Federal Reserve Bank of Minneapolis
Research Department Staff Report 315

January 2003

Does Neoclassical Theory Account for the Effects of Big Fiscal Shocks? Evidence From World War II*

Ellen R. McGrattan

Federal Reserve Bank of Minneapolis
and University of Minnesota

Lee E. Ohanian

University of California, Los Angeles
and Federal Reserve Bank of Minneapolis

ABSTRACT

Some economists argue that the neoclassical growth model cannot account for the macroeconomic effects of big fiscal shocks. This paper reassesses this view. We test the theory using data from World War II, which is by far the largest fiscal shock in the history of the United States. We take observed changes in fiscal policy during the war as inputs into a parameterized, dynamic general equilibrium model and compare the values of all variables in the model to the actual values of these variables in the data. Our main finding is that the theory quantitatively accounts for macroeconomic activity during this big fiscal shock.

*We thank the National Science Foundation for financial support. We also thank Casey Mulligan, Ed Prescott, and Julio Rotemberg for helpful comments on earlier drafts. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1. Introduction

The neoclassical growth model is the main tool used to analyze the positive and normative consequences of big fiscal changes, such as wars, tax reforms, or other major public policy programs. Implicit in this use is the view that this model can account for the macroeconomic impact of big fiscal changes. However, a popular view, based in part on evidence from World War II, is that neoclassical theory does not account for the macroeconomic effects of big fiscal changes, and that an alternative theoretical framework is required.[1]

This paper reassesses the view that neoclassical theory does not account for the macroeconomic effects of big fiscal changes by using a more systematic and comprehensive analysis than is found in the literature.[2] We do this by feeding the World War II fiscal shock into a standard neoclassical growth model and comparing the variables in the model to the actual values of these variables during the war. We focus our analysis on World War II because it is by far the largest fiscal shock in U.S. history and thus provides a very strong test of the theory. We show that standard neoclassical theory successfully accounts for macroeconomic activity during World War II.

This study builds on recent analyses of wartime macroeconomic activity by Braun and McGrattan (1993) and Ohanian (1997), but it differs in three important ways. First, this analysis provides a much more complete and detailed evaluation; Braun and McGrattan focus on the behavior of real wages and productivity during World War II, while Ohanian focuses on the welfare costs of alternative fiscal policies during World War II and the Korean War. The analysis in this paper evaluates the model's predictions for hours worked, output, consumption, investment, after-tax wages, and after-tax returns to capital. Second, both the Braun-McGrattan and Ohanian models abstract from some key wartime features. This study uses a model that includes five key wartime elements: distorting taxes, conscription, military spending, rationing, and uncertainty. Third, this paper addresses recent claims that the standard neoclassical model does not account for the effects of big fiscal shocks. Mulligan (1998) argues that the theory cannot quantitatively account for the large increase in labor input that occurred during World War II, while Rotemberg and Woodford (1991, 1992) argue that the theory cannot account for the behavior of real wages. This paper focuses on the theory's performance in light of these other claims.

Our main finding contrasts with these claims. We find that the model explains most of the variation in output, labor input, consumption, investment, wages, and the return to capital during the war. Moreover, these results are robust to reasonable variations in parameter values and in the specification of the stochastic processes for the exogenous variables.

The paper is organized as follows. Section 2 reviews the qualitative effects of wars in a simple neoclassical growth model. Section 3 summarizes how we modify the simple model before we take it to the data. Section 4 presents the model that is used in the quantitative analysis, and Section 5 presents the specification of the exogenous processes and parameter values. Section 6 conducts the quantitative analysis. Section 7 reconciles the results with the literature. Section 8 discusses some sensitivity analysis based on changes in parameter values and the stochastic specification. Section 9 concludes.

2. The Effects of Fiscal Shocks in a Simple Model

We begin by reviewing Hall's (1980) and Barro's (1981) qualitative analysis of a temporary increase in government spending, abstracting from other elements of fiscal policy, to highlight the income and intertemporal substitution effects arising from a fiscal shock in the neoclassical model.[3]

Preferences for the representative household are given by

$$(1) \qquad \max \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - l_t),$$

where c is consumption and $1 - l$ is nonmarket time. The resource constraint is

$$(2) \qquad f(k_t, l_t) + (1-\delta)k_t \geq c_t + g_t + k_{t+1},$$

where $f(k, l)$ is a constant returns to scale technology with capital k and labor l as the inputs and δ as the depreciation rate. The variable g is government spending, which is a pure resource drain — government spending does not substitute for private consumption, nor does it affect production possibilities. Government spending is financed with lump-sum taxes.

Hall (1980) and Barro (1981) argue that higher government spending raises labor input through wealth and intertemporal substitution effects. Higher spending reduces wealth, which induces households to consume less leisure and work more. Households also work more and invest less to smooth out the effect of the temporary shock.

However, the simple model above abstracts from several key elements of fiscal policy that will change these income and substitution effects. For example, one important omission is income taxes, which rose substantially during World War II, and which will tend to reduce hours worked and savings, ceteris paribus. Thus, the substitution effect of taxes will tend to work in the opposite direction of the income effect of the increase in government expenditures.

This means that it is unclear whether the neoclassical model is quantitatively or even qualitatively consistent with World War II macro activity. To address this issue, we need to define the fiscal shock, feed it into a parameterized model and compute the equilibrium. The first step in this process is specifying the additional elements that make up the fiscal shock. We summarize each of the elements below, discussing how each effect in isolation will tend to affect household decisions. We then describe how we model them in Section 4.

3. Extending the Model to Study World War II

We now specify the elements that comprise the fiscal shock in our model. These are income taxation, conscription, government consumption, government investment, wage payments to military personnel, rationing, and uncertainty.

A. Distorting taxes

There were significant increases in labor and capital income taxes during the war. Joines' (1981) estimates show that the average marginal labor tax rate rose from 9 percent in 1940 to 19 percent in 1944 and that the average marginal capital income tax rate rose from 45 percent in 1940 to 60 percent in 1944. These large increases in tax rates will tend to reduce the supply of labor and capital in private production.

B. Conscription

At the peak of the war, about 17 percent of the labor force (or, equivalently, 11 percent of the adult population) was in military service. We therefore add conscription to the model, because it reduced the quantity of labor available to produce market output. This reduction in the household's time endowment will tend to reduce hours worked, since it raises the marginal utility of leisure.

C. Government spending and its components

Not all World War II government spending was government consumption, as assumed in the Hall (1980) and Barro (1981) papers. The government also substantially increased expenditures on wage payments to military personnel and investment in plant and equipment. Separately accounting for these different types of spending is important because they have very different macroeconomic effects. Purchases of military goods induce the wealth and substitution effects described in the simple model above, because these purchases do not substitute for private consumption. However, military wage payments do not have these same wealth effects, because these payments are income for military personnel. The last government expenditure category is government investment in plant and equipment. The government made substantial capital investment during the war, which increased capacity. We therefore include this spending in the model as investment spending, since it substituted for private investment. Increases in government consumption will tend to increase hours worked, since such increases raise the marginal utility of consumption. Increases in government military wage payments will tend to reduce hours, since such increases raise income. Increases in government investment will tend to raise hours, since such increases raise the marginal product of labor.

D. Rationing

Some goods were rationed during the war, which means that households were not able to purchase as much of those goods at the controlled price of the good. Some of our experiments will incorporate rationing in which households will be constrained from consuming as much as they demand. Rationing reduces hours worked, since it prevents households from equating the marginal rate of substitution between consumption and leisure to the after-tax real wage, given the controlled price.

E. Uncertainty

The outbreak of war, the size and duration of the wartime fiscal shock, and the state of the postwar economy are uncertain events, and this uncertainty may affect the incentives to work and invest. We therefore conduct some of our experiments with a stochastic specification that adds uncertainty over the duration and size of the fiscal shock and uncertainty over the postwar state of the economy.

F. Abstractions

We abstract from other shocks in our analysis, such as monetary and technology shocks. We abstract from monetary shocks because they were also small during the war (M1 rose about 10 percent per year during the war) and because adding money to the model complicates the analysis. We abstract from technology shocks because they were small during World War II — total factor productivity was close to its trend level during 1941–46. (See Braun and McGrattan 1993.) We therefore use a purely real model with just fiscal shocks and evaluate how well it can account for wartime macroeconomic activity. We now turn to the specification of the model.

4. Model Economy

There is an infinitely lived representative family with two types of family members: "civilians" and "draftees."[4] Both types of family members have identical preferences given by $U(c,l) = \log(c) + V(1-l)$, where V is a concave and continuously differentiable function. There are N_t total family members in period t, with fraction a_t who are in the military and fraction $(1-a_t)$ who are civilians.[5]

The family optimally chooses consumption of both types, which we denote by c_c and c_d, respectively. The family also chooses private investment in physical capital, i_p, and civilian labor input, l_c, to maximize its lifetime utility. Labor input for family members in the military is exogenously fixed at $\bar{l}_d$. The family's maximization problem is given by

$$(3) \qquad \max_{\{c_{ct}, c_{dt}, i_{pt}, l_{ct}, b_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-a_t)U(c_{ct}, l_{ct}) + a_t U(c_{dt}, \bar{l}_d) \right\} N_t$$

subject to

$$(4) \qquad (1-a_t)c_{ct} + a_t c_{dt} + i_{pt} + b_{t+1}$$
$$= (1-\tau_{kt})r_{pt}k_{pt} + (1-\tau_{lt})w_t(1-a_t)l_{ct} + \tau_{kt}\delta k_{pt} + R_t b_t + a_t w_t \bar{l}_d$$

(5) $$k_{pt+1} = [(1-\delta)k_{pt} + i_{pt}]/(1+\gamma_n)$$

(6) $$N_t = (1+\gamma_n)^t$$

(7) $$c_{ct} \leq \bar{c}_t,\ c_{dt} \leq \bar{c}_t,\ i_{pt} \geq 0$$

where k_{pt} is the beginning-of-period capital stock in period t, r_{pt} is the rental rate paid for that capital, w_t is the wage rate in t, τ_{kt} and τ_{lt} are proportional tax rates on capital income and labor income, respectively, in t, $R_t b_t$ is the value of matured government debt, and b_{t+1} is new debt holdings. The term $\bar{c}_t$ allows for rationing. All quantities are in per-capita terms; the constant growth rate of the population is given by γ_n. The processes for a_t, r_{pt}, w_t, τ_{kt}, τ_{lt}, and R_t are taken parametrically by the family and are specified later.

