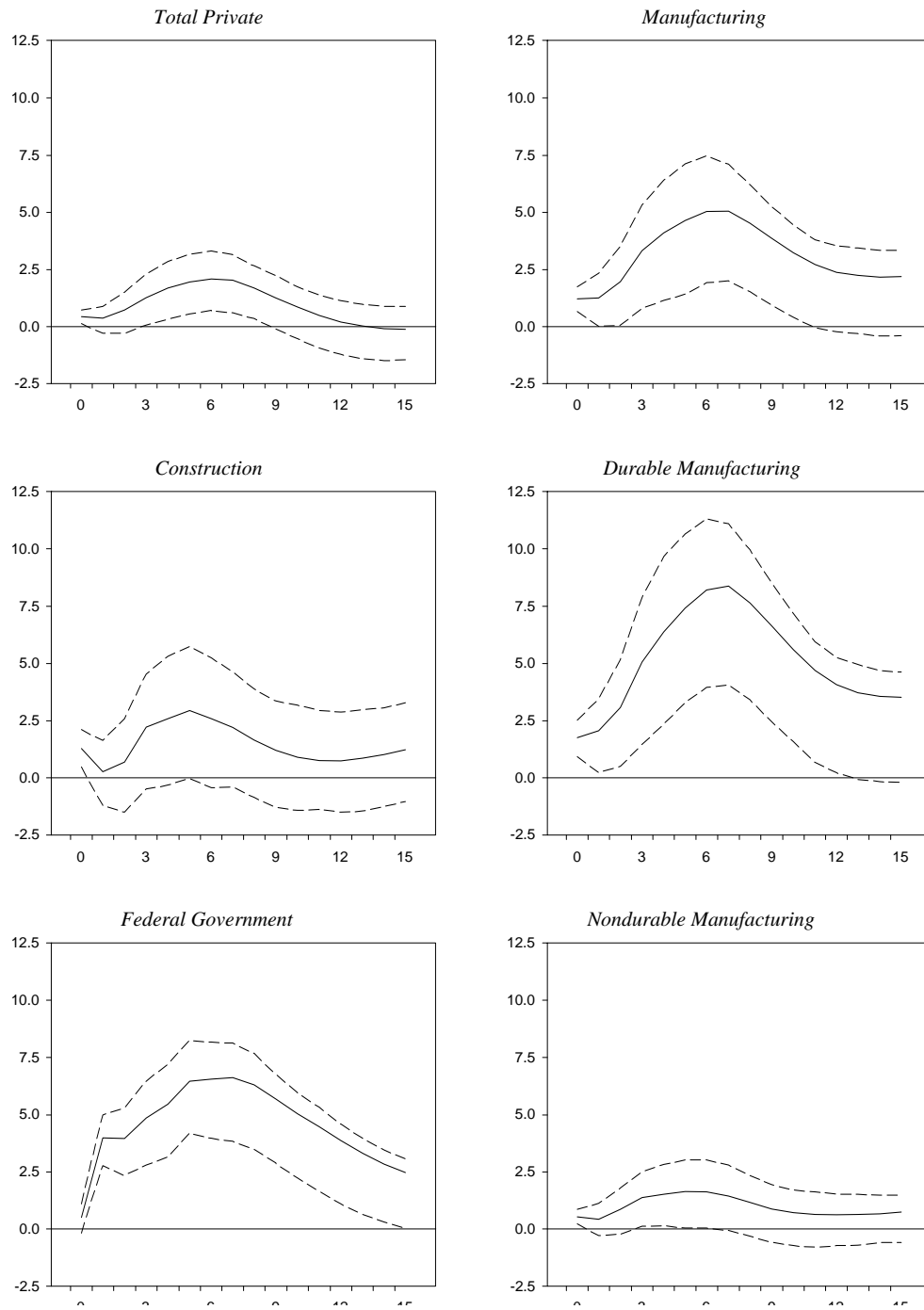


Figure 4: Responses of Consumption and Investment

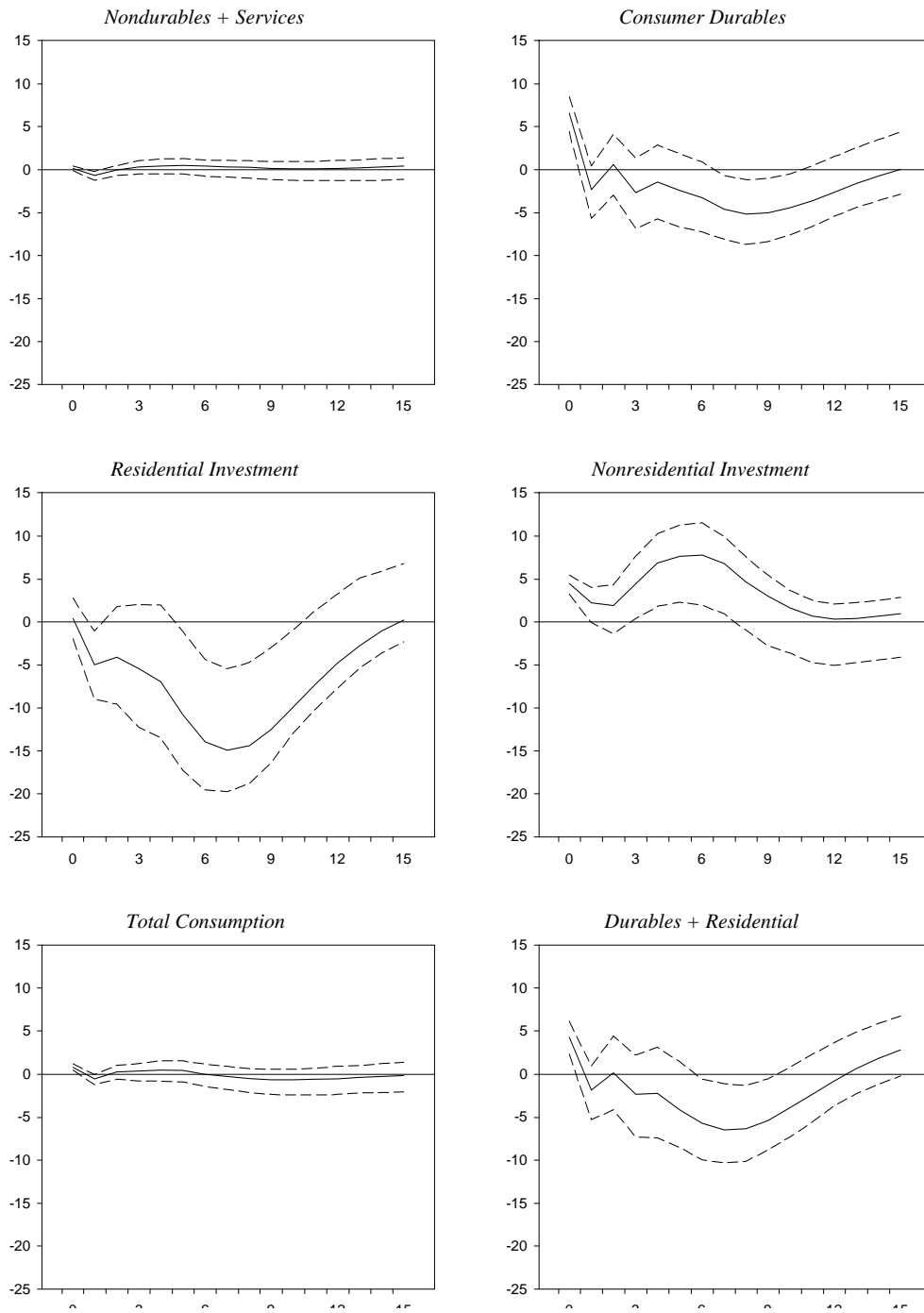


Figure 5: Responses of Different Types of