NBER WORKING PAPER SERIES

FISCAL SHOCKS AND THEIR CONSEQUENCES

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Working Paper 9772
http://www.nber.org/papers/w9772

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 2003

This paper is a substantial revision to "Assessing the Effects of Fiscal Shocks" which appeared as NBER working paper no. 7459. We would like to thank Lawrence J. Christiano and Lars Hansen for helpful conversations. In addition we would like to thank several referees for useful comments. The views expressed in this paper do not necessarily represent the views of the Federal Reserve Bank of Chicago, the Federal Reserve System or the World Bank. Martin Eichenbaum gratefully acknowledges the financial support of a grant from the National Science Foundation to the National Bureau of Economic Research. Craig Burnside gratefully acknowledges the support of a National Fellowship from the Hoover Institution. The views expressed herein are those of the authors and not necessarily those of the National Bureau of Economic Research.

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NBER Working Paper No. 9772
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JEL No. E1, E6

ABSTRACT

This paper investigates the response of hours worked and real wages to fiscal policy shocks in the U.S. during the post World War II era. We identify these shocks with exogenous changes in military purchases and argue that they lead to a persistent increase in government purchases and tax rates on capital and labor income, and a persistent rise in aggregate hours worked as well as declines in real wages. The shocks are also associated with short lived rises in aggregate investment and small movements in private consumption. We describe and implement a methodology for assessing whether standard neoclassical models can account for the consequences of a fiscal policy shock. Simple versions of the neoclassical model can account for the qualitative effects of a fiscal shock. Once we allow for habit formation and investment adjustment costs, the model can also account reasonably well for the quantitative effects of a fiscal shock.

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1. Introduction

This paper investigates the response of hours worked and real wages to fiscal policy shocks in the U.S. during the post World War II era. We identify these shocks with exogenous changes in military purchases and argue that they lead to a persistent increase in government purchases and tax rates on capital and labor income, and a persistent rise in aggregate hours worked as well as declines in real wages. The shocks are also associated with short lived rises in aggregate investment and small movements in private consumption.

The basic question that we address is whether standard neoclassical models can account for the response of hours worked and real wages to a fiscal policy shock. If taxes were lump sum in nature, the answer would be unambiguously yes. The negative income effect associated with a rise in government purchases would increase the aggregate supply of hours worked. With diminishing marginal productivity to labor, we would observe a rise in hours worked along with a decline in real wages.[1]

But taxes are not lump sum in nature and, according to our results, distortionary taxes rise in response to increases in government purchases. In neoclassical models, the consequences of a fiscal policy shock depend on how increases in government purchases are financed. Taken together these observations imply that analyses based on the lump sum tax assumption may yield misleading results.[2] Baxter and King (1993) forcefully demonstrate this point. Using a neoclassical model, they show that when an increase in government purchases is financed by lump sum taxes, hours worked rise and real wages fall. But when the increase in government purchases is financed entirely by distortionary income taxes, both

[1] See Ramey and Shapiro (1998) and Edelberg, Eichenbaum and Fisher (1999) for quantitative analyses of the consequences of an increase in government purchases in real business cycle models when all taxes are lump sum. Also see Rotemberg and Woodford (1992) and Devereux, Head and Lapham (1996) for similar analyses of models embodying imperfect competition and increasing returns to scale.

[2] See Braun (1994), McGrattan (1994) and Jones (2000) for analyses of the effects of shocks to government purchases and tax rates in a business cycle context.

hours worked and after-tax real wages fall.[3] In a similar vein, Mulligan's (1998) argument that neoclassical models cannot account for the rise in U.S. employment during WWII rests critically on the observation that marginal income tax rates rose dramatically.[4]

Yet many analyses of U.S. fiscal policy in the post war era assume that increases in government purchases are entirely financed by lump sum taxes.[5] The results in Baxter and King (1993) and Mulligan (1998) suggest that this assumption *may* give rise to misleading results. The only way to know is to confront models with an experiment that is commensurate with what occurred in the data. That is what we try to do in this paper. Both the World War II experiment and the post-war experiments that we identify involved a rise in tax rates and in government purchases.

The key empirical problem is identifying exogenous changes in fiscal policy. The literature has pursued various approaches.[6] We build on the approach used by Ramey and Shapiro (1998) who focus on changes associated with exogenous movements in defense spending. To isolate such movements, they identify three political events, arguably unrelated to developments in the domestic U.S. economy, that led to large military buildups. We refer to these events as 'Ramey-Shapiro episodes'.

We analyze the performance of two versions of the neoclassical model. The first, which we refer to as the benchmark model, corresponds to a standard growth model. The second extends the benchmark model to allow for habit formation and investment adjustment costs. We refer to the resulting model as the modified

[3]In related work Ohanian (1997) analyzes the welfare consequences of the different tax policies pursued in the U.S. during World War II and Korea.

[4]McGrattan and Ohanian (1999) take issue with Mulligan's conclusion and argue that reasonable perturbations to the neoclassical model render it consistent with World War II data.

[5]See for example Christiano and Eichenbaum (1992), Devereaux, Head and Lapham (1996), Edelberg, Eichenbaum and Fisher (1999), Ramey and Shapiro (1998) and Rotemberg and Woodford (1992).

[6]See Blanchard and Perotti (1998), Ramey and Shapiro (1998) and Edelberg, Eichenbaum and Fisher (1999) for discussions of alternative approaches.

benchmark model. Our main results with respect to the benchmark model can be summarized as follows. First, the model can account for the qualitative effects of a fiscal shock on both hours worked and real wages. Even after taking into account the rise in tax rates, the model implies that a rise in government purchases leads to a boom in hours worked and a fall in real wages. Second, the benchmark model can also account for the qualitative responses of investment and consumption: the former rises and the latter falls.

Third, in the benchmark model, the primary impact of distortionary tax rates is on the timing of how hours worked responds to the shock. In the data a fiscal policy shock leads to hump-shaped rises in tax rates, government purchases and hours worked. When all taxes are lump sum, the model is able to reproduce this basic pattern. Allowing for movements in distortionary taxes shifts the rise in employment counterfactually, closer to the time of the fiscal shock. Indeed the peak response of hours worked occurs at the time of the shock.

The intuition for this result can be described as follows. In the data, a fiscal policy shock leads to highly correlated hump-shaped movements in labor income tax rates and government purchases. A rise in government purchases raises the present value of agents' taxes, thus triggering an increase in aggregate labor supply. A hump-shaped rise in tax rates has both intratemporal and intertemporal substitution effects on labor supply. Once these substitution effects are taken into account, simple neoclassical models counterfactually predict that, after a fiscal policy shock, hours worked respond most strongly initially, before labor income tax rates begin to rise. The mismatch between model and data is worse the more elastic labor supply is assumed to be.

Fourth, the benchmark model can account quantitatively for the average increase in hours worked and the overall volatility of hours worked in response to a fiscal shock. But the ability to do so depends on the assumption that labor supply is quite elastic, say of the magnitude assumed in typical real business cycle models. Fifth, the benchmark model does quite well at accounting quantitatively for the dynamic response of real wages. Sixth, the benchmark model can account for the qualitative response of consumption and investment to a fiscal policy shock. Both in the data and in the model, a fiscal shock leads to a fall in consumption and a rise in investment. But the benchmark model does a poor of accounting for the quantitative responses of consumption and investment. Basically this is because it substantially overstates the decline in consumption and the rise in investment that follow in the wake of a fiscal policy shock. These shortcomings are serious because they cast doubt on the mechanism by which hours worked and real wages respond in the benchmark model.

We argue that the quantitative shortcomings of the benchmark model can be substantially improved upon by allowing for habit formation and investment adjustment costs. Numerous authors have argued that allowing for these features of preferences and technology improves the ability of neoclassical models to account for various features of post World War II business cycles.[7] We show that these modifications considerably improve the performance of those models in our context as well. Habit formation in consumption mutes the fall in consumption that occurs in the benchmark model. While the decline in consumption is still large, the model based impulse response function lies within the confidence intervals of the estimated impulse response function. Investment adjustment costs induce a hump shaped response of investment and generate a sympathetic hump shaped response of hours worked. Consequently, this version of the model can account for the timing of how hours worked responds to a fiscal policy shock, even in the face of movements in distortionary tax rates.

Overall we find relatively little formal evidence against the modified benchmark model, at least for the hypotheses that we consider. To the extent that it has important shortcomings these pertain to the behavior of consumption and the model's reliance on an elasticity of labor supply that is high relative to existing micro evidence. These problems notwithstanding, we conclude that the modified benchmark model does a reasonably good job at accounting for both the

[7] See for example Boldrin, Christiano and Fisher (2001), Christiano, Eichenbaum and Evans (2001) and the references therein.

qualitative and quantitative effects of a shock to fiscal policy.

The remainder of this paper is organized as follows. Section 2 presents our evidence on the effects of a fiscal shock. Section 3 discusses a limited information strategy for assessing the implications of a model for the consequences of a fiscal shock. Section 4 reports the results of implementing this strategy on the benchmark and modified benchmark neoclassical models. Section 5 contains concluding remarks.

2. Evidence on the Effects of a Shock to Fiscal Policy

In this section we describe our strategy for estimating the effects of an exogenous shock to fiscal policy and present our results.

2.1. Identifying the Effects of a Fiscal Policy Shock

Ramey and Shapiro (1998) pursue a 'narrative approach' to isolate three arguably exogenous events that led to large military buildups and increases in total government purchases: the Korean War, the Vietnam War and the Carter-Reagan defense buildup. Based on their reading of history, they date these events at 1950:3, 1965:1 and 1980:1. The weakness of this approach is that they only identify three episodes of exogenous shocks to fiscal policy. In our view this weakness is more than offset by the compelling nature of their assumption that the war episodes are exogenous. Certainly their assumption seems plausible relative to the assumptions required to isolate the exogenous component of statistical innovations in government purchases and tax rates. See Edelberg, Eichenbaum and Fisher (1999) for further discussion.