There is a single physical good which is produced from a constant returns to scale technology. The technology is operated by a competitive, representative firm, which hires private capital, public capital, and labor services. Output is given by

(8) $$Y_t = F(K_{pt}, K_{gt}, Z_t L_{pt})$$

where K_{pt} is the beginning-of-period private capital stock for the economy in t, K_{gt} is the beginning-of-period public capital stock used by the private sector in t, Z_t is the level of labor-augmenting technology in t, and L_{pt} is the total labor input in the private sector in t. We assume that the level of technology grows at the constant rate γ_z: $Z_t = z(1+\gamma_z)^t$.

We include government capital in production because the federal government financed increases in industrial construction and producers' durable equipment during World War II, including significant investments in the aircraft, automotive, and aluminum industries. Gordon (1969) estimates that government-owned, privately operated capital increased the manufacturing capital stock by 30 percent between 1940 and 1945. (See also Gordon 1970, Jaszi 1970, and Wasson, Musgrave, and Harkins 1970.) We denote government investment expenditures by I_g.

Government purchases of consumption goods are denoted by C_g, and government payments to military personnel are denoted by $N_t a_t w_t \bar{l}_d$. Total government spending is the sum of the three expenditure items:

$$G_t = C_{gt} + I_{gt} + N_t a_t w_t \bar{l}_d. \quad (9)$$

Government capital evolves according to the following law of motion:

$$K_{gt+1} = (1-\delta)K_{gt} + I_{gt} \quad (10)$$

with K_{g0} and the process for I_{gt} given. We assume that private and public capital depreciate at the same rate δ.

The government satisfies present-value budget balance:

$$\sum_{t=0}^{\infty} p_t G_t = \sum_{t=0}^{\infty} p_t [\tau_{kt}(r_{pt} - \delta)K_{pt} + \tau_{lt} w_t L_{pt} + r_{gt} K_{gt}], \quad (11)$$

where p_t is the Arrow-Debreu price and r_{gt} is the rental rate on government capital.

We close the model by specifying the functions that the family takes parametrically when solving its optimization problem in (3). Since firms are competitive, the rental prices for the factors of production are equal to their marginal products. Therefore, the rental rates in (4) and (11) and the wage rate in (4) are equal to the partial derivatives of the production function F in (8) with respect to K_p, K_g, and L_p, respectively.

There are seven exogenous processes in the model, six of which have already been discussed — conscription (a_t), the tax rate on capital income (τ_{kt}), the tax rate on labor income (τ_{lt}), rationing ($\bar{c}_t$), government consumption (C_{gt}), and government investment (I_{gt}). The seventh exogenous process is related to the state of the postwar economy. For the deterministic model, this postwar state is the actual postwar state of the economy, which we describe in the following section. For the stochastic model, this process can take on two values — the actual postwar state or a postwar depression. We allow for the possibility of a postwar depression in the stochastic model because wartime surveys show that individuals as well as professional economists placed a significant probability on the event that the Great Depression would return after the war. In testimony to the U.S. Senate Special Committee on Post-War Economic Policy and Planning in May of 1944, economists reported that they expected a depression.[6] Their forecasts of postwar unemployment rates were in the range of 14 to 35 percent — much higher than the actual 1946–47 rate of 3.9 percent. Gallup poll surveys show that households also feared a postwar depression.

In the depression state, the values for taxes and spending are set at their average levels between 1934 and 1939, and there is a restriction on the number of hours that civilians can work. We use $\bar{l}_{ct}$ to denote the maximum hours of work; this variable is our seventh exogenous variable. This is a simple way of generating a depression and is motivated by Cole and Ohanian (1999, 2001), who present evidence that post-1933 labor and industrial policies led to cartelization and high wages that restricted employment and output.

The evolution of the seven exogenous variables in the model is governed by a single stochastic state variable s_t; that is, the index of s_t specifies a particular set of values for a_t, τ_{lt}, τ_{kt}, C_{gt}, I_{gt}, $\bar{c}_t$, and $\bar{l}_{ct}$. The state variable s_t is modeled as a Markov chain. This specification can be used for both the deterministic and the stochastic versions of the model. If individuals have perfect foresight, the process s_t is degenerate. In cases where expectations are not perfect, we specify the transition probabilities over s_t.

We now define an *equilibrium* for this economy: a collection of allocations for households c_{ct}, c_{dt}, l_{ct}, i_{pt}, and k_{pt} for firms K_{pt}, K_{gt}, and L_{pt}; and sequences of prices r_{pt}, r_{gt}, w_t, and R_t that satisfy the following conditions: (i) taking prices and exogenous policies for a_t, τ_{kt}, and τ_{lt} as given, households maximize utility subject to constraints (4)–(5); (ii) taking prices as given, firms maximize profits period by period $Y - r_p K_p - r_g K_g - w L_p$; (iii) factor markets clear:

$$(12) \quad K_{pt} = N_t k_{pt}$$

$$(13) \quad L_{pt} = N_t(1 - a_t)l_{ct};$$

(iv) the resource constraint

$$(14) \quad C_{pt} + I_{pt} + C_{gt} + I_{gt} = Y_t$$

holds, where $C_{pt} = N_t[a_t c_{ct} + (1 - a_t)c_{dt}]$ and $I_{pt} = N_t i_{pt}$; and (v) (11) is satisfied.

5. Parameter Values and Fiscal Policy

This section describes functional forms, parameter values, and the specifications for the exogenous processes. We conduct two types of simulations: deterministic and stochastic. The deterministic case is the baseline model since it is the simplest case we consider. We treat the stochastic specification as a robustness check on the deterministic results. We will later show that the results from the stochastic economy are very similar to those from the deterministic economy. We first discuss common elements to both economies and then describe the specification of the exogenous processes for the stochastic economies.

The values of all parameters and restrictions are summarized in Table 1. Preferences are given by

$$(15) \quad U(c, l) = \log(c) + \psi(1 - l)^{\xi}/\xi,$$

which implies a compensated labor supply elasticity of $(1 - l)/[l(1 - \xi)]$. We choose a benchmark value of $\xi = 0$, which implies log preferences over leisure. We later evaluate the robustness of our results by choosing an alternative value of ξ that yields a lower labor supply elasticity.

The parameter ψ is chosen so that hours of work in the deterministic steady state are 27 percent, consistent with the observed U.S. average time in market work. We also need to specify the exogenous hours requirement for those in the military — we assume that $\bar{l}_d = 50/84$, which implies that soldiers work 50 out of their 84 discretionary hours per week. We found that the quantitative results are not sensitive to changes in this value. Period t preferences are discounted by β^t. The period length is one year. The parameter β is chosen so that the steady-state rate of return to capital is 4 percent.

The production technology is

$$F(k_p, k_g, zl) = (bk_p^\rho + (1-b)k_g^\rho)^{\frac{\theta}{\rho}}(zl)^{1-\theta}. \tag{16}$$

We assume that government capital and private capital are perfect substitutes, which implies that $\rho = 1$. The parameter b governs the relative productivities of government and private capital. We assume that these two types of capital are equally productive, which implies that $b = 1/2$. We chose $\theta = .36$, which is consistent with the U.S. share of income paid to capital.

The depreciation rate (δ) for both government and private capital is 7 percent. This value is chosen so that the model is consistent with estimates of stocks and flows of U.S. fixed assets. The value of the technology parameter z is set so that model output in 1946 = 1. The growth rates of the technology parameter and the population are set to their average values over this period: $\gamma_z = 1.6$ percent and $\gamma_n = 1.6$ percent.

Realizations of the fiscal variables for the deterministic economy in each period are chosen so that they are equal to the data. Figures 1–3 show government spending, the conscription rate, and tax rates. (Appendix A describes the data sources and the transformations we make to the raw series.)

Figure 1 shows the three components of government spending. Government investment includes only plant and equipment expenditures used by either the private sector or the civilian government sector. This investment is primarily government-owned, privately operated (GOPO) capital. Government consumption is defined residually: it is total government spending less government investment and less military compensation.[7]

Figure 2 shows the fraction of the adult population (16 and over) in the military. Not surprisingly, this pattern is very similar to military compensation, with the peak of the series occurring in 1944, when about 11 percent of the adult population was in the military.

Figure 3 shows the average marginal tax rates for labor and capital income constructed by Joines (1981). These pictures show that both tax rates rose significantly during the war: the labor income tax rate more than doubled to about 20 percent, and the capital income tax rate rose from about 45 percent to about 60 percent.

We now discuss the specification of the stochastic economies. The realizations of the fiscal policy variables are the same as in the deterministic case (Figures 1–3), but the expectations of these realizations are governed by a Markov chain over the fiscal state s_t. Introducing uncertainty in the model requires filling in the transition probabilities in the Markov transition matrix. Since the purpose of the stochastic model is to assess the robustness of our deterministic results, we compute equilibria from the stochastic model for many different values for the entries in the transition matrix and then compare those results with those of the deterministic model. We will later see that the results from the deterministic model are very robust to allowing for uncertainty.