Nonresidential Investment

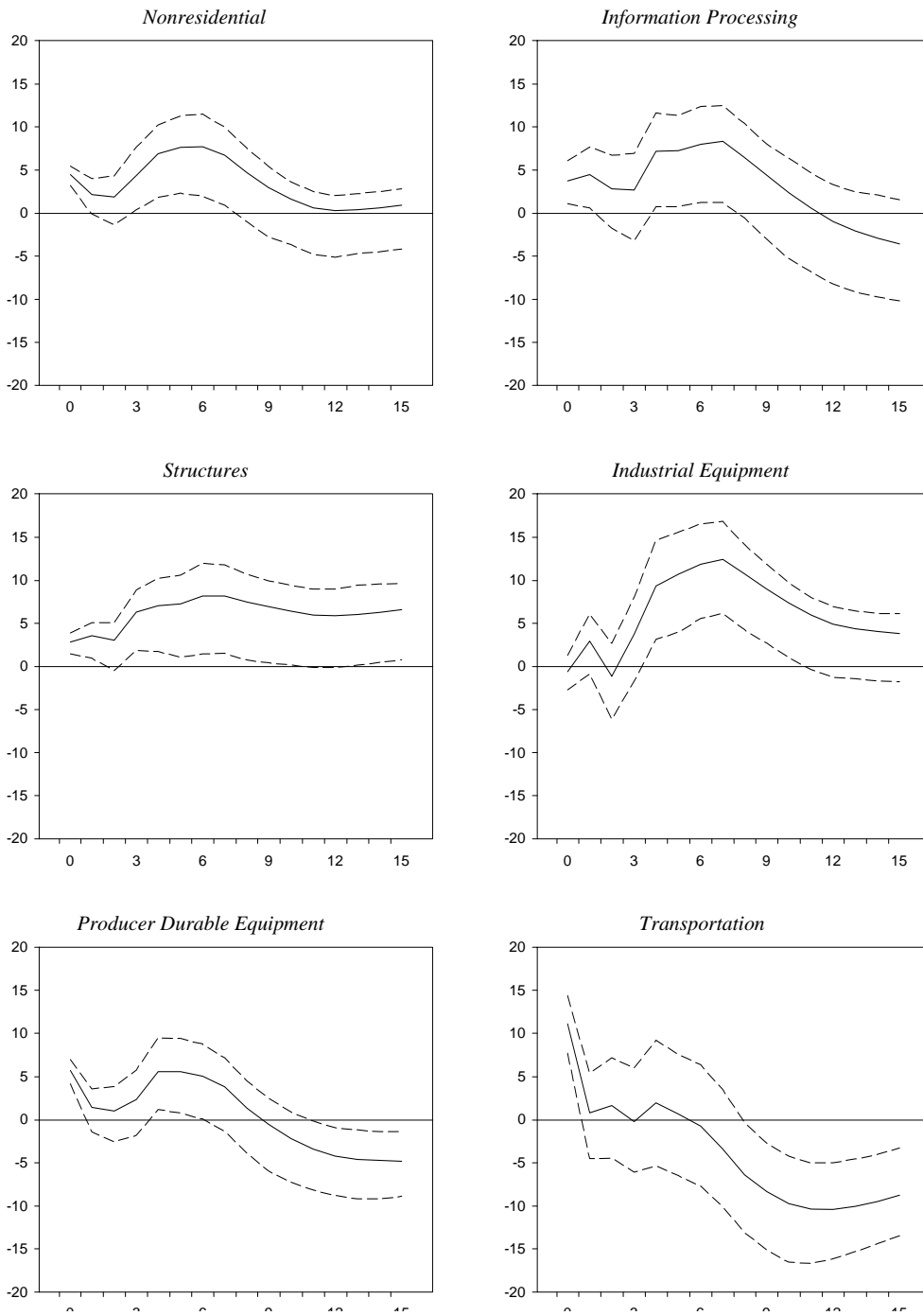


Figure 6: Sectoral Output Responses

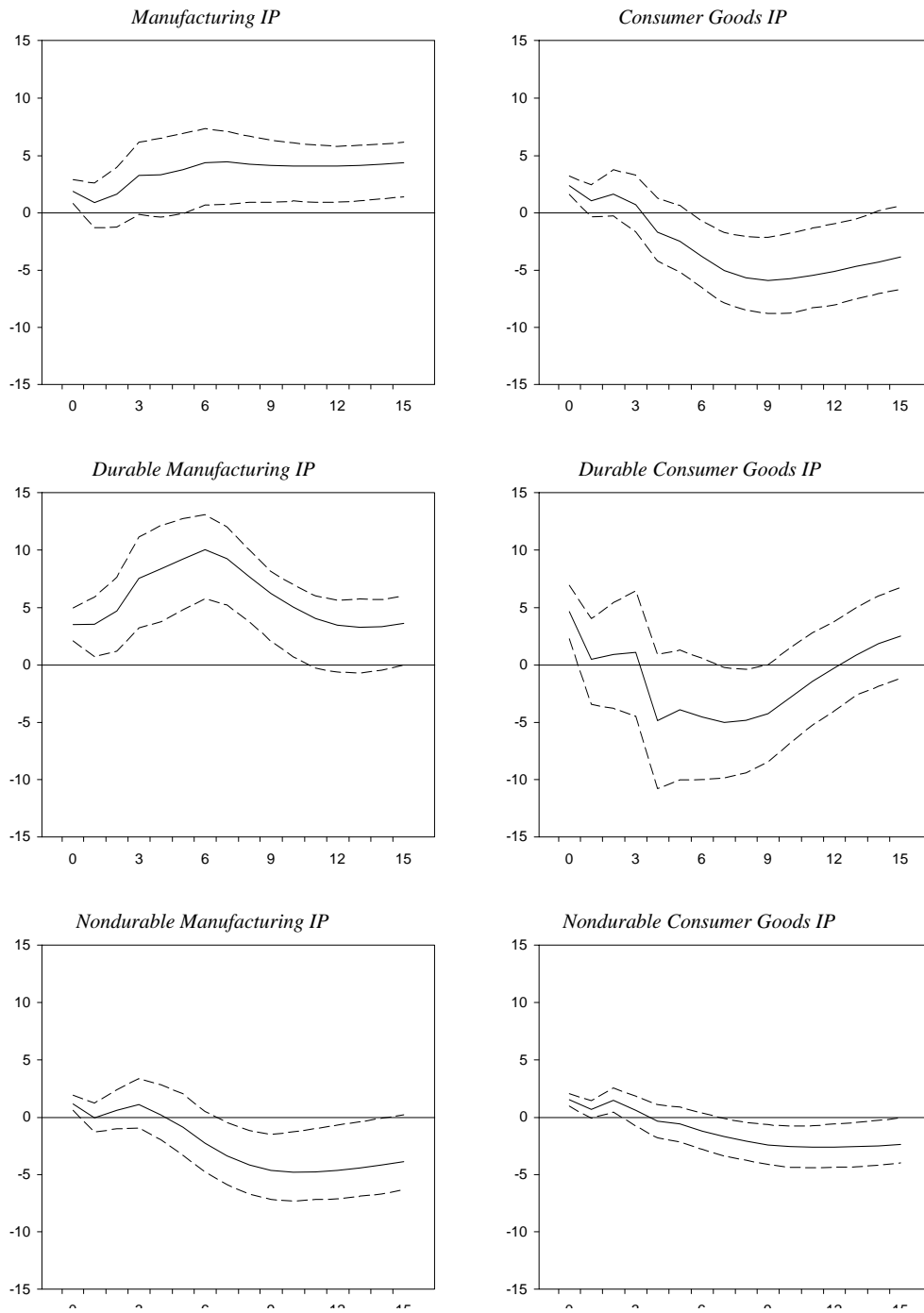


Figure 7: Responses of Real Labor Compensation