To estimate the impact of exogenous movements in government purchases, G_t, capital and labor income tax rates, τ_{kt} and τ_{nt}, on the economy, we use the following procedure. Suppose that G_t, τ_{kt} and τ_{nt} are elements of the vector stochastic process Z_t. Define the three dummy variables D_{it}, $i = 1, 2, 3$, where

$$D_{it} = \begin{cases} 1, & \text{if } t = d_i \\ 0, & \text{otherwise} \end{cases}$$

and d_i denotes the i^{th} element of

$$d = \left(\begin{array}{ccc} 1950{:}3 & 1965{:}1 & 1980{:}1 \end{array} \right)'.$$

We assume that Z_t evolves according to:

$$Z_t = A_0 + A_1 t + A_2(t \geq 1973:2) + A_3(L)Z_{t-1} + \sum_{i=1}^{3} A_4(L)\psi_i D_{it} + u_t, \quad (1)$$

where $Eu_t = 0$,

$$Eu_t u'_{t-s} = \begin{cases} 0, \text{ for all } s \neq 0 \\ \Sigma, \text{ for } s = 0, \end{cases}$$

Σ is a positive definite matrix of dimension equal to the number of elements in Z_t, t denotes time, and $A_j(L)$, $j = 3, 4$ are finite ordered vector polynomials in nonnegative powers of the lag operator L. As in Ramey and Shapiro (1998) we allow for a trend break in 1973:2.[8]

The ψ_i in (1) are scalars with ψ_1 normalized to unity. The parameters ψ_2 and ψ_3 measure the intensity of the second and third Ramey-Shapiro episodes relative to the first. This specification allows us to depart from the assumption in Ramey and Shapiro (1998) and Edelberg, Eichenbaum and Fisher (1999) that the fiscal episodes under investigation are of equal intensity, i.e. $\psi_i = 1$, $i = 1, 2, 3$. Relation (1) implies that while the fiscal episodes may differ in intensity, their dynamic effects are the same, up to a scale factor, ψ_i. While arguable, this assumption is consistent with the maintained assumptions in Ramey and Shapiro (1998) and Edelberg, Eichenbaum and Fisher (1999). It is also consistent with the assumptions in Rotemberg and Woodford (1992) who identify an exogenous shock to government purchases with the innovation to defense purchases estimated from a linear time invariant vector autoregressive representation of the data.

[8] In practice we found that our results were robust to not allowing for a break in trend, i.e. to setting $A_2 = 0$.

We estimated (1) by maximum likelihood assuming a Gaussian likelihood function. A consistent estimate of the response of Z_{it+k}, the i^{th} element of Z at time $t+k$, to the onset of the i^{th} Ramey-Shapiro episode is given by an estimate of the coefficient on L^k in the expansion of $\psi_i \left[I - A_3(L)L\right]^{-1} A_4(L)$.

2.2. Empirical Results

In this subsection we present the results of implementing the procedure discussed above. In deciding how to specify Z_t we must deal with the following trade-off. On the one hand, we would like, in principle, to include all of the variables in our analysis in one large unconstrained VAR and report the implied system of dynamic response functions. The disadvantage of this strategy is that it requires estimating a large number of parameters simultaneously. On the other hand, if we include too few variables in the VAR, then we would encounter significant omitted variable bias. In light of these considerations, we chose the following intermediate strategy. In all cases our specification of Z_t includes the log of time t per-capita real GDP, the log of per-capita real government purchases and average capital and labor income tax rates. To estimate the effect of a fiscal policy shock on some other variable, we add it to the list of variables in Z_t. The variables that we consider include the log of per-capita hours worked, the log of after-tax real wages, the log of per capita consumption and the log of per capita investment. Note that in all cases, Z_t, includes only variables that also are included in the model that we study below. We assume that Z_t depends on six lagged values of itself, i.e. $A_3(L)$ is a sixth order polynomial in L. This lag length was chosen using the modified likelihood ratio test described in Sims (1980). All estimates are based on quarterly data from 1947:1 to 1995:4. The Appendix describes the data used in our analysis.

Column 1 of Figure 1 displays the log of real defense expenditures and the share of real government purchases in GDP, along with vertical lines at the dates of Ramey-Shapiro episodes. The time series on real defense expenditures is dominated by three events: the large increases in real defense expenditures associated with the Korean war, the Vietnam war and the Carter-Reagan defense buildup. The Ramey-Shapiro dates essentially mark the beginning of these episodes. In the models that we explore it is total government purchases, rather than military purchases that is relevant. Figure 1 shows that the Ramey-Shapiro episodes also coincide with rises in real government purchases.

The second column of Figure 1 displays our measure of capital and labor income tax rates, along with vertical lines at the Ramey-Shapiro dates. These tax rate measures were constructed using quarterly data from the national income and products accounts using the method employed by Jones (2002).[9] Note that labor tax rates rise substantially after all three Ramey-Shapiro dates while capital tax rates rise after the first two episodes. These observations suggest the potential importance of taking into account movements in tax rates when evaluating the macroeconomic effects of an increase in government spending.

Recall that we normalize the first episode (Korea) to be of unit intensity. Our point estimates of the intensities of the second and third episodes are equal to 0.08 and 0.12, respectively.[10] Below we report the dynamic response function of various aggregates to an episode of unit intensity. This simply scales the size of the impulse response functions.

Column 1 of Figure 2 reports the dynamic responses of real government purchases and output to a fiscal shock.[11] The solid lines display point estimates while the dashed lines correspond to 95% confidence interval bands.[12] As can be seen,

[9]This method is closely related to the approach of Mendoza, Razin and Tesar (1994) and is similar to the procedures used in Joines (1981) and McGrattan (1994). The main difference between Jones and Joines and McGrattan is that the Joines and McGrattan estimate the personal income tax rate as a marginal tax rate from tax records, rather than as an average rate from the national accounts. See Jones (2002) for a detailed comparison of his tax rate measures and those of Joines (1981) and McGrattan (1994).

[10]The associated 95% confidence intervals are $(0.001, 0.17)$ and $(0.04, 0.19)$, respectively. These were computed imposing the restriction that intensities had to be nonnegative.

[11]With two exceptions, the impulse response functions are reported as percentage deviations from a variable's unshocked path. The exceptions are the impulse response functions of labor and capital tax rates (Figure 2), which are reported as deviations from their unshocked levels, measured in percentage points.

[12]These were computed using the bootstrap Monte Carlo procedure described in Edelberg,

the onset of a Ramey-Shapiro episode leads to large, persistent, hump-shaped rises in total government purchases and output.[13] Column 2 of Figure 2 displays the dynamic response of capital and labor tax rates to a fiscal policy shock. Four results are worth noting. First, the labor tax rate rises in a hump-shaped pattern, mirroring the dynamic response of government purchases, with the peak occurring about two years after the onset of a Ramey-Shapiro episode. Second, the maximal rise in the labor tax rate is roughly 2.7 percentage points after nine quarters. This represents a rise of about 27% in the tax rate relative to its value in 1949. Third, the capital tax rate also rises in a hump-shaped manner, but the maximal rise occurs before the peak rises in government purchases and labor tax rates. Fourth, the rise in the capital tax rates is large, with the maximal rise of 11.0 percentage points occurring after three quarters.

The third row of Figure 2 reports the response of hours worked and after-tax real wages to the onset of a Ramey-Shapiro episode. A number of interesting results emerge. First, paralleling the response of total government purchases, hours worked display a delayed hump-shaped response. The peak response in hours worked is roughly 9.7% and occurs about 10 quarters after the onset of a Ramey-Shapiro episode.[14] Second, after-tax real wages fall after the fiscal shock, with a peak decline of 7.5% roughly 9 quarters after the shock.

Finally, to help assess our model, the last row of Figure 2 reports the response

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Eichenbaum and Fisher (1999). 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 the analysis perturbing the Ramey and Shapiro dates. Edelberg, Eichenbaum and Fisher (1999) document the robustness of inferences under the assumption that the different episodes are of equal intensity.

[13] Working with an equal intensity specification ($\psi_i = 1,\ i = 1, 2, 3$) Ramey and Shapiro (1998) show that the response of real defense purchases is larger in size but similar in shape to the response of total government purchases. This is still the case here where we allow the Ramey-Shapiro episodes to be of different intensities.

[14] See Ramey and Shapiro (1998) and Edelberg, Eichenbaum and Fisher (1999) for the responses of real GDP and various other measures of hours worked obtained under the assumption that the Ramey-Shapiro episodes are of equal intensity. The qualitative nature of these responses is unaffected by allowing for different intensities.

of consumption and investment to the onset of a Ramey-Shapiro episode. Notice that consumption does not respond strongly to the fiscal policy shock. At the same time investment rises by about 10% in the first period of the shock and then quickly declines to its pre shock level. In both cases there is substantial sampling uncertainty. Still, as discussed below, these responses are useful in evaluating the ability of the neoclassical model to account for the affects of a fiscal policy shock.

In sum, a Ramey-Shapiro episode is marked by a statistically significant rise in purchases, output, hours, tax rates and investment as well as a fall in after-tax real wage rates. These results are consistent with the features of the World War II episode emphasized by Mulligan (1998) and McGrattan and Ohanian (1999).

3. A Model Based Experiment

In the previous section, we displayed our estimates of the dynamic consequences of a fiscal policy shock. In this section we discuss a procedure for assessing the ability of our model to account for the effects of such a shock. The basic idea is to subject the model economy to the same experiment that we claim to have isolated in the data. Specifically, beginning from the nonstochastic steady state of a model economy, we imagine that agents are confronted with a sequence of changes in government purchases and tax rates equal to our point estimates of the changes following a Ramey - Shapiro episode. We then compare the response of variables in the model economy to our estimates of how the U.S. economy responded to the same experiment.

Define $D_t = \psi_i D_{it}$. Also, let θ be a vector containing every parameter of the representation for Z_t given by (1). We partition Z_t as $Z_t = (\begin{array}{cc} z_t' & f_t' \end{array})'$, where z_t is a 3×1 vector whose elements consist of model variables, excluding the measures of fiscal policy. The vector f_t contains the fiscal policy variables: the log of per capita real government purchases and average capital and labor income tax rates.

Multiplying (1) by $[I - A_3(L)]^{-1}$ we can express z_t and f_t as a moving averages of u_t and D_t:

$$\begin{aligned} z_t &= \pi_z(L)u_t + h_z(L)D_t && (2) \\ f_t &= \pi_f(L)u_t + h_f(L)D_t, && (3) \end{aligned}$$

where u_t is defined in (1), and $\pi_z(L)$, $\pi_f(L)$, $h_z(L)$ and $h_f(L)$ are square summable non-negative polynomials in the lag operator L. For simplicity here we have abstracted from constants and trends. The polynomials in (2) and (3) are implicitly functions of θ and we will, on occasion, make this dependence explicit.

The economic model described in Section 4 implies that z_t evolves according to

$$z_t = \kappa_k' k_t + \kappa_f' f_t \qquad (4)$$

where k_t is the capital stock at time t. In addition κ_k and κ_f are 1×4 and 3×4 matrices. The path of k_t can be written as

$$k_t = \rho k_{t-1} + \sum_{j=-\infty}^{+\infty} \mu_j' E_{t-1} f_{t+j} \qquad (5)$$

Here ρ is a scalar and the μ_j's are 3×1 matrices. The parameters κ_k, κ_f, ρ, and $\{\mu_j\}_{j=-\infty}^{+\infty}$ depend only on the model parameters describing preferences and technology, not on the parameters governing the law of motion of f_t.