We first describe how we generate the elements for the transition matrix, and then we describe how we compare the stochastic results to the deterministic results. We generate values for the transition matrix entries by randomly drawing values. Appendix B describes this procedure in detail, and we summarize it here. We restrict the draws so that the average duration of a war, the frequency of war, and the fraction of years in war are similar to those in the data. For the actual data that include U.S. wars through World War II, the average duration of these wars was 3.7 years, the fraction of years a war was started was 4.1 percent, and the fraction of years in war was 15.2 percent.[8] We therefore randomly generate probability matrices (500,000 in all) and use all those matrices that satisfy the following criteria: (*i*) the average duration of a war is between 2.6 and 4.8 years; (*ii*) the fraction of years a war was started is between 2.9 and 5.3 percent; and (*iii*) the fraction of years in war is between 10.6 and 19.8 percent. Thus, the range for each statistic is 70 percent to 130 percent of the average U.S. value for that variable.

We now describe how we model the postwar state and expectations of transition to the postwar state. Recall that we assume that the postwar state can be either normal or depressed. In the normal state, government spending and tax rates are equal to the average U.S. values during the years 1946–49. In the depressed state, individuals are constrained to work at most 80 percent of normal steady-state hours, the average duration of depression is seven years, and government spending and tax rates are equal to the average U.S. values during the years 1934–39.

Expectations about the postwar state are based on survey responses in each of the years 1941 through 1945. We use these responses to set the transition probabilities for the postwar state. Participants in a Gallup poll in September of 1941 were asked, Do you think we are likely to have a greater prosperity, or another depression after the present war? Seventy-eight percent of respondents said, “another depression.” In June of 1942 Gallup poll participants were asked, Which do you think the United States will have for the first two or three years after the war — depression or prosperity? At that time, 43 percent said, “depression.” In June of 1944 and again in May of 1945, a Roper poll asked, Do you expect we probably will have a widespread depression within 10 years or so after the war is over, or do you think we probably will be able to avoid it? Fifty-one percent said, “depression” in 1944 and 44 percent in 1945.[9] We use these wartime survey responses as the model expectations. Appendix B describes this mapping.

To compare the stochastic results to the deterministic results, we plot each variable from the deterministic model during World War II, and we also plot upper and lower bounds for that variable for those years from the stochastic model. The upper bound is the value of that variable such that only 2.5 percent of values from the simulations exceed that value. The lower bound is defined in an analogous way.

6. Comparing the Model to the Data

We now compare the simulated results of the models with U.S. data during World War II. We start with a brief description of the U.S. data to which we compare our model. We then describe our numerical results.

A. The U.S. Data

We compare six variables from the model to their counterparts in the U.S. data from 1942 to 1950. There are four quantity variables (real GNP, consumption, investment, and hours worked) and two price variables (real wages and the real return to capital). We discuss the quantity and price variables in turn.

We compare production plus military compensation in the model $(Y + wNa\bar{l}_d)$ to real U.S. GNP. We compare private consumption in the model to U.S. personal consumption expenditures.[10] We compare private investment in the model to U.S. gross private domestic investment plus foreign net investment. We compare total hours worked in the model to Kendrick's (1961) manhours for the national economy. (Both series are measured relative to the working-age population and normalized by discretionary time.) For both the model and the data, we report GNP, consumption, and investment in per-capita, detrended terms. In the model z is chosen so that output Y is equal to 1 in 1946.

We now discuss the data for after-tax wages and returns to capital. Since there is no standard measure of the economywide wage rate, we consider four measures: compensation per hour for the nonfarm sector, compensation per hour for full-time equivalent employees, compensation per hour for manufacturing, and average hourly earnings in 25 manufacturing industries. All wage rates are divided by the deflator for GNP less military compensation, and we construct after-tax wage rates by multiplying each real wage rate by the factor one minus Joines' (1981) average marginal labor tax rate. Figure 4 shows these wage data as indices with 1940 equal to 1. This figure shows slight increases in the nonfarm and full-time equivalent after-tax real wages relative to trend and a slight decrease in the after-tax real manufacturing wage relative to trend.[11]

We will compare our model wage rate to the manufacturing compensation per hour shown in Figure 4. Both Mulligan (1998) and Rotemberg and Woodford (1991, 1992) use data for manufacturing in their critiques of the neoclassical model for World War II. It is worth noting that there are some differences between our wage rate measure and theirs. Our measure includes all compensation for all manufacturing industries. Mulligan and Rotemberg and Woodford both use hourly earnings of 25 manufacturing industries, which is a downward biased estimate of compensation since it does not include nonwage compensation. Our measure of the price deflator excludes military compensation, which is appropriate for our model. Mulligan deflates the wage using the CPI. Rotemberg and Woodford deflate World War II wages using the GNP deflator, which includes military compensation. Finally, we construct an after-tax wage using Joines' (1981) estimate of the labor tax rate. Mulligan uses the Barro-Sahasakul (1986) tax rate that mixes tax rates on labor and capital income. Our results are robust to these differences in tax rates and most of the differences in price indices.

The final variable that we consider is the after-tax return on capital. The return in the model is compared to after-tax U.S. profits from the corporate and noncorporate sectors divided by the total capital stock. We use Joines' (1981) average marginal capital income tax rate.[12]

B. Results from the Deterministic Model

We first consider results for the deterministic model without rationing. We begin the simulations in 1942 because the data are annual and because the United States does not enter the war until December 1941.[13] The year-end 1941 levels of private and public capital, which are the initial conditions for our simulations, are set equal to the actual 1941 levels for the United States. We compute equilibria for this model using the finite element method. (See McGrattan 1996.)

Figures 5A–5F show time series for the model and data between 1942, which is the first full year of war, and 1950. The solid line is the actual variable, and the dashed line is the model variable. A successful model for World War II should account for the large increases in output and hours, the decreases in consumption and investment, and the moderate decreases in after-tax real wages and returns to capital.

The main finding is that the time series for the model and data are very similar. Figure 5A shows that real detrended GNP, in both the model and data, rises about 40 percent through the war, with a large decline occurring between 1945 and 1946. Figure 5B shows that private consumption in both the model and the data falls during the war and begins rising in 1944. Figure 5C shows that private investment in both the model and the data are at or near zero through the middle of the war. Figure 5D shows that total hours — like GNP — rise close to 40 percent in both the model and the data.

Hours worked and output rise in response to the fiscal shock because the wealth effect arising from the shock outweighs the negative substitution effects arising from higher income tax rates. The increased spending far exceeds the tax revenues raised over the period 1941–45.

Figures 5E and 5F show the after-tax factor prices for both the model and the data. Figure 5E shows the after-tax wage index. The model wage remains flat, falls to about 5 percent below the 1942 level and then rises steadily. The actual after-tax wage index is roughly constant over the war period and then falls in 1945. By 1950, both actual and model wages are close to the 1942 level.

Figure 5F shows the after-tax returns to private physical capital. There is close to a percentage point discrepancy at the start of the war, but the rates are similar at the end of the war and into the postwar period. Mulligan (1998) has argued that the standard model would require very high wartime rates to create sufficient pecuniary incentives for households. Figure 5F shows that the model prediction is actually below that of the data and yet the predictions for household saving and hours of work are consistent with the data.

Note that we compute deviations between the model and the data for each variable individually. Some authors use an alternative approach by computing deviations between the household's first-order condition that equates the marginal rate of substitution between consumption and leisure to the after-tax real wage in the model and the data.[14] Deviations in this condition are thus a combination of deviations in consumption, hours worked, and the after-tax real wage rate. We have also computed deviations in this first-order condition between the model and the data. The deviation in this condition averages 4.4 percent between 1942 and 1945 and reaches a maximum of 5.8 percent during this period.

If we assume that the first year of war is 1941 rather than 1942, the results for the 1942 to 1950 period displayed in Figure 5 change very little. There is a discrepancy between the data and the model in 1941, however, when we start in 1941 because the entire year is treated as a wartime period. (See, for example, Figure 8 in McGrattan and Ohanian 1999.)

We next introduce rationing into the deterministic model to see if our results change. Since there are no standard estimates of the effects of rationing during the war, we assume that all of the difference between consumption in the model without rationing and actual consumption is due to rationing. Therefore, we constrain households in the model to consume no more than the actual level of consumption in the data between 1942 and 1945, and then we check to see if this affects the model's predictions for the other variables. Figures 6A–6F show the results of this experiment. We find that the model's predictions for GNP, private investment, hours worked, and factor prices change little. In fact, it is interesting to note that imposing rationing brings the model somewhat closer to the data.

We turn next to a stochastic version of our model to see if adding uncertainty significantly changes the findings. We will see that this modification does not change our results.

C. The Results from the Stochastic Versions of the Model

This section introduces uncertainty into the model. We follow the same format for presenting the results as in the deterministic model: Figures 7A–7D compare the quantity variables in the model with the data, and Figures 7E–7F compare the factor price variables in the model with the data. The only difference here is that we are reporting the results of many simulations on each graph by displaying bounds. The bounds for a particular variable at a particular date are the highest and lowest outcomes after 5 percent of them have been dropped (2.5 percent from the top and 2.5 percent from the bottom). We omit rationing in the stochastic model because it did not significantly affect the deterministic results.[15]

Our results are robust to adding uncertainty; the simulations from the stochastic model are very similar to those from the deterministic model. In fact, adding uncertainty reduces some of the deviations between the deterministic model and the data, particularly for investment and hours. We see this by comparing Figure 7C with Figure 5C for investment and 7D with 5D for hours in the two models. These figures show that for many of the simulations, hours and investment in the stochastic model are more in line with U.S. observations at the start of the war than in the case of the deterministic model. If households fully anticipate the large increase in government spending that occurs later in the war, then they invest and work more.

In summary, we find that the stochastic versions of our model, with probabilities chosen to be consistent with historical wartime experiences, are also quantitatively consistent with World War II macroeconomic activity.