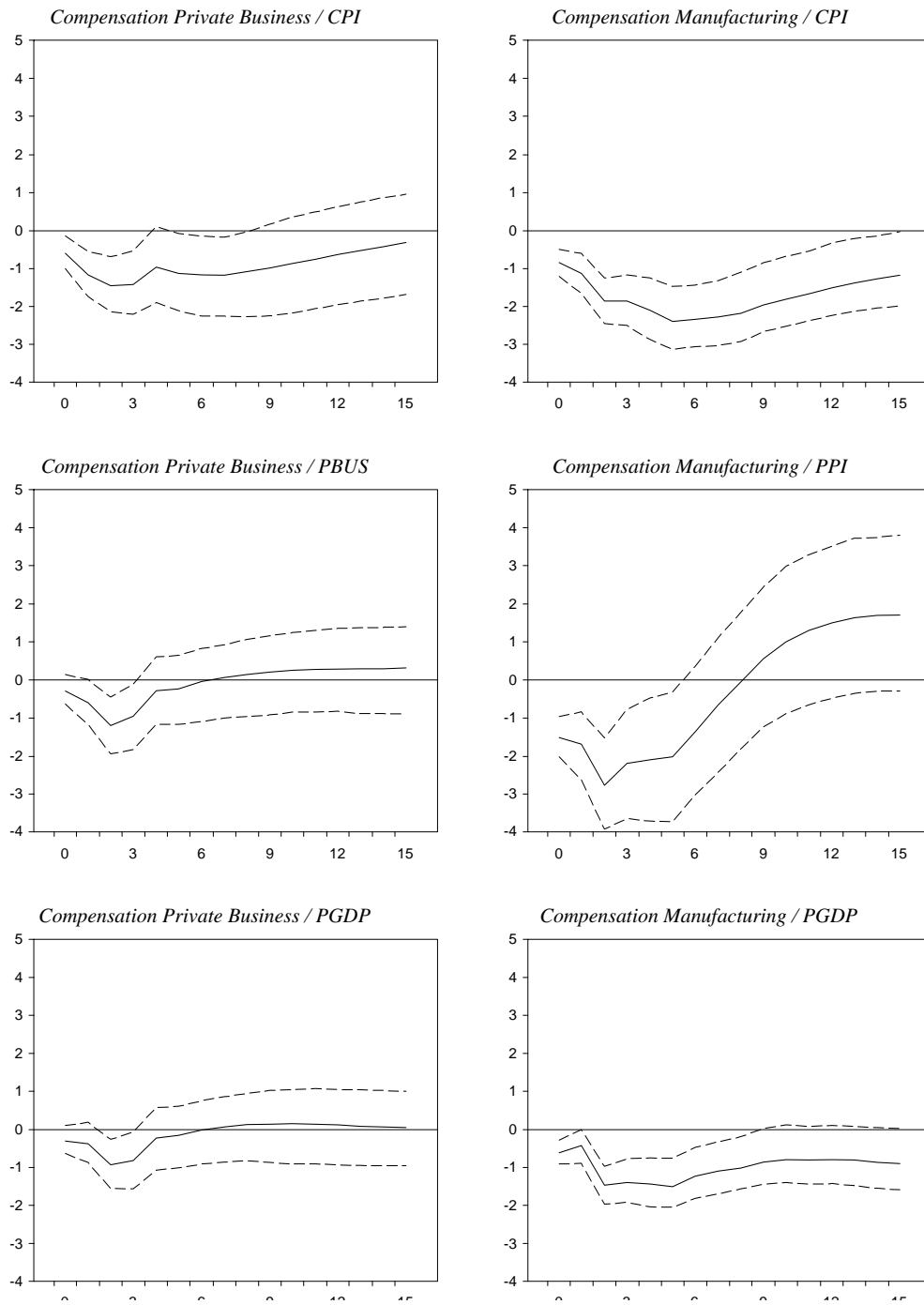


Figure 8: Average Marginal Tax Rates

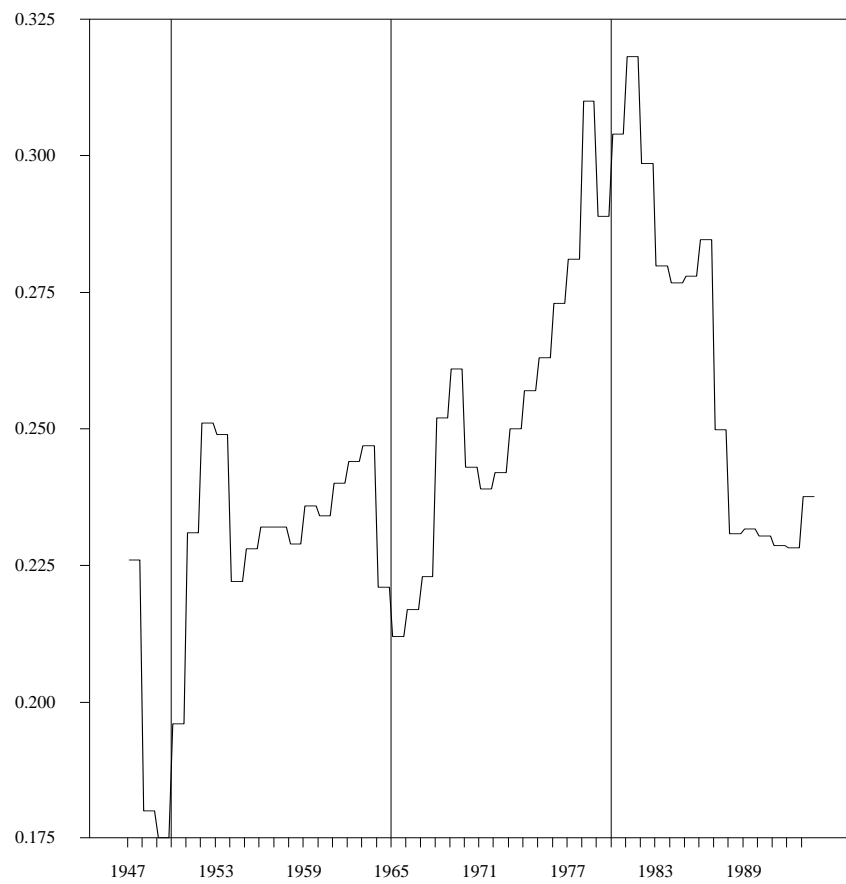


Figure 9: Responses of Real Wages