There are two ways to measure the dynamic responses of z_t to the onset of a Ramey-Shapiro episode. First, we can infer these responses directly from $h_z(L)$ in (2). That is, we can write the impulse response function $I_D(i+1;\theta) = \partial E_t z_{t+i}/\partial D_t = h_{zi}$ where h_{zi} is the coefficient on L^i in $h_z(L)$. Since $I_D(i+1;\theta)$ is computed using a statistical representation of Z_t, we refer to it as the *data* response function.

Second, we can use the economic model in conjunction with the estimated moving average representation for f_t to compute an alternative response function. Equation (4) implies that

$$\frac{\partial E_t z_{t+i}}{\partial D_t} = \kappa_k' \frac{\partial E_t k_{t+i}}{\partial D_t} + \kappa_f' \frac{\partial E_t f_{t+i}}{\partial D_t}. \qquad (6)$$

Then, from (5) we have that

$$\frac{\partial k_t}{\partial D_t} = 0 \text{ and } \frac{\partial E_t k_{t+i}}{\partial D_t} = \rho \frac{\partial E_t k_{t+i-1}}{\partial D_t} + \sum_{j=-\infty}^{+\infty} \mu_j' \frac{\partial E_t f_{t+i+j}}{\partial D_t}, \text{ for } i \geq 1. \quad (7)$$

Finally, (3) implies

$$\frac{\partial E_t f_{t+i}}{\partial D_t} = h_{fi}, \text{ for } i \geq 0. \quad (8)$$

Combining (6)–(8), the recursive system

$$\begin{aligned} \frac{\partial k_t}{\partial D_t} &= 0 \qquad \frac{\partial E_t k_{t+i}}{\partial D_t} = \rho \frac{\partial E_t k_{t+i-1}}{\partial D_t} + \sum_{j=-i}^{+\infty} \mu_{fj}' h_{f(i+j)}, \text{ for } i \geq 1. \\ \frac{\partial z_t}{\partial D_t} &= \kappa_f' h_{f0} \qquad \frac{\partial E_t z_{t+i}}{\partial D_t} = \kappa_k' \frac{\partial E_t k_{t+i}}{\partial D_t} + \kappa_f' h_{fi} \quad \text{for } i \geq 1. \end{aligned}$$

defines an alternative impulse response function $I_M(i+1, \theta)$. We refer to this as the *model* response function.

Notice that both response functions, I_D and I_M, depend on the parameters of representation (1), θ. However, only I_M depends on the parameters of preferences and technology in the neoclassical model. Under the null that the model is true, I_D and I_M are the same. To test the model we could simply test whether I_D and I_M were identical for all i. Rather than do this, we focus on whether specific features of the two response functions are the same.

To give a concrete example, in Section 4 we will examine the average response of hours worked in the first four periods after the onset of a Ramey and Shapiro episode. Suppose we define

$$g(\theta) = \frac{1}{4} \sum_{i=0}^{3} I_{Dn}(i+1, \theta) - \frac{1}{4} \sum_{i=0}^{3} I_{Mn}(i+1, \theta),$$

where the subscript n simply indicates the elements of I_D and I_M that correspond to the response of hours worked. If the model is true, then the hypothesis $g(\theta) = 0$ ought to hold. To test this hypothesis, we first compute an estimate of $g(\theta)$, denoted $g(\hat{\theta})$, by (i) obtaining an estimating, $\hat{\theta}$, of the parameters of representation (1), (ii) computing $I_D(i+1, \hat{\theta})$, (iii) calibrating the model parameters and (iv) computing $I_M(i+1, \hat{\theta})$. We then test whether $g(\hat{\theta})$ is significantly different from 0. To do this we exploit a result from Eichenbaum, Hansen and Singleton (1984): the test statistic

$$J = Tg(\widehat{\theta})'\widehat{\mathrm{Var}}[\sqrt{T}g(\widehat{\theta})]^{-1}g(\widehat{\theta}) \tag{9}$$

is asymptotically distributed as a chi-squared distribution with 1 degree of freedom, if $\sqrt{T}\widehat{\mathrm{Var}}[g(\widehat{\theta})]$ is a consistent estimator of $\mathrm{Var}[\sqrt{T}g(\widehat{\theta})]$.[15]

Our test takes the sampling uncertainty in $\hat{\theta}$ into account. Strictly speaking, we should also take sampling uncertainty in the model parameters into account. However, results in Burnside and Eichenbaum (1996) suggest that this source of uncertainty is unlikely to significantly affect inference for the model we discuss in this paper.[16]

In sum, this section provides a rationale for our procedure for assessing whether the neoclassical model can account for the estimated response of the U.S. economy to an exogenous fiscal policy shock. A key step in this analysis was to attribute views to agents about how fiscal policy evolves after the onset of a Ramey-Shapiro episode. These views are summarized by (3).

Implicit in our analysis is the assumption that at any date t, agents expect D_{t+j}, $j > 0$, to be zero. In addition, we assume that a realization of $D_t = 1$ does not affect agents' future expectations of D_t, i.e. they continue to expect

[15]In practice we computed our test statistic using the bootstrap procedure described in Edelberg, Eichenbaum and Fisher (1999). Specifically, let θ_i be the point estimate of θ generated by the ith bootstrap draw, $i = 1, \ldots, N$, where $N = 500$. Define $\bar{g} = (1/N)\sum_{i=1}^{N} g(\theta_i)$. Then we compute $J = g(\hat{\theta})'V^{-1}g(\hat{\theta})$ where

$$V = \frac{1}{N-1}\sum_{i=1}^{N}[g(\theta_i) - \bar{g}][g(\theta_i) - \bar{g}]'.$$

[16]Burnside and Eichenbaum calculate confidence intervals for the dynamic response functions in a standard real business cycle model to a shock in government purchases. They argue that the size of the confidence intervals is determined primarily by sampling uncertainty regarding the law of motion for government purchases, rather than the other parameters of the models, at least when the latter are estimated using the generalized method of moment techniques employed in Burnside and Eichenbaum (1996).

that future values of D_t will equal zero. So from their perspective, a realization of $D_t = 1$ is just like the realization of an i.i.d exogenous shock to f_t. But once such a shock occurs, the expected response of f_{t+j} is given by the coefficient on L^j in the polynomial $h_f(L)$. An alternative approach would be to model agents' subjective probability distribution over rare events such as the outbreaks of war and major military buildups induced by exogenous shocks. We adopted our approach given the difficulty of this task and the paucity of data on such events.

4. Fiscal Policy in a Neoclassical Model

In this section we describe a neoclassical model and study its implications for how the economy responds to a fiscal policy shock. The model incorporates adjustment costs to investment and habit formation. While these do not affect its qualitative properties, they lead to a considerable improvement of the model's quantitative properties. 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 model's quantitative properties.

4.1. Theoretical Framework

A representative household ranks alternative streams of consumption and hours worked according to

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\{ \log(C_t^*) + \eta V(1-n_t) \} \right], \tag{10}$$

where

$$C_t^* = C_t - bC_{t-1}, \quad b \geq 0 \tag{11}$$

$$V(1-n_t) = \begin{cases} \frac{1}{1-\mu}(1-n_t)^{1-\mu}, & \mu \geq 0 \\ \ln(1-n_t), & \mu = 1 \end{cases} . \tag{12}$$

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 and the fraction of the household's time endowment devoted to work, respectively. When $b > 0$, (10) allows for habit formation in consumption. Given (12), the representative household's Frisch elasticity of labor supply, evaluated at the steady state level of hours, n, is equal to $(1-n)/(n\mu)$.[17]

The household owns the stock of capital, whose value at the beginning of time t we denote by K_t. Absent adjustment costs, capital evolves according to:

$$K_{t+1} = (1-\delta)K_t + I_t, \quad 0 < \delta < 1, \tag{13}$$

where I_t denotes time t investment in capital. We also consider a version of the model in which there are costs of adjusting investment. There are various ways to model these costs. Here we proceed as in Christiano, Eichenbaum and Evans (2001) and suppose that K_{t+1} evolves according to

$$K_{t+1} = (1-\delta)K_t + F(I_t, I_{t-1}) \tag{14}$$

where

$$F(i_t, i_{t-1}) = (1 - S\left(\frac{I_t}{I_{t-1}}\right))I_t. \tag{15}$$

Notice that the functional form for F in (15) penalizes changes in I_t. Many authors in the literature adopt specifications which penalize the level of investment. Christiano, Eichenbaum and Evans (2001) argue that it is difficult to generate hump shaped responses of investment to shocks with the latter specification. In contrast, hump shaped responses of investment emerge naturally with specification (15). As we show below, this improves the performance of the model by inducing a sympathetic hump shape in hours worked.[18]

[17]For $\mu = 0$, this elasticity must be interpreted with some care. Hansen (1985) and Rogerson (1988) describe model economies in which the competitive equilibrium allocation is given by the solution to a social planning problem in which leisure enters into the planner's objective function in a linear manner ($\mu = 0$) - even though leisure need not enter individual agents' objective function linearly. So in their model, there is no link between individuals' Frisch elasticity of labor supply and the corresponding elasticity implied by the planner's preferences.

[18]See Christiano, Eichenbaum and Evans (2001) for a more detailed comparison of the two cost of adjustment specifications.

We restrict the function, S, to satisfy the following properties: $S(1) = S'(1) = 0$, and $s \equiv S''(1) > 0$. Under our assumptions, in a nonstochastic steady state $F_1 = 1$, $F_2 = 0$. The steady state values of the variables are not a function of the adjustment cost parameter, s. Of course, the dynamics of the model are influenced by s. When $s = 0$ the model is equivalent to one without adjustment costs. Given our solution procedure no other features of the S function need to be specified.

The household rents out capital and supplies labor in perfectly competitive spot factor markets. We denote the real wage rate per unit of labor by w_t and the real rental rate on capital by r_t. The government taxes rental income net of depreciation, and wage income at the rates τ_{kt} and τ_{nt}, respectively. Consequently, after-tax real wage and rental rate on capital are given by $(1 - \tau_{nt}) W_t$ and $(1 - \tau_{kt})r_t + \delta\tau_{kt}$, respectively. Therefore, the household's time t budget constraint is given by

$$C_t + I_t \leq (1 - \tau_{nt}) W_t n_t + (1 - \tau_{kt}) r_t K_t + \delta\tau_{kt} K_t - \Phi_t \tag{16}$$

where Φ_t denotes lump sum taxes paid by the household.