7. Reconciling the Results with the Literature

This section discusses why our conclusions differ from those of Rotemberg and Woodford (1991, 1992) and Mulligan (1998). We discuss each in turn.

Our conclusion differs from Mulligan's because of our different analytical approach. Mulligan does not simulate the effects of the fiscal shock in a model economy, but rather examines after-tax factor prices and argues that those prices are too low to be consistent with higher labor input. He states that "empirical support ... cannot be found because after-tax wages do not appear to be temporarily high during the war period. The primary force working against wage motives is the massive across-the-board income tax increases that occurred during the war" (p. 1071). In contrast, our results show that the model is indeed consistent with a lower after-tax real wage, a lower after-tax return to capital, and higher labor input. An important reason why labor rises in our model, despite lower after-tax factor prices, is because of the resource drain of government consumption. To see this, note that at the peak of the war in 1944, government consumption was about 80 percent of trend output. This indicates that if labor input had not increased, private consumption would have dropped substantially.

Our conclusion differs from Rotemberg and Woodford's because of differences in how we assess the deviation between the pre-tax real wage in the model and in the data, that is, the rates in Figure 5E before subtracting labor taxes. The largest deviation between the pre-tax real wage index in the model and the pre-tax compensation per hour index for U.S. manufacturing is 5.6 percent, which occurs in 1945. This difference is due to the actual pre-tax real wage being 5.5 percent above trend and our model pre-tax real wage being 0.1 percent below trend.[16]

Rotemberg and Woodford reject the standard model on the basis of this deviation.[17] Our view is that the model should not be rejected because of this deviation. One reason is that the deviation is quantitatively small, and thus could be largely due to measurement error in the real wage, changes in the composition of output, or other factors that might affect the wage but that are omitted from our simple model. Another reason is that the assessment of the model should be based on its predictions for all the variables, rather than just for the pre-tax real wage. Figures 5–7 compared the model to the data for all the variables and show that the model comes quite close to capturing the wartime movements in the data. We agree that introducing some nonpecuniary elements into the model, as advocated by Mulligan, or some noncompetitive elements into the model, as advocated by Rotemberg and Woodford, could improve the match between the model and the data, but our results show that standard theory accounts quite well for the effect of this big fiscal shock.

It is natural to ask how sensitive our results are to changes in the shocks or to changes in the economic environment. We will focus on changes in tax rates and changes in the labor elasticity. The next section shows that either taxes would have to be much higher than measured tax rates or the labor supply elasticity would have to be much lower than that of the log utility case to choke off the wartime economic expansion.

8. Sensitivity Analysis

This section addresses two questions. First, how high would tax rates have to be such that, on average, output and hours worked in the deterministic model do not rise during the war? Second, how low would the labor supply elasticity have to be such that output and hours worked in the deterministic model do not rise during the war?

We conduct three tax experiments. The first increases just the labor tax, the second raises the capital income tax to 99 percent and then calculates the necessary change in the labor tax, and the third calculates the percentage point increase necessary for both capital and labor taxes. We find that tax rates would have to be much larger than those reported by Joines (1981) — or any other estimates of U.S. tax rates — to keep the average values of output and hours worked during the war equal to their 1941 values.

Table 2 shows the results of the three tax experiments. In the first experiment, the labor tax rate needs to rise to 32.3 percent — almost twice the estimate of Joines — to choke off increases in average private hours during the war. The rate has to rise to over 29.8 percent to choke off increases in average private output. Even with the capital tax rate set to 99 percent, the labor tax rate still needs to be significantly higher than Joines' estimates. The values for the labor tax rate are 30 percent for no increase in private hours and 24.8 percent for no increase in private hours. If we increase both rates by equal percentage points, we need an average labor tax rate of 30.8 percent and an average capital tax rate of 74.1 percent for no increase in private hours; we need an average labor tax rate of 28.4 percent and an average capital tax rate of 71.8 percent for no increase in private output. These rates are high compared to the estimates of 18 percent and 61 percent in Joines.

Table 2 also shows the result of the labor supply elasticity experiment. We find that the labor supply elasticity needs to drop by more than a factor of 5 relative to the log utility case used in the benchmark model to keep the average value of output equal to its trend level. To keep the average value of hours worked equal to its trend level, we need to drop the labor supply elasticity even more, by a factor of about 8. The elasticity for the log utility case is 2.7 percent, compared with 0.5 percent and 0.34 percent, respectively, in these experiments.

The elasticities used in these experiments are much too low for an aggregate representative household model. To see this, consider replacing the log utility function in the prototype business cycle models studied by McGrattan (1994) with (15). We can set ψ and ξ so as to achieve the same steady-state hours worked and lower labor elasticities. In her benchmark case with technology shocks only and divisible labor, a labor elasticity of 0.5 generates a standard deviation of hours worked equal to 0.3; the standard deviation for U.S. hours is 1.52. (See McGrattan 1994, Table 1.) Similar results are found for her model with taxes. In that case, a labor elasticity of 0.5 generates a standard deviation of hours worked equal to 0.51 — again, much lower than that in the data. For a labor elasticity of 0.34, the results are even more striking: the standard deviations of hours worked predicted by the model are in the range from 0.22 to 0.38 — significantly below the data. This implies that implausibly low labor supply elasticities are required in our model to choke off the World War II economic expansion.

In summary, our sensitivity analysis shows that the results are robust to large changes in tax rates or in the labor supply elasticity.

9. Conclusion

Some economists have argued that neoclassical theory cannot account for the impact of big fiscal shocks and point to World War II as an important case in which this theory fails. We have found that standard neoclassical theory successfully accounts for the World War II economic boom through the income effects of the enormous fiscal shock. In particular, we found that feeding in the observed increases in government consumption and investment, tax rates on labor and capital, and conscription into a standard growth model generates movements in output, consumption, investment, labor input, wage rates, and returns to capital that are very similar to the data. These findings stand in contrast to the views that standard theory cannot account for changes in factor prices or quantities and that an alternative theoretical framework is required to understand the impact of big fiscal shocks.[18]

The main normative implication is how to finance wars or other large public finance shocks. Optimal public finance depends on the theoretical framework being analyzed, and the time path of optimal taxes may differ considerably between a standard neoclassical model and models with patriotism (put forward by Mulligan 1998) or with large noncompetitive elements (put forward by Rotemberg and Woodford 1992). Given the success of the positive analysis of the theory, we find that standard neoclassical optimal fiscal policy developed by Barro (1979), Lucas and Stokey (1983), Judd (1985), Chamley (1986), and Chari, Christiano, and Kehoe (1994) is the best tool for evaluating how best to finance large fiscal shocks.

Appendix A. U.S. Data

In this appendix, we report our data sources and measures.

A1 Sources

- *National Income and Product Accounts of the United States, 1929–82* (U.S. Department of Commerce 1986) is the source for real aggregates in 1982 dollars, namely, GNP, personal consumption, government purchases (Table 1.2), and the deflator for federal compensation of employees (Tables 3.7A, 3.8A).
- *Fixed Reproducible Tangible Wealth in the U.S., 1925–85* (U.S. Department of Commerce 1987) is the source for real government investments in equipment and structures in 1982 dollars (Table B12).
- *National Income and Product Accounts, 1929–2000* (U.S. Department of Commerce 2001b) and *Fixed Assets and Durable Goods, 1925–1999* (U.S. Department of Commerce 2001a) are the sources for nominal capital stocks (Table 1-KCU) and nominal national income data (Tables 1.14, 1.16) used to construct wage rates and the return on capital.
- *Statistics of Income* (U.S. Department of the Treasury, various dates) is the source for the stock of inventories.
- Kendrick (1961) is the source for persons engaged in the military (Table A-VI) and manhours for the national economy, the civilian economy, the nonfarm economy (Table A-X), and manufacturing (Tables A-XI and D-II).
- *Historical Statistics of the United States, Colonial times to 1970* (U.S. Department of Commerce 1975) is the source for the population over 16 (series A39), military wages (series F167), and average hourly earnings in manufacturing (series D830).
- Joines (1981) is the source for labor and capital tax rates (Series MTRL1, MTRK1).

A2 Measures

To construct per-capita series, we divide by population over 16. Per-capita series that grow due to technological change (e.g., GNP) are normalized by $(1+\gamma_z)^t$. Hours measures are total manhours for the group (e.g., civilian) divided by population over 16 and normalized by discretionary time (52 weeks times 84 hours per week).

Real GNP and real personal consumption expenditures are adjusted slightly by removing part of indirect business taxes from both, namely, the federal excise taxes and state and local sales taxes. This makes the data accounting consistent with the model accounting.

Real government consumption is residually determined from total real government purchases less real government investment and real military compensation. Government investment is total federal, state, and local nonresidential investment less investment in military equipment and less half of investment in military facilities. Real military compensation is constructed by dividing nominal military wages by the deflator for federal compensation of employees.

Wage rate series are constructed for the following three groups of workers: nonfarm, manufacturing, and full-time equivalent employees. The *wage rate* for a group is defined to be *real labor income* in that group divided by manhours in that sector. For both nonfarm and manufacturing, we measure real labor income as compensation plus 80 percent of proprietors' income, with the sum divided by a price deflator. For manufacturing, we also use deflated average hourly earnings for 25 industries as a measure of real labor income. For full-time equivalent employees, real labor income is compensation divided by a price deflator. Manhours in Kendrick (1961) are only available for persons engaged. For full-time equivalent employees, we assume the same hours per worker as persons engaged. To deflate all wages, we use the deflator for GNP less military expenditures. For after-tax wages, we multiply the wage rate by one minus Joines' (1981) labor tax rate.