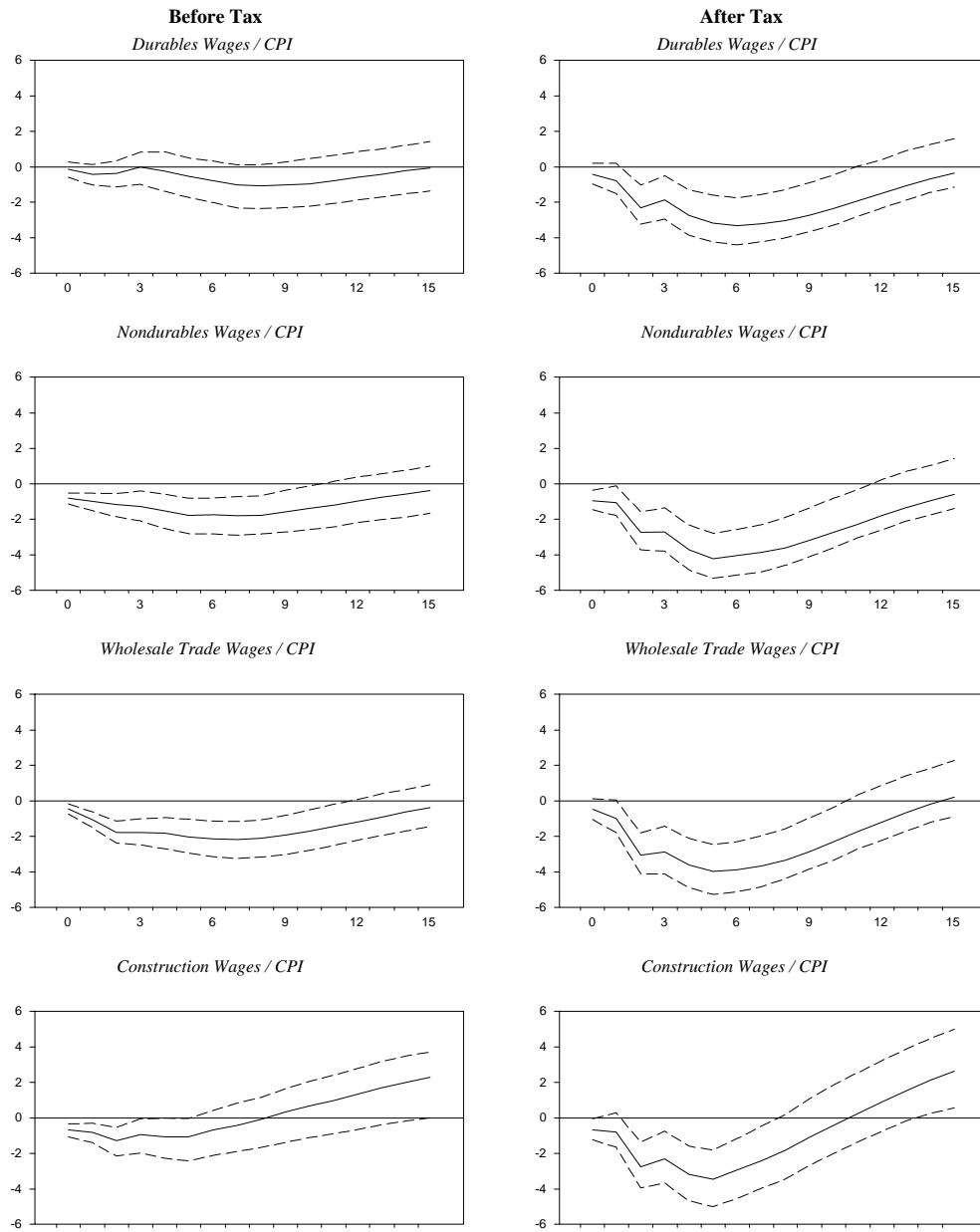


Figure 10: Responses of Different Measures of Manufacturing Real Wages

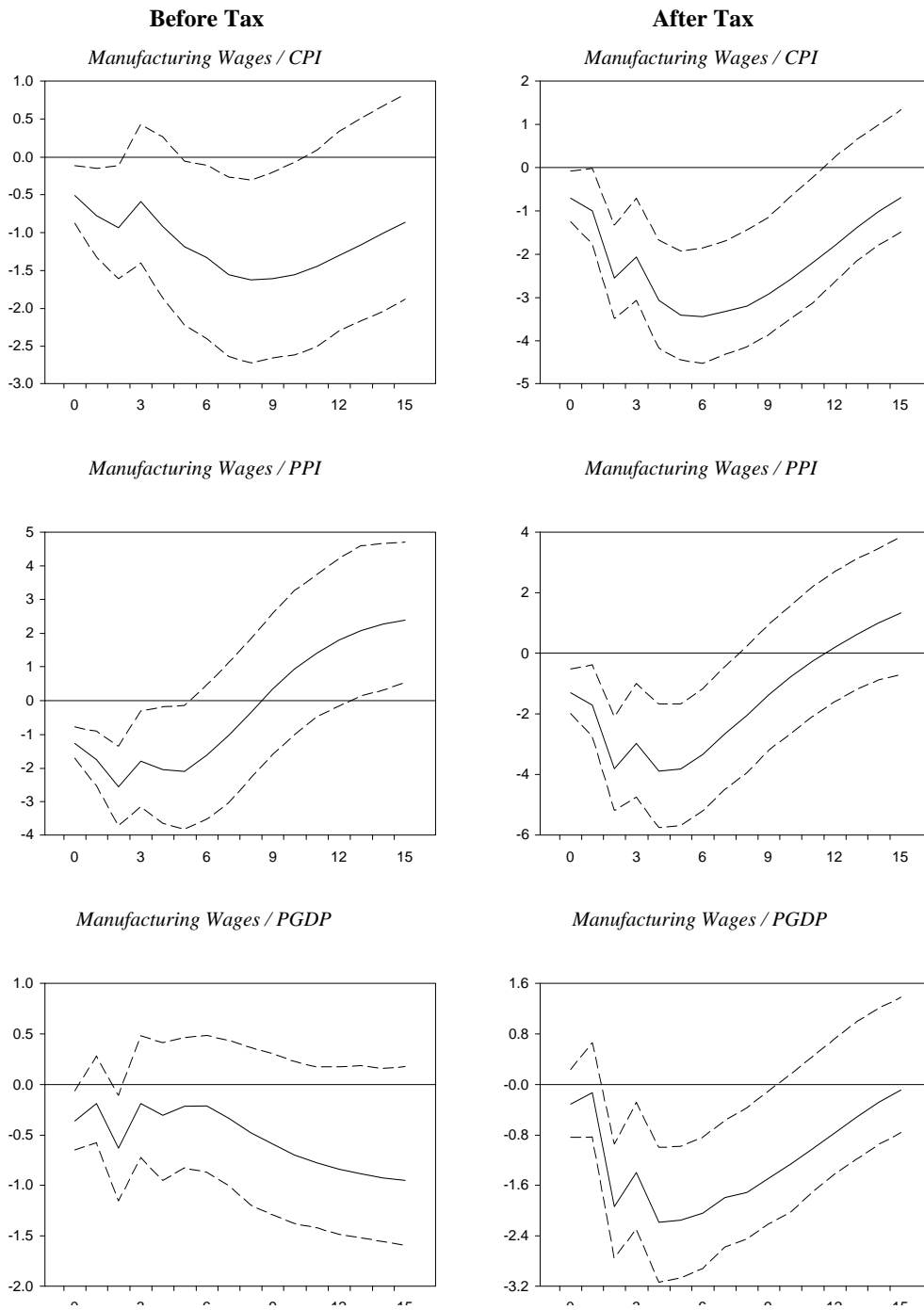