A perfectly competitive firm produces output, Y_t, according to[19]

$$Y_t \leq K_t^{\alpha} {n_t}^{1-\alpha}, \quad 0 < \alpha < 1. \tag{17}$$

The firm sells its output in a perfectly competitive goods market and rents labor and capital in perfectly competitive spot markets.

The government purchases G_t units of output at time t. For simplicity we assume the government balances its budget every period. Government purchases are financed by capital taxes, labor taxes and lump sum taxes, Φ_t. Consequently the government's budget constraint is given by

$$G_t = \tau_{nt} W_t n_t + \tau_{kt}(r_t - \delta) K_t + \Phi_t.$$

Given our assumptions, Ricardian equivalence holds with respect to the timing of lump sum taxes.[20] So we could allow the government to borrow part of the

[19] To conserve on notation we abstract from growth when describing the model. In practice we allow for growth arising from technological progress when calibrating the model.

[20] This assumes the absence of distortionary taxes on government debt.

difference between its expenditures and revenues raised from distortionary taxes, subject to its intertemporal budget constraint, and it would not affect our results.

The vector $f_t = [\log(G_t), \tau_{kt}, \tau_{nt}]'$ evolves according to

$$f_t = f + h_f(L)\varepsilon_t. \tag{18}$$

Here ε_t is a zero mean, iid scalar random variable that is orthogonal to all model variables dated time $t-1$ and earlier. In addition $h_f(L) = [h_1(L), h_2(L), h_3(L)]'$ where $h_i(L)$, $i = 1, 2, 3$ is a q^{th} ordered polynomial in nonnegative powers of the lag operator L, and f denotes the steady state value of f_t. Note that ε_t is common to both government spending and taxes. This formalizes the notion that government spending and taxes respond simultaneously to a common fiscal shock.

The problem of the representative household is to maximize (10) subject to (16), (12), (14), (11), (18) and a given stochastic process for wage and rental rates. The maximization is by choice of contingency plans for $\{C_t, K_{t+1,}n_t\}$ over the elements of the household's time t information set that includes all model variables dated time t and earlier.

The firm's problem is to maximize time t profits. Its first order conditions imply

$$\begin{aligned} W_t &= (1-\alpha)\left(K_t/n_t\right)^{\alpha}, \text{ and} \\ r_t &= \alpha\left(n_t/K_t\right)^{1-\alpha}. \end{aligned} \tag{19}$$

We use the log-linearization procedure described by Christiano (1998) to solve for the competitive equilibrium of this economy. To conserve on notation we abstracted from growth when presenting our model. However we do allow for growth when calibrating the model. Specifically we assume that total factor productivity grows at the constant growth rate γ, so that production is given by $Y_t = \gamma^t K_t^{\alpha} n_t^{1-\alpha}$.

This model of growth is inconsistent with the way we treated growth in section 2 where we assume a trend break in 1973:2. To understand the nature of the approximation involved, note that Christiano's solution procedure involves taking a log linear approximation about the model's steady state. Suppose that the break in trend is unanticipated and the model has converged to its stochastic steady state by the time of the third Ramey Shapiro episode. One way to implement Christiano's procedure is to compute two log linear equilibrium laws of motion for the model corresponding to the pre and post 1973:2 periods. The difference between the two is that the log linear approximation is computed about two different steady states of the model corresponding to the pre and post 1973:2 growth rate of technology. We approximate this procedure by computing one law of motion around the steady state of the model assuming a growth rate of output, $\gamma = 1.005$. This is equal to the average growth rate of output over the whole sample period.

4.2. Model Calibration

In this subsection we briefly describe how we calibrated the model's parameter values. We assume that a time period in the model corresponds to one quarter and set $\beta = 1.03^{-1/4}$. To evaluate the dependence of the model's implications on the Frisch labor supply elasticity we consider three values for μ. The first, $\mu = 0$, corresponds to the Hansen-Rogerson infinite elasticity case. The second, $\mu = 1$, implies the utility function for leisure is logarithmic. Combined with our assumption that the representative agent spends 24 percent of his time endowment working (see, for example, Christiano and Eichenbaum (1992)), this value corresponds to a Frisch labor supply elasticity of 3.16. Finally, we consider $\mu = 10$, which corresponds to a Frisch labor supply elasticity of 0.33. As a reference point, note that the value of the Frisch labor supply elasticity for males is estimated in the labor literature to be close to zero (see Card (1991), Killingsworth (1983) and Pencavel (1986)). Estimates of the Frisch labor supply elasticity for females typically falls in the range 0.5 to 1.5 (see for example, Heckman and Killingsworth (1986)). The parameter η was set to imply that in nonstochastic steady state the representative consumer spends 24% of his time endowment working. The rate of depreciation on capital δ was set to 0.021 while α was set to 0.34 (see Christiano and Eichenbaum 1992).

Initially we set the habit formation and cost of adjustment parameters, b and s to zero. We refer to this version of the model as the *benchmark model.* We then consider a version of the model, referred to as the *modified benchmark model,* where $b = 0.8$ and $s = 2.0$. This value of b is close to values used in the literature (see for example Boldrin, Christiano and Fisher (2001)). The value of s is close to the value estimated by Christiano, Eichenbaum and Evans (2001).[21] They show that $1/s$ is the elasticity of investment with respect to a one percent temporary increase in the price of installed capital.[22] So a value of s equal to two implies this this elasticity is equal to 0.5. We chose this value because it led to a better performance of the model (see below).[23]

Interestingly, this parameterization does not lead to a deterioration of the model's performance for consumption and investment in a version of the model driven only by technology shocks. To establish this we simulated the model assuming the only source of shocks was a multiplicative shock to the production function. As in Hansen (1985) we assumed the shock was governed by a first order autoregressive process with autocorrelation coefficient 0.95 and innovation standard deviation equal to 0.00763. We logged and HP filtered the data from

[21]Their point estimate of s is 3.60 with a standard error of 2.24.

[22]A more persistent change in the price of capital induces a larger percentage change in investment. This is because adjustment costs induce agents to be forward looking. For example, a permanent one-percent change in the price of capital induces a $1/[s(1-\beta)] = 67$ percent change in investment.

[23]Interestingly, this parameterization does not lead to a deterioration of the model's performance for consumption and investment in a version of the model driven only by technology shocks. To establish this we simulated the model assuming the only source of shocks was a multiplicative shock to the production function. As in Hansen (1985) we assumed the shock was governed by a first order autoregressive process with autocorrelation coefficient 0.95 and innovation standard deviation equal to 0.00763. We logged and HP filtered the data from the model and calculated the standard deviation of consumption and investment relative to the standard deviation of output. We found that consumption was 40 percent as volatile as output and investment was 2.5 times as volatile as output. These model statistics are consistent with the analogue statistics using US data (see for example, Boldrin, Christiano and Fisher 2001). Evidently, along these dimensions our parameterization of habit formation and investment adjustment costs does not lead to counterfactual implications.

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Our specification for the j^{th} coefficient in the expansion of $h_i(L), i = 1, 2, 3$ is given by the estimated response of real government purchases, the capital income tax rate and the labor income tax rate at $t + j$ to the onset of a Ramey-Shapiro episode at time t. In practice we use 50 coefficients in $h_1(L)$ and 16 coefficients in $h_2(L)$ and $h_3(L)$.[24] We refer to this as the *distortionary tax specification*. We also consider a version of the model in which all taxes are lump sum. In this specification, $h_2(L)$ and $h_3(L)$ are set to zero. We refer to this as the *lump sum tax specification*.

4.3. Quantitative Implications of the Benchmark Model

We begin by considering the benchmark model in which there are no investment adjustment costs ($s = 0$) and no habit formation ($b = 0$). Figure 3 displays the dynamic response of hours worked, real wages, consumption and investment to a fiscal shock. Columns 1 and 2 report results corresponding to the lump sum and distortionary tax specifications, respectively. The dark solid lines in columns 1 and 2 display the estimated impulse response functions of hours worked, real wages, investment and consumption. In the lump-sum tax case wages are before-tax. In the distortionary tax case, wages are after-tax.[25] The dotted lines correspond to model based impulse response functions for $\mu = \{0, 1, 10\}$. We start by analyzing the implications of the model for hours worked and wages. We then turn to the

[24] These are displayed in Figure 2.

[25] The estimated impulse response functions for the distortionary tax specification are reproduced from Figure 2.

behavior of consumption and investment to help assess the plausibility of the basic mechanisms at work in our model.

4.3.1. The Response of Hours Worked

We initially consider the properties of hours worked in the lump sum tax specification of the model. First, notice that for all values of μ, the model generates a prolonged rise in n_t in response to a positive fiscal policy shock. This is because an increase in G_t raises the present value of the household's taxes and lowers its permanent income. Since leisure is a normal good, equilibrium hours worked rises.

Second, when labor supply is infinitely elastic ($\mu = 0$), the model predicts a strong positive response of hours worked. Indeed model based hours overshoot relative to the data. For example, the peak responses of n_t in the model and the data are 13.2% and 9.7%, respectively. Hours worked responds less strongly for lower elasticities of labor supply (higher values of μ). With a labor supply elasticity of 3.16% ($\mu = 1$) the peak rise in n_t in the model is about the same as in the data. But when the labor supply elasticity equals 0.33 ($\mu = 10$), the peak rise in n_t is only 2.6%, roughly 20% of the estimated peak response of n_t in the data.

The basic intuition for this result is as follows. The larger is μ the more the household wishes to smooth hours worked. Since hours worked do not change in steady state, as μ becomes larger, the household finds it optimal to respond to a rise in the present value of its taxes by reducing private consumption by relatively more and varying hours worked less. Finally, notice that the hump-shaped rise in n_t becomes less pronounced for lower elasticities of labor supply. Again this reflects the fact that the household is less willing to vary hours worked for higher values of μ.

Turning to the distortionary tax specification, a number of interesting results are worth noting. First, for all values of μ, there is still a prolonged rise in n_t. So even after taking into account the rise in tax rates, the model can still account qualitatively for the fact that an increase in government purchases leads to a boom in n_t. As we discussed in the introduction, there is no a priori reason why this must be the case. Our results indicate that the model's qualitative implications are robust to allowing for empirically plausible responses of tax rates.