The return on capital measure is after-tax profits divided by the total capital stock (both nominal). After-tax profits is the sum of (*i*) after-tax corporate profits; (*ii*) 20 percent of proprietor's income multiplied by one minus Joines' labor tax rate; (*iii*) rental income; (*iv*) half of net interest; and (*v*) the service flow from consumer durables equal to 4 percent times the stock of durables.[19] The capital stock divisor is the sum of net stocks of (*i*) total private fixed assets; (*ii*) total government fixed assets; (*iii*) consumer durable goods; and (*iv*) inventories.

Appendix B. Stochastic Simulations

In this appendix, we describe the specific steps taken for the stochastic simulations. In particular, we describe how we compute the results displayed in Figures 7A–7F of the main text.

1. Generate $5N$ (N=100,000) probability transition matrices π (with $\pi(j,i)$ equal to the probability of going from state i to state j) for stochastic variable s_t as follows:
   (a) 1st N: randomly draw each element from uniform [0,1] and then normalize columns to sum to 1.
   (b) 2nd N: randomly draw each element of the first row from uniform [0,1], randomly draw each element i of the second row from uniform $[0, 1-\pi(1,i)]$, and so on until the matrix is filled in.
   (c) 3rd N: do the same exercise as for the 2nd N except start with the last row of the matrix and work up.
   (d) 4th N: randomly draw from uniform [0,1] each of the diagonal elements (i,i) and call these draws $\pi(i,i)$. For the first lower off diagonals $(i,i+1)$, draw from the uniform $[0, 1-\pi(i,i)]$, and call these draws $\pi(i,i+1)$. For the first upper off diagonals, draw from the uniform $[0, 1-\pi(i,i)-\pi(i,i+1)]$ and so on until the matrix is filled in.
   (e) 5th N: do the same exercise as for the 4th N except start with the first lower off diagonal as the initial draw and then work out to fill in the matrix. Note that, for our case, we generated 6×6 matrices with state 1 being 'before war,' states 2–5 being in war, and state 6 being postwar. We include the variations in (b)–(e) because the uniform draw in (a) generates very few transition matrices that pass the test in step 3.
2. For each matrix generated in step 1, compute the following statistics:
   (a) probability of being in the war states (2–5),
   (b) average duration in war,
   (c) probability of entering war.
3. Discard all matrices whose statistics in step 2 are not in the range from 70 percent to 130 percent of U.S. estimates.
4. Eliminate all repeats in the set of matrices remaining. Assume that we have M total matrices in the remaining set.

5. Convert each of the M 6×6 transition matrices denoted π into 7×7 matrices denoted Π to allow for two postwar states — no depression (state 6) and depression (state 7) — as follows:

$$\Pi = \begin{bmatrix} & & \pi_{1:5,1:5} & & & \pi_{1:5,6} & \pi_{1:5,6} \\ .22\pi_{6,1} & .57\pi_{6,2} & .53\pi_{6,3} & .49\pi_{6,4} & .56\pi_{6,5} & \pi_{6,6} & .1 \\ .78\pi_{6,1} & .43\pi_{6,2} & .47\pi_{6,3} & .51\pi_{6,4} & .44\pi_{6,5} & 0 & \pi_{6,6} - .1 \end{bmatrix}$$

where $\Pi(j,i)$ is the probability of going from state i today to state j tomorrow. The last two rows are based on survey responses. (See main text.)

6. Compute M equilibria using the M transition matrices, with all other parameters held fixed.

7. Simulate and plot output, consumption, investment, hours, wages, and returns for all M cases over the period 1942–50. For each series and each year, drop the highest 2.5 percent and the lowest 2.5 percent outliers. Display the upper and lower bounds after outliers are dropped.

Notes

[1]See Rotemberg and Woodford (1991, 1992) and Mulligan (1998) for critiques of the neoclassical model.

[2]Other papers examining the effects of fiscal shocks include Rotemberg and Woodford (1991, 1992), Braun and McGrattan (1993), Ohanian (1997), Ramey and Shapiro (1998), Mulligan (1998), Blanchard and Perotti (2002), and Burnside, Eichenbaum, and Fisher (2002). One key difference between these papers and ours is that our fiscal shock is more comprehensive: we include not just government spending, but also taxes, the draft, government investment, military wages, rationing, and uncertainty over the fiscal shock and over the post-shock state of the economy. Another difference is that most of these papers include a lot of data from small fiscal shocks, which makes it harder to disentangle the effects of the fiscal shocks from other shocks in the analysis. Our paper focuses on the enormous World War II fiscal shock, which likely dwarfs the effects of other possible shocks.

[3]See Aiyagari, Christiano, and Eichenbaum (1992) and Baxter and King (1993) for related analyses.

[4]This model of the draft, which explicitly preserves the representative agent construct, differs from that in Ohanian (1997) in which some families were hit by the draft and others were not. Ohanian (1997) preserves the representative agent construct by assuming separable consumption and leisure and by assuming that military labor income and private labor income are identical.

[5]Because preferences are separable between consumption and leisure, consumption for civilians and draftees will be equated.

[6]Testimony was given by Harold Moulton, president of the Brookings Institution; A.F. Hinrichs, acting commissioner of the Bureau of Labor; Matthew Noll of the American Federation of Labor; and Robert Nathan, representing the Commission for Economic Development.

[7]Most of this government consumption residual is military equipment expenditures. This component is recorded in the national accounts as government investment, but we treat it as government consumption since it is not an input into civilian production.

[8]These statistics are from the American Revolution, the War of 1812, the Mexican

War, the American Civil War, the Spanish American War, World War I, and World War II.

[9]We did not have survey results for 1943 and therefore chose a probability of postwar depression intermediate to our estimates of 1942 and 1944.

[10]We subtract indirect business taxes for sales from both GNP and personal consumption expenditures.

[11]All of our wage measures exclude estimates of wages of farm proprietors because, in general, it is hard to estimate the fraction of proprietor's income that is labor income and, more specifically, because the relative price of farm output nearly doubled during World War II. Accounting for this enormous relative price change is beyond the scope of our one-sector model. It should be noted that the wages of farm employees are included in our full-time equivalent wage measure.

[12]Mulligan (1998) focuses attention on bond returns, which were low during World War II. We focus on the return to capital, which is relevant for the theory. Another important reason to focus on the return to capital rather than bonds is the major regulatory policy changes that took place during the war. McGrattan and Prescott (2002) argue that regulations on production and consumer credit were important contributors to temporarily low bond returns. Incorporating these regulations into this model is beyond the scope of this study.

[13]We have also conducted our analysis with the simulation beginning in 1941. Our results are robust to this choice.

[14]See, for example, Parkin 1986, McGrattan 1991, Ingram, Kocherlakota, and Savin 1994, Hall 1997, Chari, Kehoe, and McGrattan 2002, Gali, Gertler, and Lopez-Salido 2002, and Mulligan 2002.

[15]Following our analysis of the deterministic model, we compare the stochastic model to the data for 1942–50. We also ran simulations of the stochastic model beginning in 1940. We found that the results for the model between 1942 and 1950 were affected little by this. We also found that the model did a good job of accounting for output in 1940 and 1941 if we assumed households expected the war with low probability in those years.

[16]The pre-tax real wage used by Rotemberg and Woodford (1992) in their analysis of World War II is average hourly earnings for 25 industries deflated by the GNP deflator; in 1945 it is 6 percent above trend. If Rotemberg and Woodford had instead deflated wages by

the deflator for GNP less military expenditures, as we do, the deviation would be only 0.1 percent.

[17]It should be noted that Rotemberg and Woodford compare the actual wage to the wage in their competitive model using a different approach from ours. They fit a regression of the change in the real wage on the lagged change in the real wage and a military spending shock using data between 1891 and 1970. This regression suggests a small deviation between the theory and the data. They find a small, positive effect of military purchases on wages: a 100 percent increase in military spending raises the real wage by 2 percent, whereas the theory would predict a small decrease in the real wage. They also use post-World War II data and compare the wage in their model to an impulse response of the wage in the data from a VAR. Their VAR analysis also shows a small deviation between the prediction of the competitive model and the data.

[18]Burnside, Eichenbaum, and Fisher (2002) also report positive results for the neoclassical model. They find that the neoclassical model, augmented with habit formation preferences, generates impulse responses that are similar to empirical vector autoregression impulse responses to fiscal shocks identified by Ramey and Shapiro (1998) during the postwar period.

[19]Roughly half of net interest payments are imputed intermediate financial services and are not included. See McGrattan and Prescott (2000) for details on imputed net interest.

References

Aiyagari, S. Rao, Lawrence J. Christiano, and Martin Eichenbaum. 1992. The output, employment, and interest rate effects of government consumption. *Journal of Monetary Economics* 30: 73–86.

Barro, Robert J. 1981. Output effects of government purchases. *Journal of Political Economy* 89: 1086–1121.

Barro, Robert J. 1979. On the determination of the public debt. *Journal of Political Economy* 87: 940–971.

Barro, Robert J., and Chaipat Sahasakul. 1986. Average marginal tax rates from social security and the individual income tax. *Journal of Business* 59: 555–566.

Baxter, Marianne, and Robert G. King. 1993. Fiscal policy in general equilibrium. *American Economic Review* 83: 315–334.

Blanchard, Olivier J. and Roberto Perotti. 2002. An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output, *Quarterly Journal of Economics* 117: 1329–1368.

Braun, R. Anton, and Ellen R. McGrattan. 1993. The macroeconomics of war and peace. In *NBER Macroeconomics Annual 1993*, pp. 197–247. Cambridge: MIT Press.

Burnside, Craig, Martin Eichenbaum, and Jonas D.M. Fisher. 2002. Assessing the effects of fiscal shocks. Discussion Paper, Northwestern University.

Chamley, Christophe. 1986. Optimal taxation of capital income in general equilibrium with infinite lives. *Econometrica* 54: 607–622.

Chari, V.V., Lawrence J. Christiano, and Patrick J. Kehoe. 1994. Optimal fiscal policy in a business cycle model. *Journal of Political Economy* 102: 617–652.

Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan. 2002. Business cycle accounting. Working paper 625, Federal Reserve Bank of Minneapolis.

Cole, Harold L., and Lee E. Ohanian. 1999. The Great Depression in the United States from a neoclassical perspective. *Federal Reserve Bank of Minneapolis Quarterly Review* 23: 2–24.

Cole, Harold L., and Lee E. Ohanian. 2001. New Deal policies and the persistence of the Great Depression: A general equilibrium analysis. Working Paper 597, Federal Reserve Bank of Minneapolis.

Gali, Jordi, Mark Gertler, and J. David Lopez-Salido. 2002. Markups, gaps, and the welfare costs of business fluctuations. NBER Working paper 8850.

Gordon, Robert J. 1969. $45 billion of U.S. private investment has been mislaid. *American Economic Review* 59: 221–238.

Gordon, Robert J. 1970. Communications: $45 billion of U.S. private investment has been mislaid: Reply. *American Economic Review* 60: 940–945.

Hall, Robert E. 1980. Labor supply and aggregate fluctuations. *Carnegie-Rochester Series on Public Policy* 12: 7–33.

Hall, Robert E. 1997. Macroeconomic fluctuations and the allocation of time. *Journal of Labor Economics* 15: 223–250.

Ingram, Beth Fisher, Narayana R. Kocherlakota, and N.E. Savin. 1994. Explaining business cycles: A multiple-shock approach. *Journal of Monetary Economics* 34: 415–428.

Jaszi, George. 1970. Communications: $45 billion of U.S. private investment has been mislaid: Comment. *American Economic Review* 60: 934–939.

Joines, Douglas H. 1981. Estimates of effective marginal tax rates on factor incomes. *Journal of Business* 54: 191–226.

Judd, Kenneth L. 1985. Redistributive taxation in a simple perfect foresight model. *Journal of Public Economics* 28: 59–83.

Kendrick, John W. 1961. *Productivity Trends in the United States.* Princeton, NJ: Princeton University Press.

Lucas, Robert E., Jr., and Nancy L. Stokey. 1983. Optimal fiscal and monetary policy in an economy without capital. *Journal of Monetary Economics* 12: 55–93.

McGrattan, Ellen R. 1991. The Macroeconomic effects of distortionary taxation. Discussion paper 37, Federal Reserve Bank of Minneapolis.

McGrattan, Ellen R. 1994. A progress report on business cycle models. *Federal Reserve Bank of Minneapolis Quarterly Review* 18: 2–16.

McGrattan, Ellen R. 1996. Solving the stochastic growth model with a finite element method. *Journal of Economic Dynamics and Control* 20: 19–42.

McGrattan, Ellen R., and Lee E. Ohanian. 1999. The Macroeconomic Effects of Big Fiscal Shocks: The case of World War II. Working Paper 599, Federal Reserve Bank of Minneapolis.

McGrattan, Ellen R., and Edward C. Prescott. 2000. Is the stock market overvalued? *Federal Reserve Bank of Minneapolis Quarterly Review* 24: 20–40.

McGrattan, Ellen R., and Edward C. Prescott. 2002. Average debt and equity returns: Puzzling? *American Economic Review*, Papers and Proceedings, forthcoming.

Mulligan, Casey B. 1998. Pecuniary incentives to work in the United States during World War II. *Journal of Political Economy.* 106: 1033–1077.

Mulligan, Casey B. 2002. A century of labor-leisure distortions. NBER Working paper 8774.

Ohanian, Lee E. 1997. The macroeconomic effects of war finance in the United States: World War II and the Korean War. *American Economic Review* 87: 23–40.

Parkin, Michael. 1986. A method for determining whether parameters in aggregative models are structural. *Carnegie-Rochester Conference Series on Public Policy* 29: 215–252.

Ramey, Valerie A., and Matthew Shapiro. 1998. Costly capital reallocation and the effects of government spending. *Carnegie-Rochester Series on Public Policy* 48: 145–194.

Rotemberg, Julio J., and Michael Woodford. 1991. Markups and the business cycle. In *NBER Macroeconomics Annual*, Cambridge: MIT Press.

Rotemberg, Julio J., and Michael Woodford. 1992. Oligopolistic pricing and the effects of aggregate demand on economy activity. *Journal of Political Economy.* 100: 1153–1207.

U.S. Department of Commerce. Bureau of the Census. 1975. *Historical Statistics of the United States, Colonial times to 1970.* Bicentennial ed., Part 2. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Commerce. Bureau of Economic Analysis. 1986. *The National Income and Product Accounts of the United States, 1929–82.* Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Commerce. Bureau of Economic Analysis. 1987. *Fixed Reproducible Tangible Wealth in the U.S., 1925–85.* Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Commerce. Bureau of Economic Analysis. 2001a. *Fixed Assets and Durable Goods, 1925–1999.* www.bea.doc.gov.

U.S. Department of Commerce. Bureau of Economic Analysis. 2001b. *The National Income and Product Accounts of the United States, 1929–2000.* www.bea.doc.gov.

U.S. Department of the Treasury, Internal Revenue Service. Various dates. *Statistics of Income.* Washington, D.C.: U.S. Government Printing Office.

Wasson, Robert C., John C. Musgrave, and Claudia Harkins. 1970. Alternative estimates of fixed business capital in the United States, 1925–1968. *Survey of Current Business* 50: 18–36. Washington, D.C.: U.S. Government Printing Office.

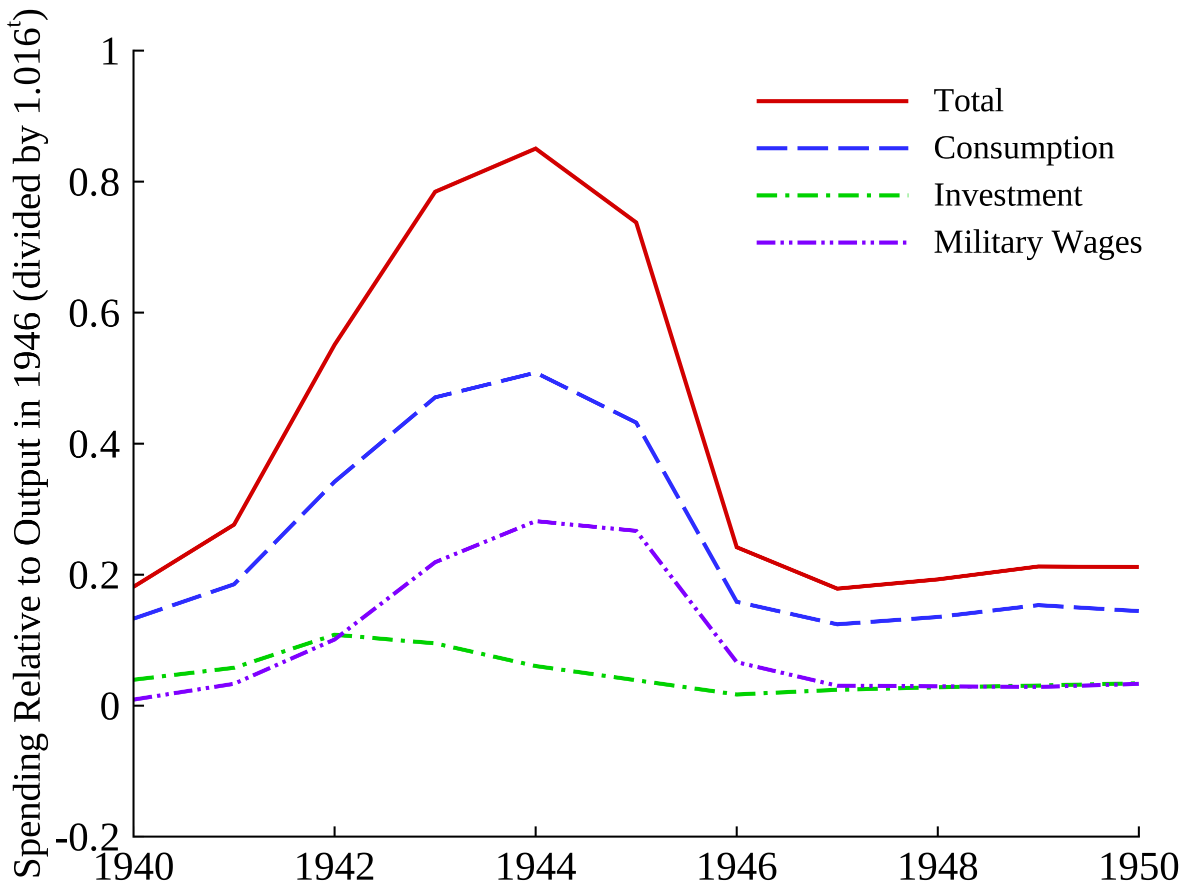

Figure 1. Components of U.S. Government Spending, 1940–50.