Figure 11: Responses of Money, Prices and Interest Rates

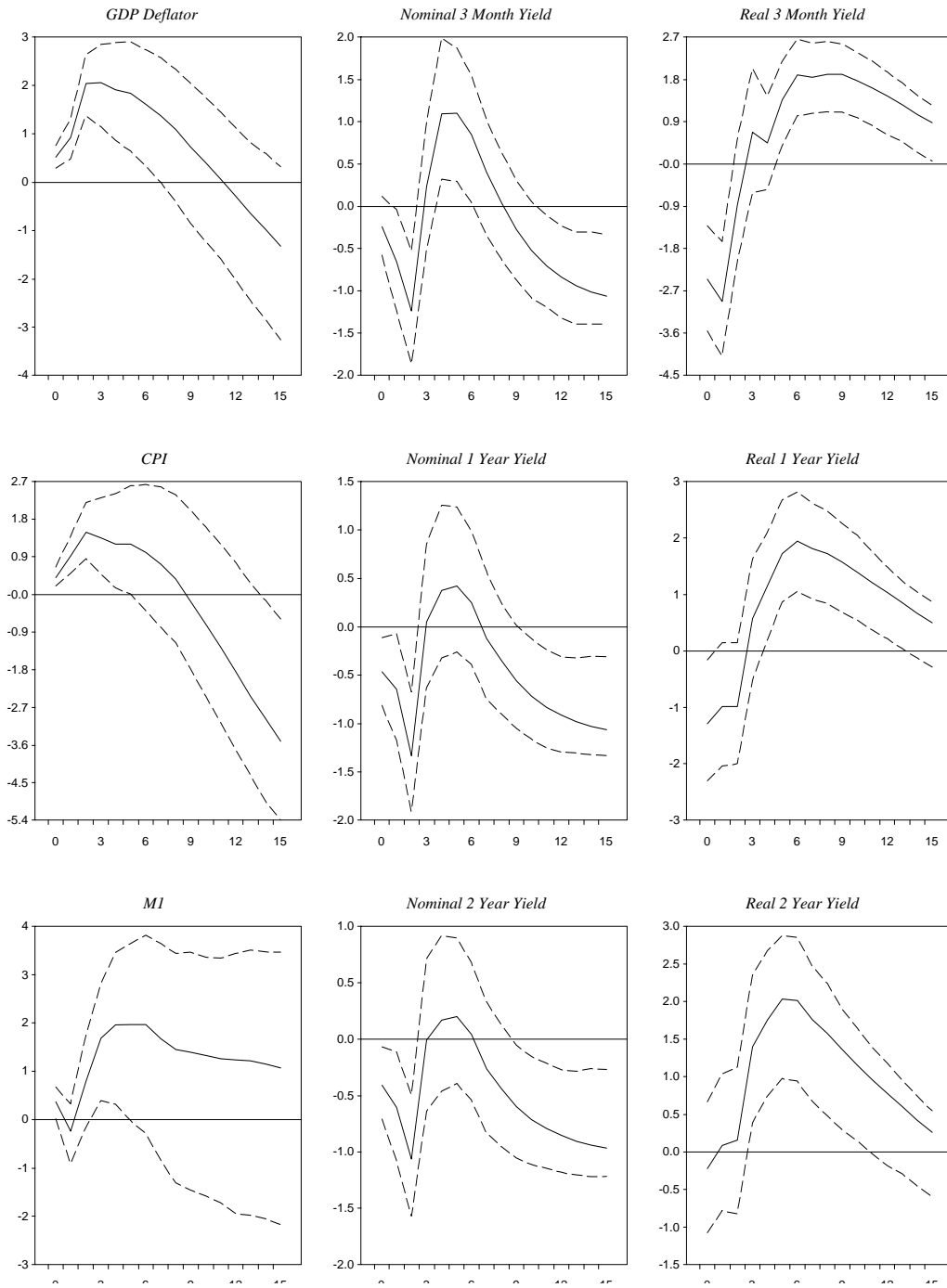


Figure 12: Sensitivity to Positive Changes in Ramey and Shapiro Dating of the Korean War Episode