Second, movements in distortionary tax rates do affect the timing of how hours worked respond to the fiscal policy shock. As can be seen from Figure 3, the key difference relative to the lump sum tax specification pertains to the shape of the dynamic response function of n_t. In the lump sum tax specification, a fiscal shock leads to a long persistent rise in n_t which slowly declines to its pre-shock level. For $\mu = 1$ and $\mu = 0$ the rise in n_t is hump-shaped with the maximal rise occurring roughly one year after the shock. Once we allow for movements in distortionary taxes, the rise in n_t is shifted, counterfactually, closer to the time of the fiscal shock. For all values of μ, the peak rise in n_t now occurs at the time of the fiscal shock. The temporal shift in the response of n_t is more pronounced the more elastic is labor supply.

The intuition for this result can be described as follows. Other things equal, a higher value of τ_{nt} gives rise to an intratemporal effect which induces the household to shift its period t allocation of time towards leisure. In addition the hump-shaped pattern of the rise in τ_{nt} gives rise to an intertemporal effect which induces the household to shift n_t towards periods in which τ_{nt} is relatively low. Since τ_{nt} moves by relatively small amounts in the first few periods after the fiscal shock, the initial intratemporal effects of the tax rate changes are small. Given the intertemporal effect of future rises in τ_{nt}, the initial rises in n_t are slightly larger than in the lump sum tax case. As marginal tax rates begin to rise significantly, the intratemporal effect becomes quantitatively important and the responses of n_t in the lump sum and distortionary tax rate models become quite different.

As Figure 3 indicates, the previous effect is more pronounced the higher is the elasticity of labor supply (the lower is μ). This is because the household is more willing to intertemporally substitute n_t over time. So while a high labor supply elasticity often improves the empirical performance of neoclassical models, here it hurts the model's performance by exacerbating the swing in the peak response of hours towards the time of the shock.

We conclude this subsection by reporting the results of formally testing the model's ability to account for certain conditional moments of the data using the J statistic defined in (9). The first moment that we consider, σ_n, is the standard deviation of hours worked induced by the onset of a Ramey-Shapiro episode. Below, σ_n^m and σ_n^d denote the values of this moment implied by the model and the data, respectively.[26] The other two moments that we consider, $R_1(n)$ and $R_2(n)$, denote the average response of n_t in period 1 through 4 and period 5 through 8 after a fiscal policy shock. We denote by $R_i^m(n)$ and $R_i^d(n)$ the value of these moments in the model and in the data, respectively. Model and data moments were calculated using the first sixteen coefficients of the relevant dynamic response function.

Table 1 reports the results of testing the individual hypotheses: $\sigma_n^d - \sigma_n^m = 0$ and $R_i^d(n) - R_i^m(n) = 0$, $i = 1, 2$. First consider the model's implications for the volatility of hours worked. Notice that the hypothesis that $\sigma_n^d - \sigma_n^m = 0$ cannot be rejected at the 5% significance level. This true for all values of μ and for both tax cases. Evidently the model does not have a problem accounting for the volatility in hours worked induced by a fiscal shock.

Next consider the ability of the model to account for the average response of hours worked in periods 1 through 4. From Table 1 we see that for both tax specifications, when $\mu = 0$ or 1, the model *overstates* the extent to which hours worked rises. But when $\mu = 10$, the model *understates* the extent to which hours worked rises. Nevertheless, the only case in which the hypothesis $R_1^d(n) - R_1^m(n) = 0$, can be rejected at more than the 1% significance level, is the lump sum tax - high labor supply elasticity specification. In the empirically relevant case of

[26] We calculated these moments as follows. Let the actual and model implied dynamic response function of a hours worked to a fiscal policy shock be given by $\hat{H}_n^1(L)D_t$ and $\tilde{H}_n^1(L)D_t$, respectively. The value of σ_n implied by the model and in the data is given by $\sigma_n^m = \{\sum_{i=0}^{\infty}[\tilde{H}_n^1(i)]^2\}^{1/2}$ and $\sigma_n^d = \{\sum_{i=0}^{\infty}[\hat{H}_n^1(i)]^2\}^{1/2}$, respectively. Here $\hat{H}_n^1(i)$ and $\tilde{H}_n^1(i)$ denote the i^{th} coefficients in the polynomial lag operators $\hat{H}_n^1(L)$ and $\tilde{H}_n^1(L)$. In practice we calculated σ_n^m and σ_n^d using the first 16 coefficients of the relevant dynamic response functions.

distortionary taxes, we cannot reject this hypothesis at even the 10% significance level when μ is equal to either 1 or 10.

We now turn to the average response of hours worked in periods 5 through 8. Consistent with our discussion above, allowing for movements in tax rates considerably mutes the rise in hours worked in these time periods. For example with $\mu = 1$, the rise in hours worked with distortionary tax rates is only 65% as large as in the lump sum tax case. As anticipated, the effect of tax rate changes is larger the higher is the elasticity of labor supply. Still, regardless of how we treat taxes, the hypothesis $R_2^d(n) - R_2^m(n) = 0$ cannot be rejected at the 5% significance level when μ is equal to 0 or 1.

We do not wish to overstate the overall ability of the benchmark model to account for the dynamic response of hours worked. Figure 3 reveals that for both tax specifications, the model has difficulty in accounting for the precise timing of how n_t responds to a fiscal policy shock. One way to make this precise is to consider $R_1(n) - R_2(n)$, the average response of n_t during periods $1 - 4$ minus the average response during periods $5 - 8$. In the data this difference is negative, roughly -5.0 percentage points. In the lump sum tax specification, $R_1^m(n) - R_2^m(n)$ is close to zero. Once we allow for movements in tax rates, $R_1^m(n) - R_2^m(n)$ is actually positive. This reflects agents' desire to work in periods when tax rates are relatively low. In this case, for all values of μ, we can reject the hypothesis $\left[R_1^d(n) - R_2^d(n)\right] - \left[R_1^m(n) - R_2^m(n)\right] = 0$ at the 2% significance level. Comparing results across the lump sum and distortionary tax specifications, we see that there is more evidence against the ability of the model to match the timing of the response in hours worked in the latter case.

4.3.2. The Response of Real Wages

We now turn to the model's implications for real wages. From Figure 3 we see that all versions of the model are consistent with the qualitative response of real wages to the shock, namely they fall.[27] This decline reflects the fact that hours worked rises and the marginal product of labor is a decreasing function of n_t. Since the rise in n_t is an increasing function of the elasticity of labor supply, real wages fall by more the higher is that elasticity.

Interestingly, the model also does well at accounting for the quantitative response of real wages. Table 2 summarizes the results of formally testing the analog hypotheses to those reported in Table 1. The first moment, σ_w, is the standard deviation of the real wage induced by the onset of a Ramey-Shapiro shock. In the lump sum and distortionary tax cases, the real wage measure pertains to before and after-tax real wages, respectively. The other two moments that we consider, $R_1(w)$ and $R_2(w)$ denote the average response of w_t in period 1 through 4 and period 5 through 8 after a fiscal policy shock.

Two features of Table 2 stand out. First, in the distortionary tax case, there is very little evidence against any of the hypotheses that we consider. Second, there is some evidence against the low labor supply elasticity version of the model ($\mu = 10$) in the lump sum tax case.[28]

We conclude that regardless of whether or not we allow for movements in distortionary tax rates, our simple benchmark neoclassical model is able to account for the qualitative effects of a fiscal policy shock on hours worked and real wages. The empirically relevant case is the one in which labor and capital income tax rates rise after an exogenous shock to government purchases. Here the model does quite well at accounting quantitatively for the dynamic response of real wages. The model also does reasonably well at accounting for the volatility and peak response of hours worked. But it has difficulty in accounting for the timing of the response of hours worked.

[27] The estimated declines in after tax real wages are larger than those of before tax real wages. This is because the former reflect both rises in τ_{nt} and declines in w_t.

[28] For example the hypothesis that $\sigma_w^d - \sigma_w^m = 0$ can be rejected at the 2% significance level. Also the hypothesis that $R_2^d(w) - R_2^m(w) = 0$ can be rejected at the 1% significance level. In part the difference between the test statistics for the lump sum and distortionary tax cases reflect the sampling uncertainty in the response of model based real wages induced by the sampling uncertainty associated with our estimate of how tax rates respond to a fiscal policy shock.

4.3.3. The Response of Consumption and Investment

We now consider the model's ability to account for the dynamic responses of consumption and investment. Figure 3 indicates that model based consumption drops in response to the fiscal policy shock. This is true for all values of μ and regardless of which tax case we consider. The drop in consumption reflects the negative wealth effect associated with the rise in government spending. The size of the drop is larger the smaller is the elasticity of labor supply (the higher is μ). This reflects agents' greater reluctance to pay for the rise in the present value of taxes by varying hours worked, rather than reducing consumption. But for all values of μ the model substantially overstates the fall in consumption.

Figure 3 also indicates that in all cases the model generates a very sharp rise in investment after a fiscal policy shock. The intuition for this is seen most easily by considering the case of a permanent rise in government purchases financed via lump sum taxes. In that case the steady state value of hours worked rises. Given our other assumptions, the steady state value of the capital - labor ratio does not change, so that steady state capital must rise. To build up the higher steady state stock of capital, 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 capital are complements, the household initially increases investment in response to the shock. Figure 3 reveals that allowing for distortionary taxes has a relatively small affect on the quantitative response of consumption and investment. But as with consumption, the model dramatically overstate the extent of the rise in investment.

Table 3 and 4, which pertain to investment and consumption, respectively, summarize the results of formally testing the analogous hypotheses to those reported in Table 1. The moments, σ_c and σ_I, are the standard deviations of consumption and investment induced by the onset of a Ramey-Shapiro shock. The other moments that we consider, $R_1(z)$ and $R_2(z), z \in \{C, I\}$ denote the average response of z_t in period 1 through 4 and period 5 through 8 after a fiscal policy shock.

A number of key results emerge here. First, the model clearly overstates the volatility of consumption and investment. In all but one case we can reject the hypotheses that $\sigma_I^d - \sigma_I^m = 0$ and $\sigma_c^d - \sigma_c^m = 0$ at the 1% significance level. The exception is the case of lump sum taxes with $\mu = 1$. Even here the hypothesis can be rejected at the 3% significance level. Second, there is very strong evidence against the other hypotheses involving the dynamic responses of consumption and investment.

In sum, we have shown that the benchmark model does well at accounting for the qualitative responses of the hours worked, real wages, investment and to a lesser extent consumption. But the model clearly has difficulty accounting for the timing of the response in hours worked and the magnitude of the responses of consumption and investment. In the next section we argue that these shortcoming are related and can be substantially improved upon by allowing for habit formation and investment adjustment costs.