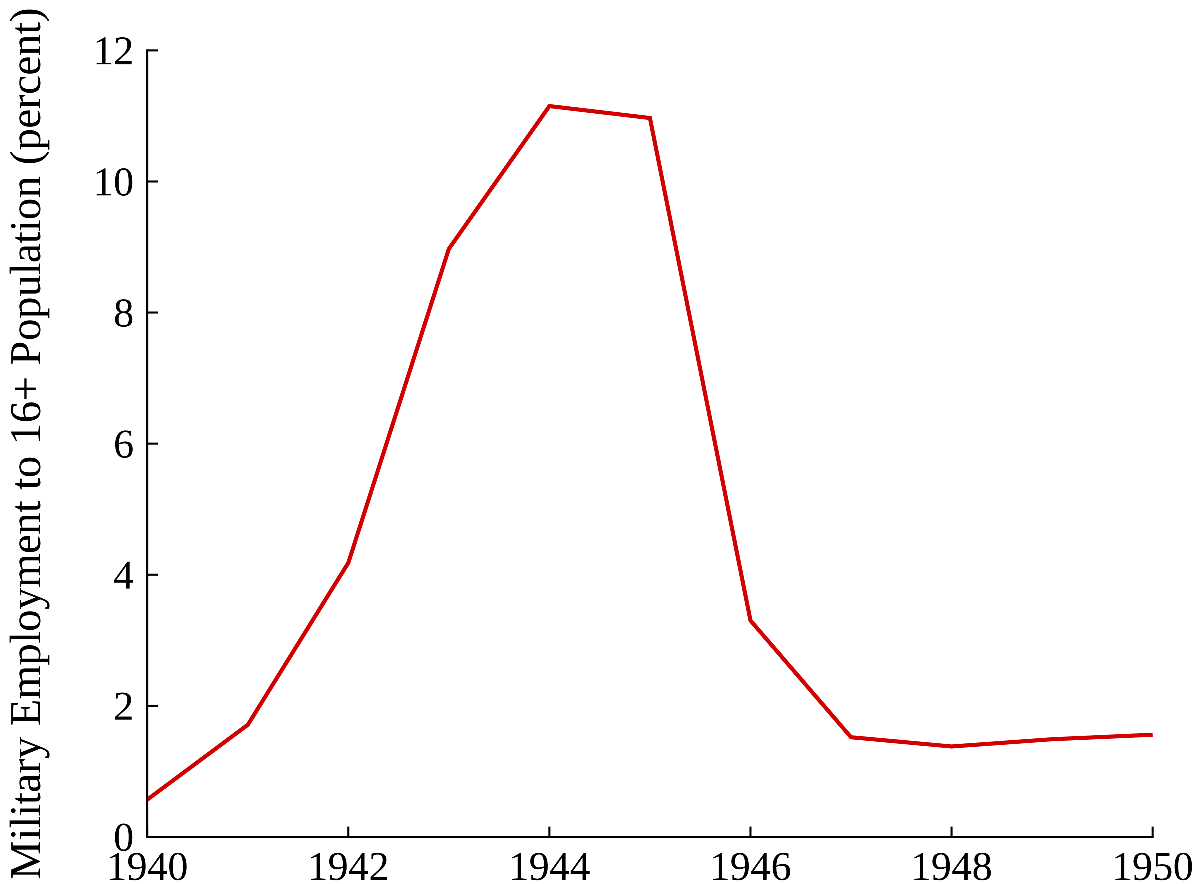

Figure 2. Fraction of U.S. Population over 16 in the Military, 1940–50.

Figure 3. Effective U.S. Tax Rates, 1940–50.

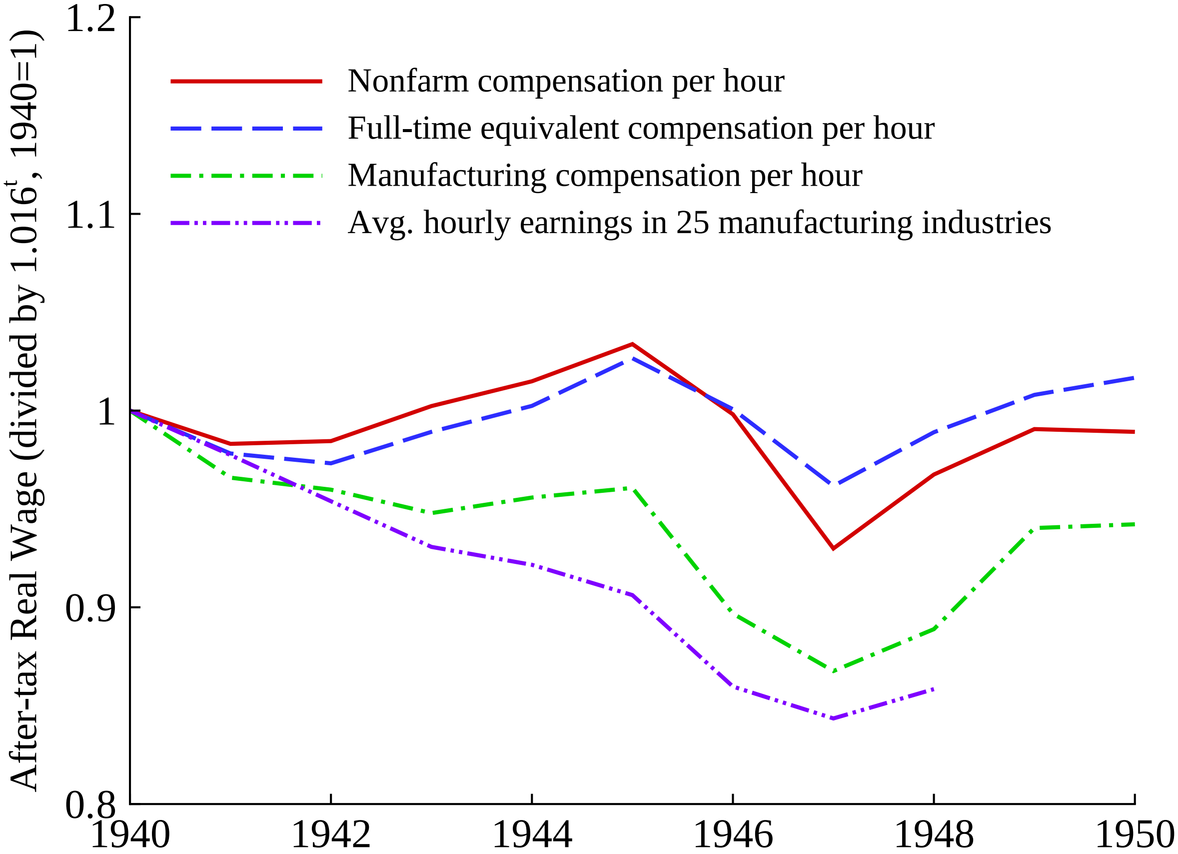

Figure 4. Real U.S. Wage Rates, 1940–50.