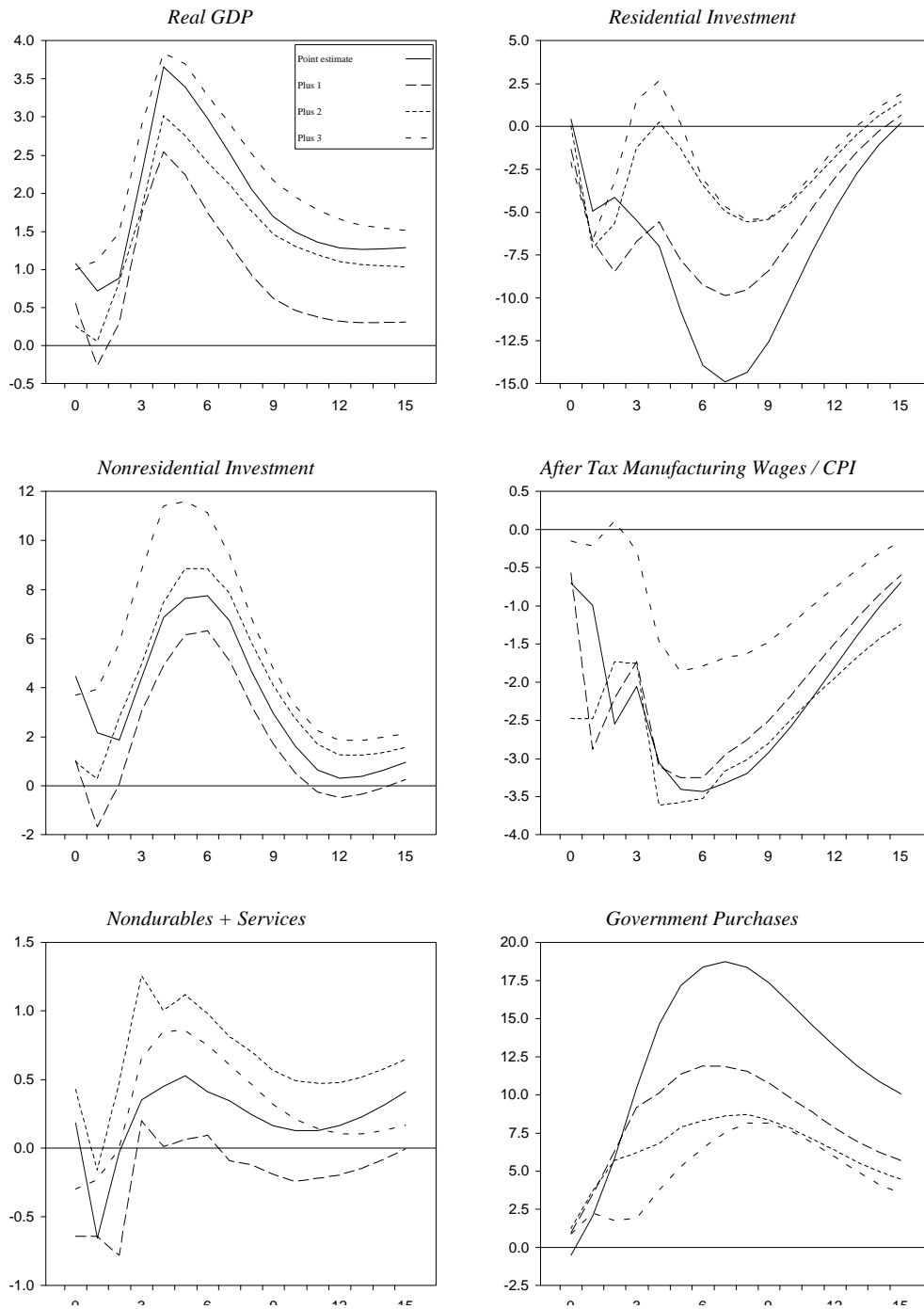


Figure 13: Sensitivity to Negative Changes in Ramey and Shapiro Dating of the Korean War Episode