4.4. Properties of the Modified Benchmark Model

In this subsection we discuss the quantitative properties of the model when we allow for habit formation and investment adjustment costs ($b = 0.80$, $s = 2$). For the sake of parsimony we focus on the high labor supply ($\mu = 0$), distortionary tax case version of the model. Figure 4 displays the dynamic responses of model based hours worked, real wages, consumption and investment to a fiscal shock for three sets of parameter values: ($b = 0.80$, $s = 2$), ($b = 0.80$, $s = 0$), ($b = 0, s = 2$). The latter two specifications allow us to disentangle the roles played by habit formation and investment adjustment costs, per se. For convenience the Figure also reports the estimated impulse response functions along with shaded regions corresponding to 95% confidence interval bands.

Consider our results when we allow for both habit persistence and investment adjustment costs. First, the model does a much better job of accounting for the estimated response of investment. In the simple benchmark model, investment jumps in the impact period of the fiscal shock, substantially overstating the actual response of investment. In the presence of adjustment costs, investment rises in a hump shaped manner, with the average response over the first year being similar to that observed in the data. Figure 4 reveals that if we set adjustment costs to zero, but retained habit formation, investment behaves much as in the simple benchmark model.

Second, the model does a better, if still imperfect job of accounting for the response of consumption. In the simple benchmark model, the drop in consumption was substantially larger than that observed in the data. The presence of habit formation mutes the decline in consumption, although not enough to closely mimic our point estimates. Figure 4 reveals that if we set habit formation to zero, but retain investment adjustment costs, the performance of the model regarding consumption deteriorates markedly.

Third, the model does much better at matching the timing of the response of hours worked which now rise in a pronounced hump shaped way with the peak response occurring over a year after the onset of the fiscal shock. The key reason for this is the presence of investment adjustment costs. Movements in tax rates aside, the household wants to worker harder because of the negative wealth effects associated with the rise in government spending. It pays to work harder in periods when the household can use part of its wages to build up the capital stock. Because of the adjustment costs, it is optimal to build up investment rates and hours worked slowly in a hump shaped way. Figure 4 reveals that the performance of the model with respect to hours worked deteriorates markedly if we retain habit formation in consumption but abandon the assumption of investment adjustment costs. Fourth, mirroring the response of hours worked, after tax real wages also fall in a hump shaped manner.

The last columns of Tables 1 through 4 report the results of formally testing the ability of the model to account for various moments of the data. Table 1 reveals that there is now very little evidence against the model involving hypotheses about hours worked. Recall that the simple benchmark model had difficulty accounting for the timing of the response of hours worked. Table 1 indicates that the modified model does not have this problem. Table 2 reveals some marginal evidence against hypotheses involving after tax real wages. But none are rejected at marginal significance rates smaller than 5%.

Table 3 reveals a dramatic improvement in the model's performance regarding investment. Recall that in the simple benchmark model, there was very strong evidence against most of the hypotheses involving investment. Table 4 reveals that there is virtually no evidence against these hypotheses once we allow for investment adjustment costs.

Finally, Table 4 reveals a marked improvement in the model's performance regarding consumption. In the simple benchmark model with the distortionary tax specification, every hypothesis involving consumption was overwhelmingly rejected. Now only the hypothesis that $\sigma_c^d - \sigma_c^m = 0$ can be rejected at roughly the 1% significance level. None of the other hypotheses can be rejected at more than the 5% significance level. Much stronger evidence against the model emerges if we retain investment adjustment costs but do not allow for habit formation in consumption.

We conclude that allowing for habit formation and investment adjustment costs alleviates the salient quantitative shortcomings of the benchmark model. The high labor supply elasticity version of the modified model does a good job of accounting for both the qualitative and quantitative effects of a fiscal policy shock. This is true even though we allow for movements in distortionary tax rates.

5. Conclusion

This paper investigated the effects of a fiscal policy shock on key macroeconomic aggregates. An important feature of our analysis is that we explicitly allow for movements in capital and labor tax rates as well as government purchases. Using post war US data, we identify fiscal policy shocks that are followed by persistent declines in real wages and rises in tax rates, government purchases, and hours worked. They are also associated with a short lived rise in investment and small movements in consumption. We assess whether a neoclassical model can account for these findings.

Our main results are as follows. First, a benchmark version of the model can account for the qualitative effects of a fiscal shock on both hours worked, real wages, consumption and investment. However this simple version of the model has important shortcomings. Specifically it has difficulty accounting for the timing of how hours responds. This is because movements in distortionary tax rates shift the rise in employment counterfactually, closer to the time of the fiscal shock. In addition, the benchmark model overstates the rise in investment and the drop in consumption that follow a fiscal policy shock.

Second, incorporating habit formation in consumption and investment adjustment costs into the model considerably enhances its quantitative performance. Indeed we find relatively little formal evidence against the model, at least for the hypotheses that we consider. The model has two important shortcomings. First, the most successful version of the model assumes an elasticity of labor supply that is high relative to the micro evidence. Second, even the model with habit formation overstates the decline in consumption that occurs after a fiscal shock. It is possible that a model which allowed for endogenous capacity utilization would lead to a larger rise in output and smaller decline in consumption than the model considered in this paper (see, for example, Burnside and Eichenbaum 1996). Despite these shortcomings, we conclude that our modified neoclassical model does a reasonably good job at accounting for the qualitative and quantitative effects of a shock to fiscal policy on key macro aggregates.

6. Data Appendix

Below we list the data series used in our analysis. All series are seasonally adjusted except for taxes and population. The Haver database mnemonic for the series is indicated where appropriate.

1. Expenditures. Output (GDPH), Defense spending (GFDH), Government purchases (Defense spending plus Federal, State and Local consumption expenditures, GFDH+GFNEH+GSEH), Consumption (Consumption of non-durables and services, CNH+CNS, plus the service flow from consumer durables, obtained from David Reifschneider of the Federal Reserve Board), Investment (Federal Non-defense investment plus State and Local investment plus consumer durables expenditures plus private fixed investment, GNIH+GSIH+CDH+FH). When series are added together they are chain weighted. This requires the nominal version of the series listed above (mnemonics for these series are the same as for the real series with the last letter removed.) All real series are in units of 1996 chain-weighted dollars. To deflate nominal compensation we use the price index associated with our measure of real consumption.

2. Labor Market. Hours (index of hours of all persons in the non-farm business sector, LXNFH), real wages (index of compensation to persons in the non-farm business sector, LXNFC, deflated by our price index), population (resident population, POP).

3. Taxes. For details of how Jones calculates average labor and capital taxes, see Appendix B to Jones (2002). Jones measures of capital and labor taxes extend from 1958 onward. To derive series extending back to 1947:I we splice his post-1958 series to closely related series we derive for the period 1947:I to 1957:IV. Our pre-1958 series are calculated as follows. First we calculate an alternative to the average personal income tax measure employed by Jones. His personal income tax is based on the sum of state, local and

federal income taxes. These are not available prior to 1958 and so we use the measure of total personal taxes (Survey of Current Business Table 3.1 line 2) which includes government fees such as marriage licences. Except for this difference, the inputs into our labor tax measure are identical to the ones Jones uses for post 1958. The resulting measure is very similar to Jones' labor tax in the period where both can be calculated. Their correlation over the period 1958:I to 1996:IV is 0.9996. We splice Jones post-1958 labor tax to our pre-1958 labor tax by accumulating changes in our measure backwards from 1958:I. Our pre-1958 capital tax measure also uses our alternative version of the average personal income tax. The only other difference with Jones' post-1958 capital tax measure is that our's excludes property taxes, which are not available prior to 1958. The dynamics of our capital tax are very similar to Jones' capital tax measure in the period in which they both can be calculated. Their correlation over the period 1958:I to 1996:IV is 0.9490. We splice Jones post-1958 capital tax to our pre-1958 capital tax in the same way we splice the labor tax series.

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Table 1. Goodness-of-fit Tests for the Response of Hours Worked

	Lump Sum Taxes			Distortionary Taxes					
	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0.8$	$b=0.8$
	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=2$	$s=0$	$s=2$
Moment	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=0$	$\mu=0$
Standard Deviation									
Data	30.90	30.90	30.90	30.90	30.90	30.90	30.90	30.90	30.90
Model	46.70	33.01	9.40	32.77	23.54	6.98	30.13	48.11	45.40
J-statistic	0.98	0.02	2.99	0.01	0.21	3.61	0.003	1.04	0.77
P-value	0.32	0.88	0.08	0.92	0.64	0.06	0.96	0.31	0.38
Average 1,2,3,4									
Data	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Model	12.20	8.70	2.48	12.28	8.23	2.23	3.70	15.24	4.68
J-statistic	10.07	5.17	0.16	5.03	2.40	0.26	0.08	9.81	0.47
P-value	<0.01	0.02	0.69	0.02	0.12	0.61	0.78	<0.01	0.49
Average 5,6,7,8									
Data	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48
Model	12.98	9.04	2.52	8.14	5.92	1.77	9.23	12.13	13.70
J-statistic	1.15	0.02	3.19	0.004	0.29	3.85	0.03	0.61	1.33
P-value	0.28	0.89	0.07	0.95	0.59	0.05	0.86	0.43	0.25
Average 1,2,3,4 less 5,6,7,8									
Data	-5.34	-5.34	-5.34	-5.34	-5.34	-5.34	-5.34	-5.34	-5.34
Model	-0.78	-0.33	-0.05	4.15	2.32	0.46	-5.53	3.11	-9.03
J-statistic	3.59	4.35	4.86	12.80	9.67	5.85	0.005	7.44	1.58
P-value	0.06	0.04	0.03	<0.01	<0.01	0.02	0.95	<0.01	0.21

Note: Based on the estimated VAR system including the variables: output, average capital taxes, average labor taxes, government spending on goods and services, and hours worked in the non-farm business sector. In the lump-sum case the real wages are before tax and in the distortionary tax case they are after tax.