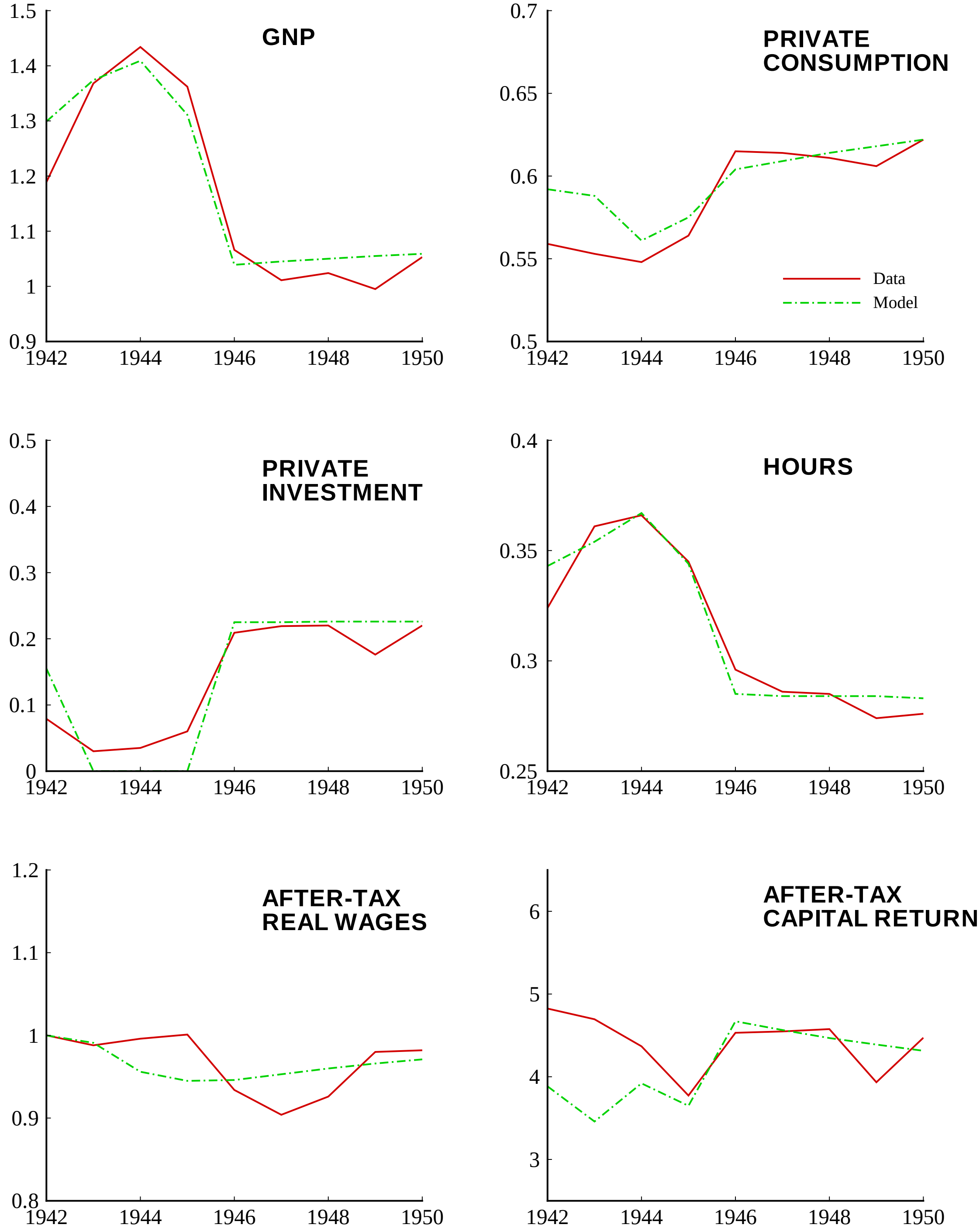

Figure 5. Results for the Deterministic Model Economy without Rationing

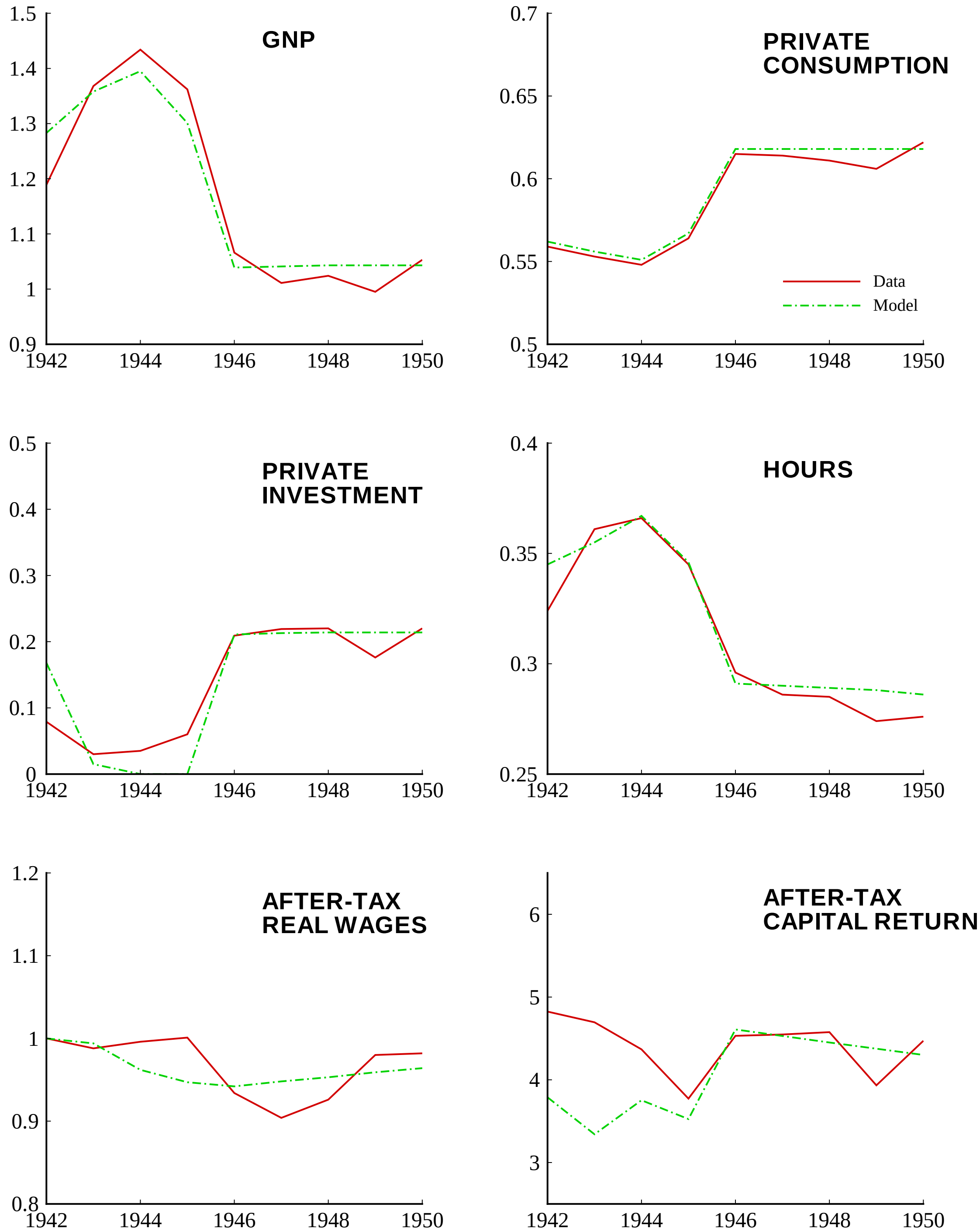

Figure 6. Results for the Deterministic Model Economy with Rationing

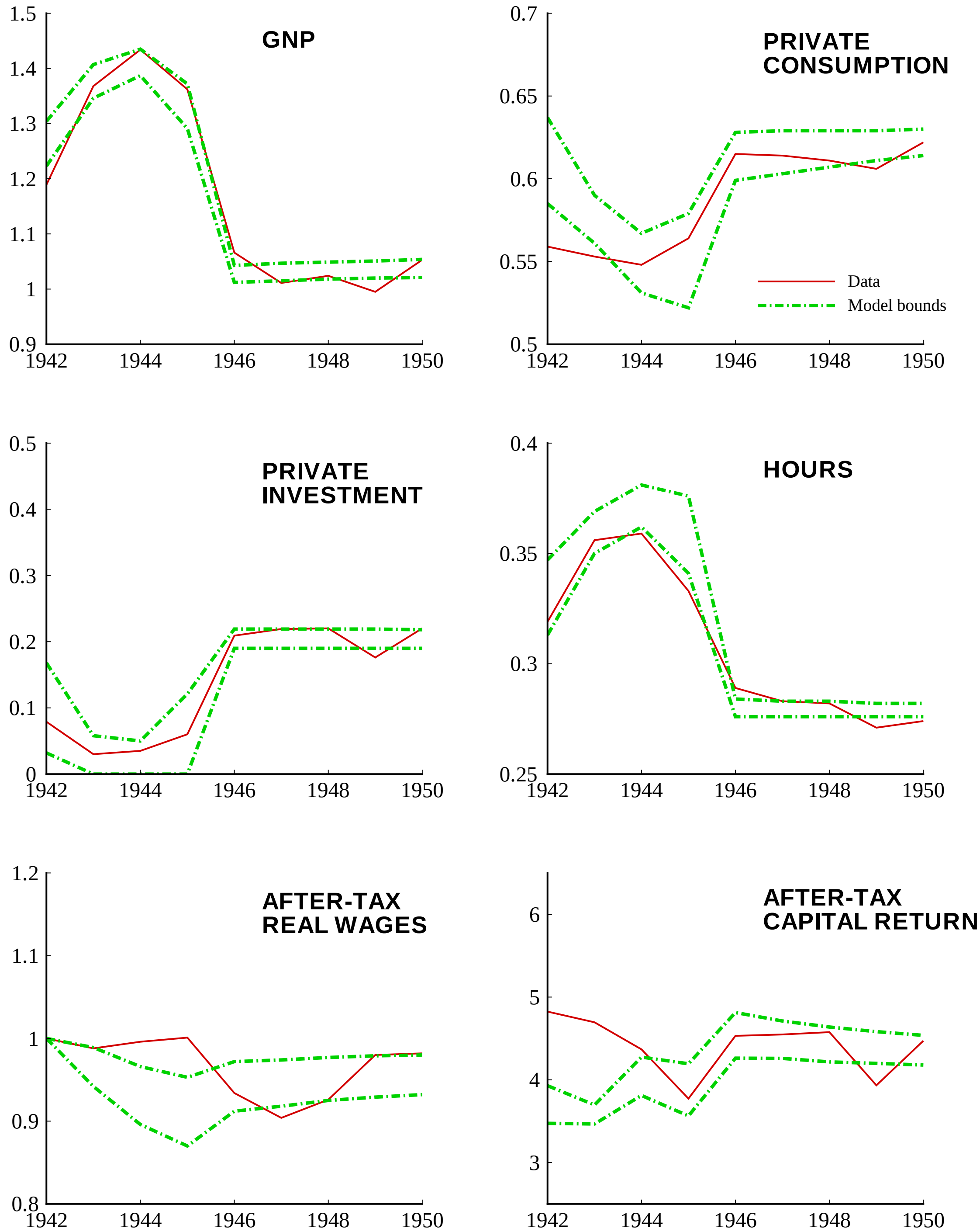

Figure 7. Results for the Stochastic Model Economies

Table 1

Parameter Values for Model Simulations

Preferences and technology scale	$\psi = 2.3$, $\xi = .0$, $\bar{l}_d = 50/84$
Deterministic economy without rationing	$\beta = .98$, $\psi = 2.3$, $\bar{z} = 3.6$
Deterministic economy with rationing	$\beta = .98$, $\psi = 2.1$, $\bar{z} = 3.5$
Stochastic economies without rationing	$\beta = .97$, $\psi = 2.3$, $\bar{z} = 3.6$
Technology	$b = 1/2$, $\rho = 1$, $\theta = .36$, $\delta = .07$
Growth	$\gamma_n = .016$, $\gamma_z = .016$
Hours limit†	$\bar{l}_c = 80\%$ (of .27)
Restrictions on Markov Chain†	
Average duration of war	in [2.6, 4.8] years
Fraction of years a war is started	in [2.9, 5.3] percent
Fraction of years in war	in [10.6, 19.8] percent
Probabilities of Postwar Depression†‡	
in 1941	78%
in 1942	43
in 1943	47
in 1944	51
in 1945	44

† Only relevant for stochastic simulations.
‡ The probability is conditional on the war ending.

TABLE 2

Sensitivity Results

Parameter	Benchmark Value	Tax Rate Needed for No Change in: Avg. Private Hours	Tax Rate Needed for No Change in: Avg. Private Output
Avg. labor tax rate, 1942–45†	17.9%	32.3%	30.4%
Avg. labor tax rate, 1942–45† with 99% capital tax rate	–	29.8%	24.8%
Avg. labor tax rate and capital tax rate, 1942–45‡	17.9% 61.2%	30.8% 74.1%	28.4% 71.8%
	Benchmark Value	**Elasticity Needed for No Change in: Avg. Private Hours**	**Elasticity Needed for No Change in: Avg. Private Output**
Labor elasticity	2.7%	.34%	.50%

† The same proportional increase is made over the benchmark rate per year.
‡ The same percentage point addition is made to the benchmark rates per year.