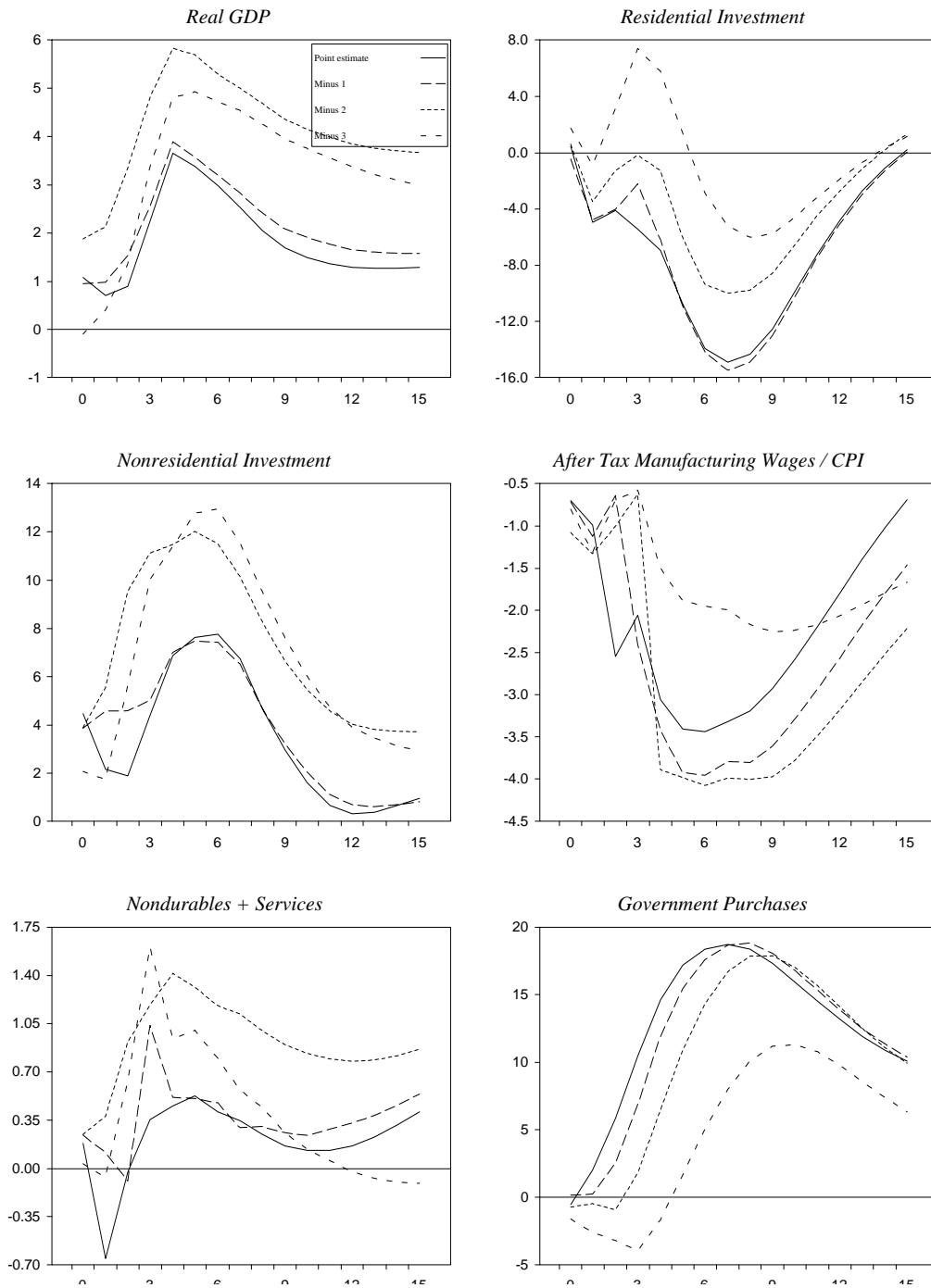


Figure 14: Responses to Randomly Selected Episodes

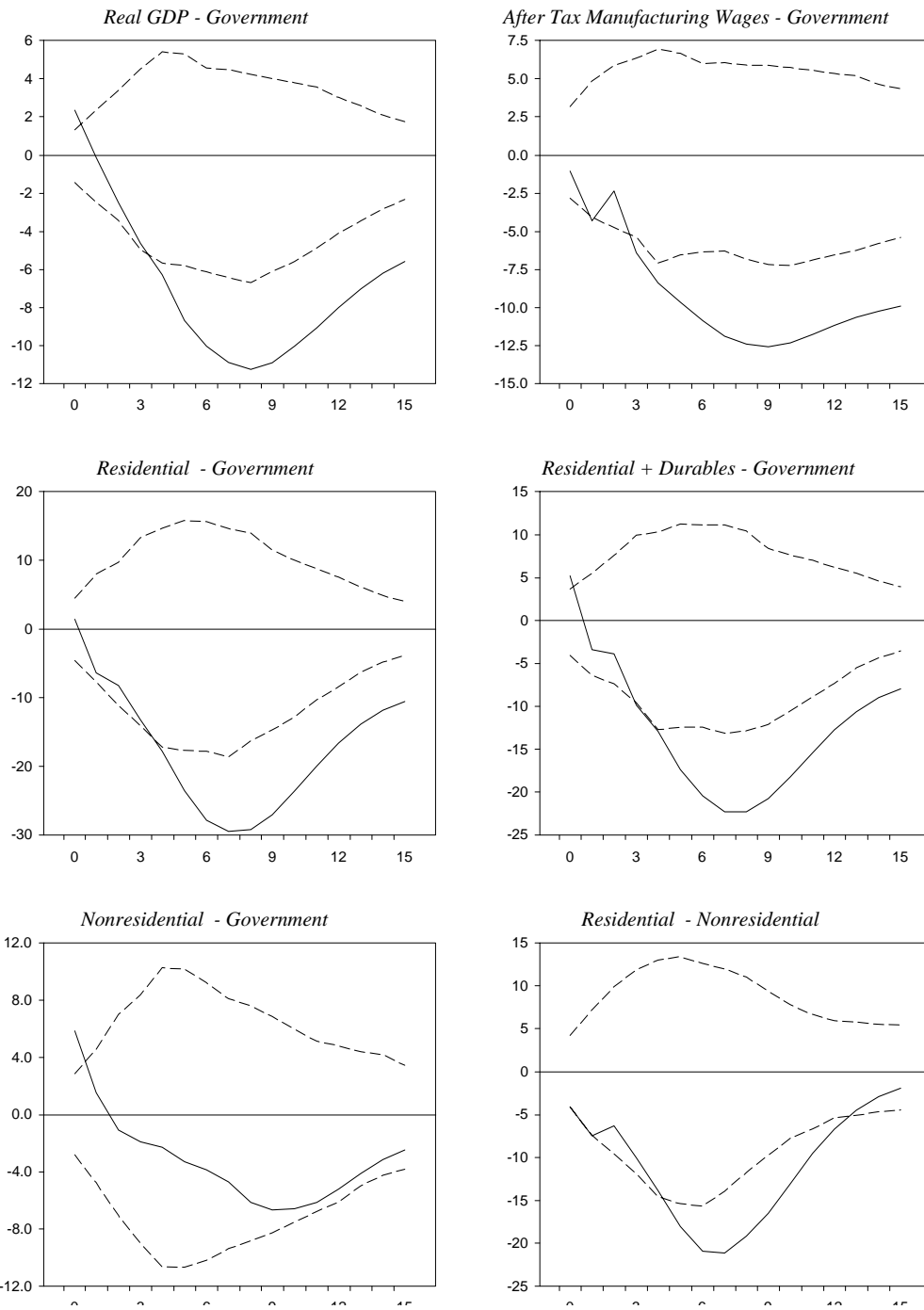


Figure 15: Model Based Impulse Response Functions: Government Purchases – IID

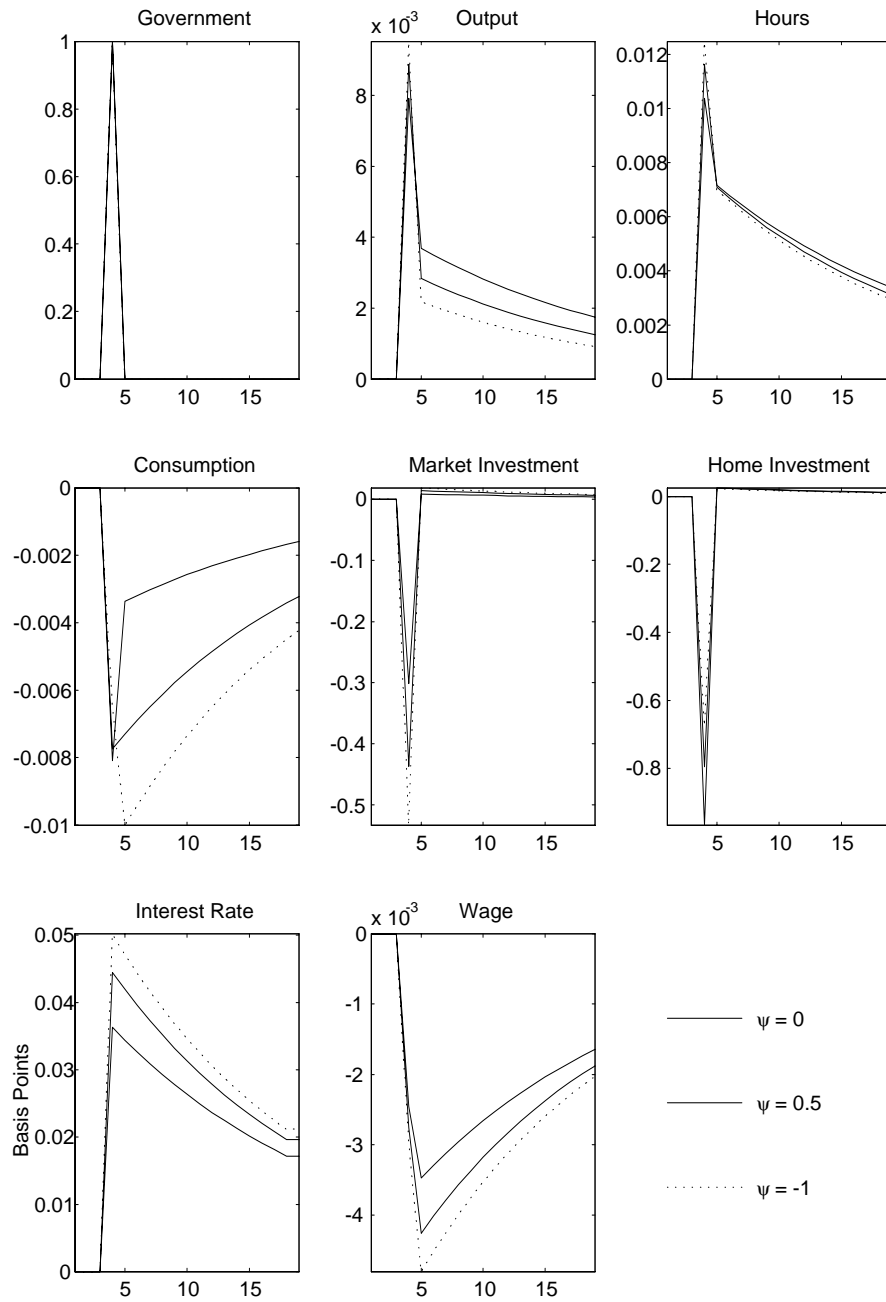