Table 2. Goodness-of-fit Tests for the Response of Real Wages

	Lump Sum Taxes			Distortionary Taxes					
	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0.8$	$b=0.8$
	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=2$	$s=0$	$s=2$
Moment	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=0$	$\mu=0$
Standard Deviation									
Data	16.47	16.44	16.44	23.89	23.89	23.89	23.89	23.89	23.89
Model	9.85	7.25	3.60	13.90	12.83	10.76	17.24	18.76	21.13
J-statistic	1.20	2.56	5.61	1.10	1.15	1.28	1.09	0.62	0.18
P-value	0.27	0.11	0.02	0.29	0.28	0.26	0.30	0.43	0.68
Average 1,2,3,4									
Data	-2.82	-2.82	-2.82	-3.19	-3.19	-3.19	-3.19	-3.19	-3.19
Model	-3.11	-2.10	-0.37	-3.34	-2.26	-0.68	-1.23	-4.18	-1.42
J-statistic	0.05	0.33	4.83	0.01	0.24	1.05	4.96	0.61	3.77
P-value	0.83	0.56	0.03	0.93	0.63	0.31	0.03	0.43	0.05
Average 5,6,7,8									
Data	-3.68	-3.68	-3.68	-6.24	-6.24	-6.24	-6.24	-6.24	-6.24
Model	-2.59	-1.68	-0.25	-3.52	-3.30	-2.63	-5.11	-4.86	-6.35
J-statistic	0.53	1.94	6.43	0.94	0.89	0.96	0.55	0.75	0.005
P-value	0.47	0.16	0.01	0.33	0.35	0.33	0.46	0.39	0.94
Average 1,2,3,4 less 5,6,7,8									
Data	0.87	0.87	0.87	3.06	3.06	3.06	3.06	3.06	3.06
Model	-0.52	-0.42	-0.13	0.19	1.04	1.96	3.88	0.68	4.93
J-statistic	1.01	0.86	0.52	3.85	1.76	0.52	0.73	3.30	3.53
P-value	0.31	0.35	0.47	0.05	0.18	0.47	0.39	0.07	0.06

Note: Based on the estimated VAR system including the variables: output, average capital taxes, average labor taxes, government spending on goods and services, and nominal labor compensation in the non-farm business sector deflated by the price index corresponding to our measure of consumption. In the lump-sum case the real wages are before tax and in the distortionary tax case they are after tax.

Table 3. Goodness-of-fit Tests for the Response of Investment

	Lump Sum Taxes			Distortionary Taxes					
	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0.8$	$b=0.8$
	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=2$	$s=0$	$s=2$
Moment	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=0$	$\mu=0$
Standard Deviation									
Data	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53
Model	76.02	65.79	69.95	115.12	91.98	79.49	33.14	101.09	32.09
J-statistic	21.21	14.55	17.11	58.27	34.12	23.76	0.76	16.06	0.71
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.38	<0.01	0.40
Average 1,2,3,4									
Data	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41
Model	35.33	31.01	22.68	35.67	28.79	19.73	5.53	37.70	8.28
J-statistic	69.20	51.22	24.15	70.74	43.02	16.98	0.05	13.62	0.60
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.82	<0.01	0.44
Average 5,6,7,8									
Data	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Model	11.67	4.21	-8.79	-6.61	-8.84	-13.79	-2.54	-4.87	-0.85
J-statistic	1.78	0.09	2.29	1.46	2.31	4.88	0.25	0.40	0.10
P-value	0.18	0.77	0.13	0.23	0.13	0.03	0.62	0.53	0.75
Average 1,2,3,4 less 5,6,7,8									
Data	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.32
Model	23.66	26.80	31.47	42.28	37.63	33.51	8.07	42.57	9.13
J-statistic	17.40	22.92	32.48	61.06	47.67	37.20	0.96	31.41	1.37
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.33	<0.01	0.24

Note: Based on the estimated VAR system including the variables: output, average capital taxes, average labor taxes, government spending on goods and services, and real private fixed investment plus consumption of durables.

Table 4. Goodness-of-fit Tests for the Response of Consumption

	Lump Sum Taxes			Distortionary Taxes					
	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0$	$b=0.8$	$b=0.8$
	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=0$	$s=2$	$s=0$	$s=2$
Moment	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=1$	$\mu=10$	$\mu=0$	$\mu=0$	$\mu=0$
Standard Deviation									
Data	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53
Model	20.70	29.09	44.75	26.72	33.04	45.48	31.84	14.71	17.73
J-statistic	4.93	7.01	8.43	16.30	13.77	8.88	15.48	3.85	6.48
P-value	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.01
Average 1,2,3,4									
Data	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
Model	-3.31	-5.09	-8.37	-3.63	-5.18	-7.94	-1.75	-2.04	-1.88
J-statistic	6.57	9.60	10.69	11.26	11.01	7.73	2.15	2.74	2.48
P-value	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.14	0.09	0.12
Average 5,6,7,8									
Data	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Model	-5.75	-7.85	-11.70	-6.99	-8.65	-11.78	-8.69	-3.73	-4.50
J-statistic	4.90	7.02	9.02	9.13	10.02	8.74	11.79	2.29	3.47
P-value	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.13	0.06
Average 1,2,3,4 less 5,6,7,8									
Data	-0.27	-0.27	-0.2654	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27
Model	2.44	2.76	3.3252	3.35	3.46	3.84	6.94	1.69	2.62
J-statistic	2.94	3.51	4.4385	5.99	6.11	6.53	17.58	1.56	3.42
P-value	0.09	0.06	0.0351	0.01	0.01	0.01	<0.01	0.21	0.06

Note: Based on the estimated VAR system including the variables: output, average capital taxes, average labor taxes, government spending on goods and services, and real consumption of nondurables and services plus the service flow from consumer durables.

Figure 1: Fiscal Variables with the Ramey-Shapiro Dates, 1947-95

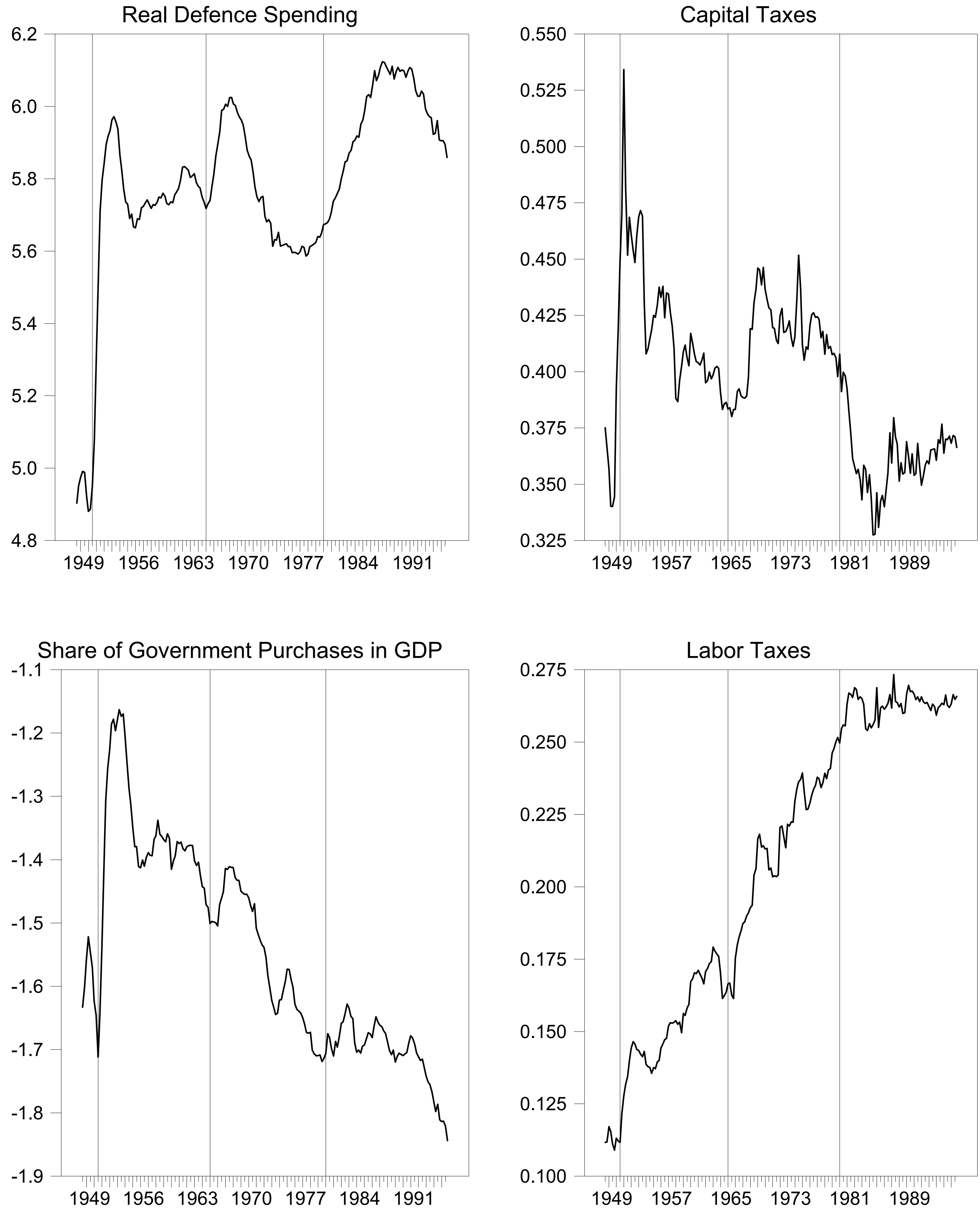
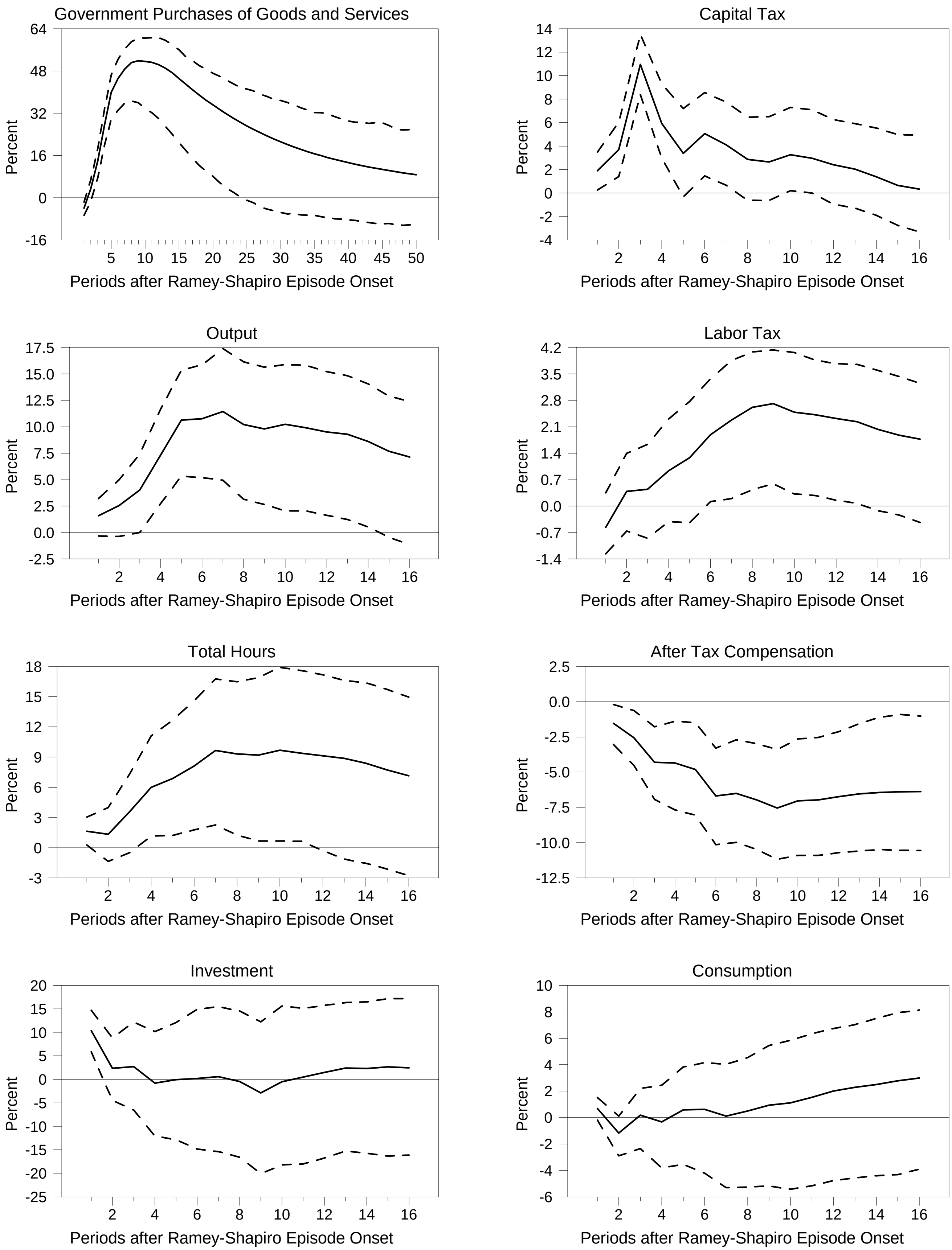
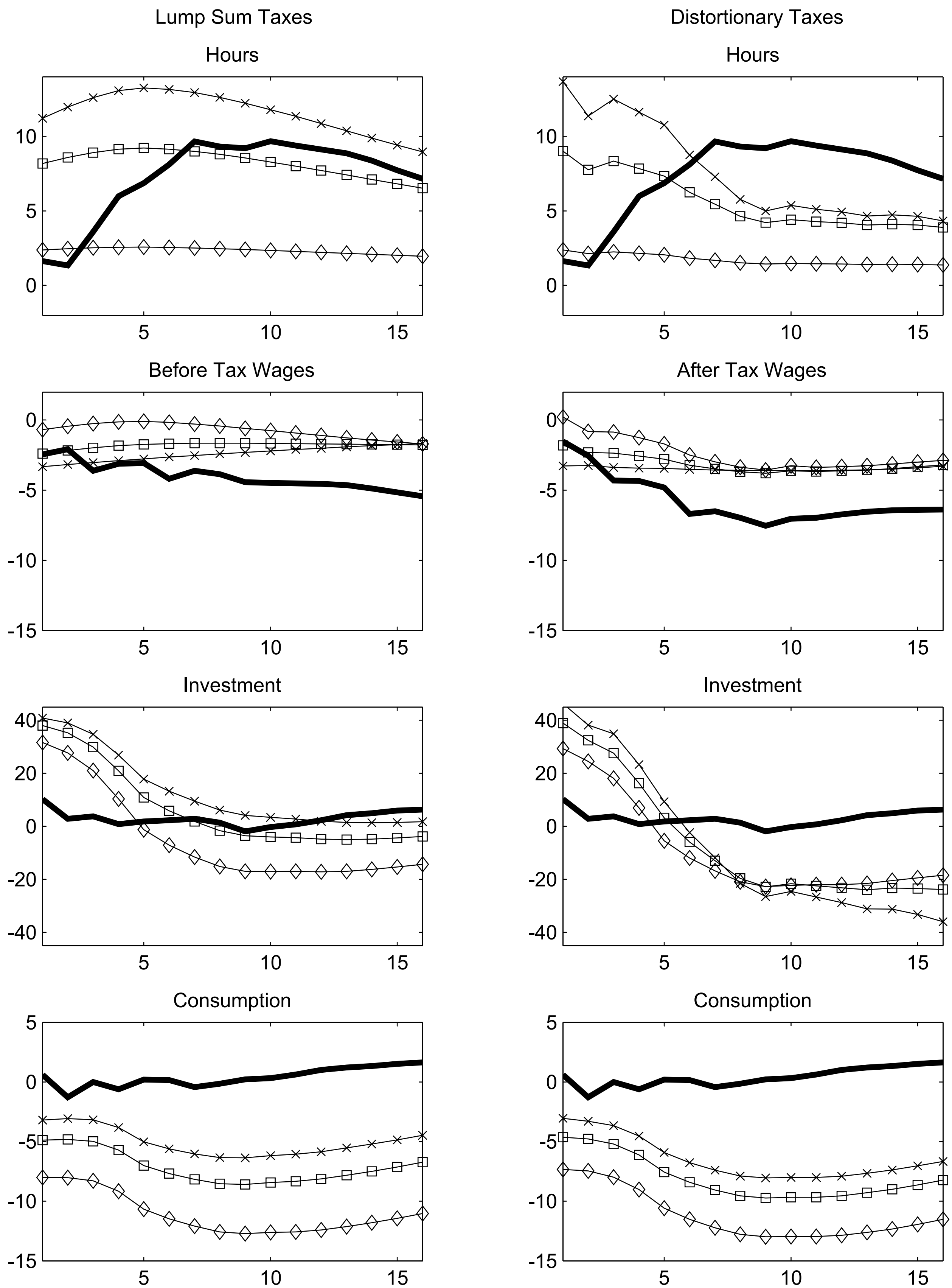


Figure 2: Estimated Responses to the Onset of a Ramey-Shapiro Episode



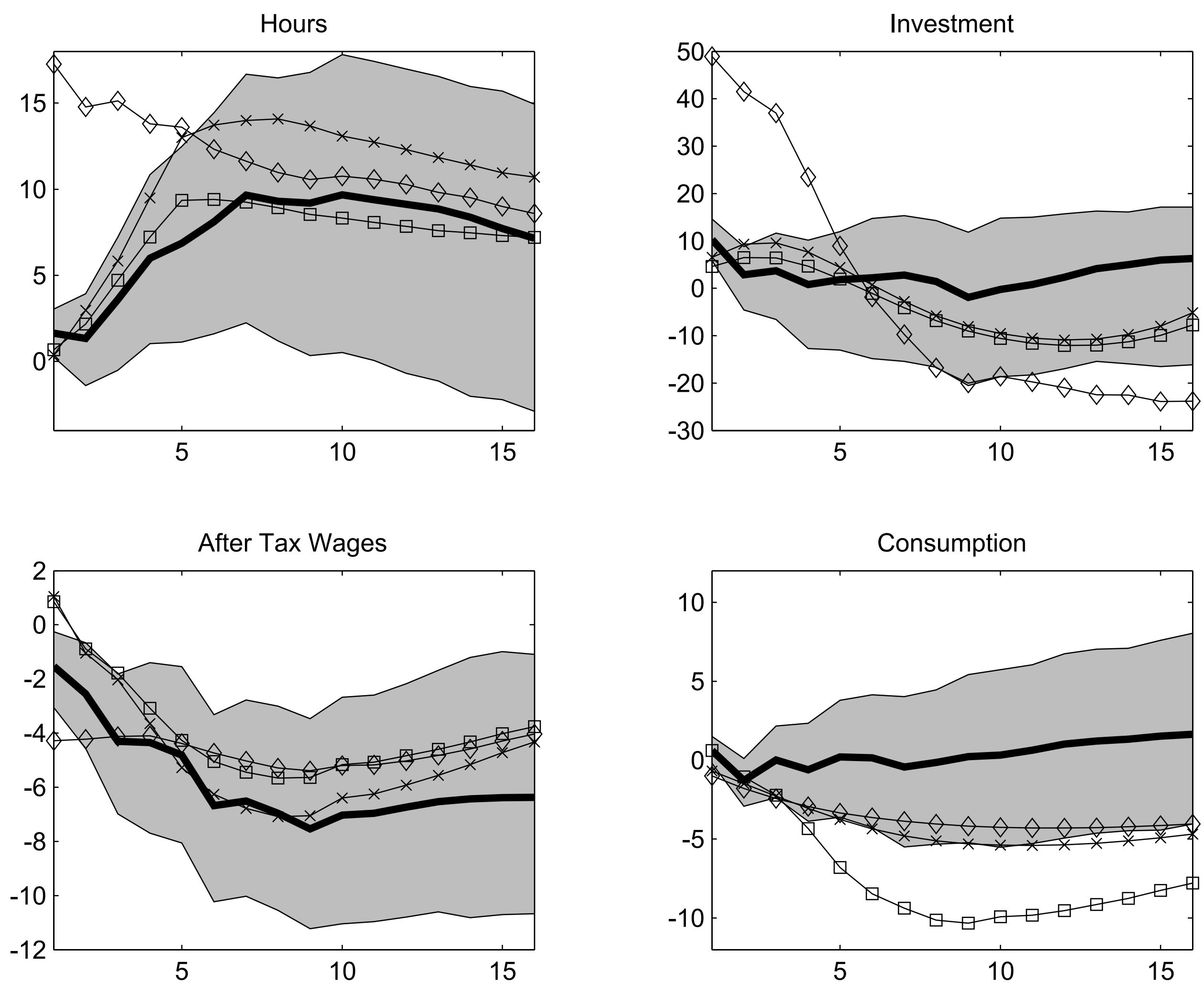
Note: Solid lines are point estimates and dashed lines denote a 95 percent confidence band

Figure 3: Responses of Variables in the Benchmark Model



Note: The solid line is the point estimate for the response of the indicated variable taken from Figure 2; Crosses denote the response of the indicated variable in the high labor supply elasticity case; Squares denote the corresponding medium elasticity case; Diamonds denote the corresponding low elasticity case.

Figure 4: Responses of Variables in the Modified Benchmark Model



Note: The solid line and the shaded region are the point estimate and 95 percent confidence band for the response of the indicated variable taken from Figure 2; Diamonds denote the response of the indicated variable in the case of habit persistence only; Squares denote the corresponding case of investment adjustment costs only; Crosses denote the corresponding case with both habit persistence and investment adjustment costs.