Figure 16: Model Based Impulse Response Functions - Government Purchases AR(1)

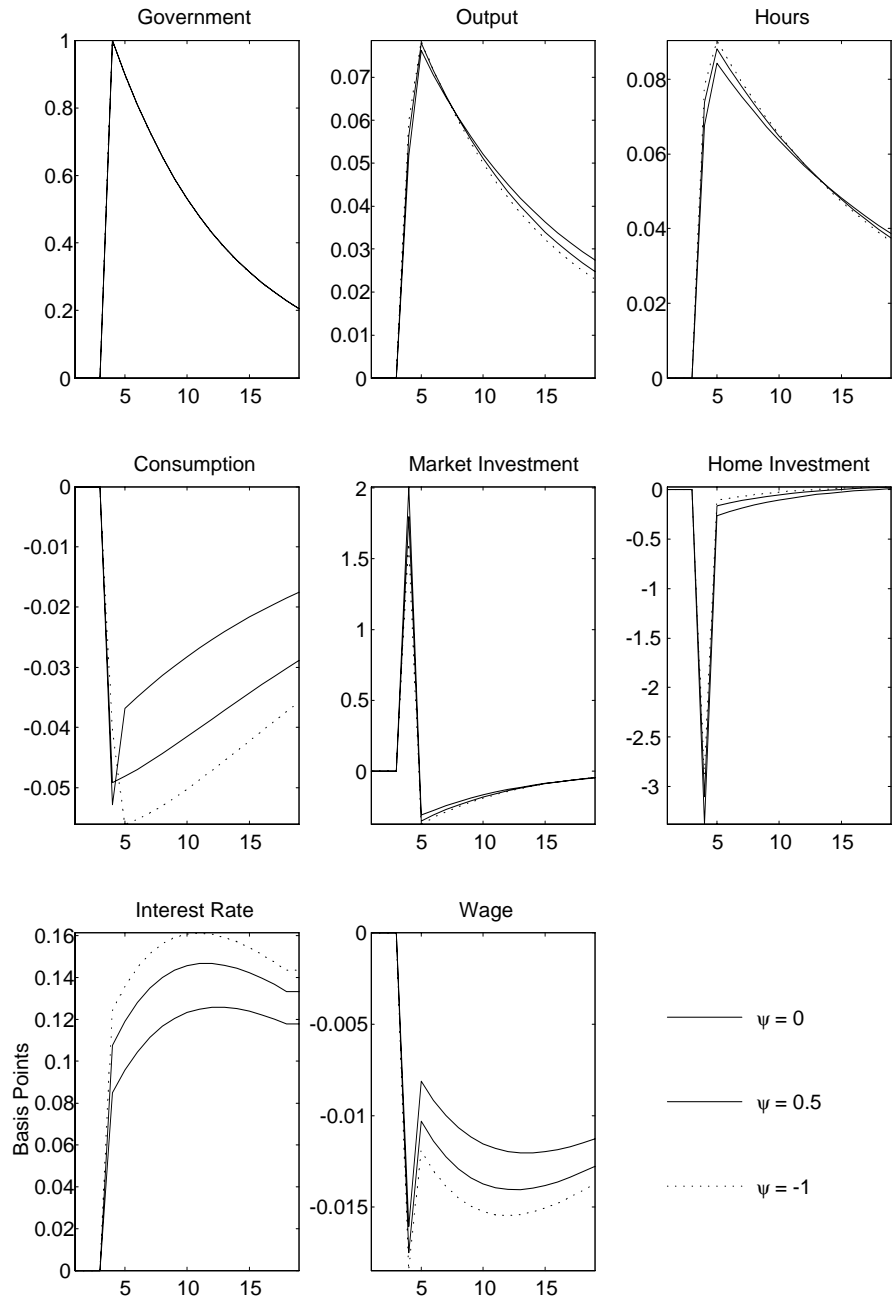


Figure 17: Model Based Impulse Response Functions: Government Purchases - Estimated Moving Average Representation

