Federal Reserve Bank of Minneapolis
Research Department Staff Report

June 2002

Does Neoclassical Theory Account For Wartime Economic Booms? Evidence from World War II

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ABSTRACT

This paper quantitatively evaluates whether standard neoclassical growth theory accounts for wartime economic booms. The analysis focuses on World War II because it is by far the biggest war in the history of the United States, and thus provides a strong test of the theory. We take observed changes in fiscal policy during the war as inputs into a parameterized, dynamic, general equilibrium model and compare the values of the key variables in the model to the actual values of these variables in the data. Our main finding is that the theory quantitatively accounts for the World War II economic boom.

*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

U.S. macroeconomic activity rises substantially during wars. For example, real gross national product (GNP) during World War II rose 52 percent between 1941 and 1944. This paper quantitatively evaluates whether standard neoclassical growth theory accounts for wartime economic booms. We do this by feeding observed changes in fiscal policy during World War II into a parameterized, dynamic general equilibrium growth model, and comparing the values of the key variables in the model – consumption, output, investment, labor input, the after-tax wage rate and the after-tax return to capital – to the actual values of these variables during World War II. We focus our analysis on World War II because it is by far the biggest war in the history of the United States, and thus provides a strong test of the theory.

This analysis builds on recent analyses of wartime macroeconomic activity by Braun and McGrattan (1993) and Ohanian (1997), but differs in two important ways from these earlier papers. First, this analysis provides a much more comprehensive and detailed evaluation of the theory than did either of the earlier papers; Braun-McGrattan focused on the behavior of real wages and productivity during World War II, while Ohanian focused on the welfare costs of alternative fiscal policies during World War II and the Korean War. Second, this paper directly addresses recent claims that the standard neoclassical model does not account for wartime economic booms. For example, Mulligan (1998) and Burnside et al. (2000) argue that the theory model cannot quantitatively account for the large increase in labor input that occur during wars, while Rotemberg and Woodford (1991,1992) argue that the theory cannot account for the behavior of real wages. This paper discusses the theory's performance in light of these claims.

Our main finding is that the theory quantitatively accounts for the World War II economic boom; 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 in the model. These findings thus contrast with the views of Mulligan, Burnside et al., Rotemberg and Woodford, and others who argue that substantial departures from standard theory are required to understand wartime macroeconomic behavior.

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

2. The Effects of Wars in a Simple Model

We start with a simple version of the neoclassical growth model to highlight the main qualitative effects of a large, temporary fiscal shock. We then discuss features that need to be included in the theory before confronting it with U.S. data during World War II.

A. The simple model

Hall (1980) and Barro (1981) describe the effects of increased military expenditures in the context of a simple neoclassical economy. Consider, for example, a representative

household with preferences given by:

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

where c is consumption and $1 - n$ is non-market time. The constraint on resources is:

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

where $f(k, n)$ is a constant returns to scale technology with capital k and labor n as the inputs and δ is the rate at which capital depreciates. The variable g is government spending, which is modeled as 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.

In this simple model, both the wealth and intertemporal substitution effects of higher government spending raise labor input and output. In particular, lower wealth induces households to consume less leisure and work more, and the temporary nature of the shock increases labor input through intertemporal substitution. The increase in the supply of labor leads to a fall in productivity and, therefore, a fall in real wages. Intertemporal substitution also raises the real interest rate, and lowers investment.

B. Extending the Model to Capture WWII

While the simple model qualitatively illustrates the macroeconomic effects of higher government purchases, it abstracts from a number of key features of actual wars that have substantive economic implications. Before taking the model to the data for WWII, we add the following four elements: conscription, distorting taxes, different types of government purchases, and uncertainty. We summarize each of these elements below, and in Section 3, we describe how we model them.

Conscription

At the peak of the war, about 17 percent of the labor force was in the military. We therefore add the draft to the model. This is important because it reduces the quantity of labor available for production of market output.

Distorting taxes

There were significant increases in labor and capital income taxation during the war. Labor tax rates rose from 9 percent in 1940 to 19 percent in 1944, and capital income tax rates rose from 45 percent in 1940 to 60 percent in 1944. This is important to include because changes in these taxes change incentives to work and save.

Different types of government purchases

Government spending on (*i*) goods, (*ii*) wage payments to military personnel, and (*iii*) investment in plant and equipment all rose significantly during the war. Separately accounting for these three types of spending is important because they have very different macroeconomic effects. Purchases of goods induce the wealth and substitution effects described in the simple model above, since these purchases do not substitute for private consumption. However, military wage payments do not have these wealth effects, as these payments represent income for military personnel rather than a drain of resources from the economy. We therefore model these wage payments as transfers. The third item is capital investment. The government made substantial capital investment during the war, which increased production possibilities. We therefore include this spending in the model as investment spending.

Uncertainty

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

It is also worth noting that we abstract from some other World War II features. We abstract from rationing and wage and price controls because households and firms found ways to get around most of these restrictions through black markets and through alternative trades (e.g. firms provided health insurance in lieu of wage increases during the war).[1] Given the difficulties of measuring the effects of these policies, we make the simplifying assumption that agents were able to get around these restrictions completely, and we report how well this version of the model performs. We also abstract from other shocks, such as those to money or technology, because they are small in comparison to the fiscal shock.[2] This simplifies the analysis considerably and it also lets us focus exclusively on the effects of the enormous shocks to taxes and government spending.

3. Model Economy

We now describe the model economy, including the four extensions introduced in the previous section. There is an infinitely-lived representative family with two types of

[1]See for example Rockoff (1984). One notable exception was new automobiles, which were not produced for private consumption. Consumption of motor vehicles and parts was 2.8 percent of GDP in 1940 and fell to 0.4 percent by 1944.

[2]Braun and McGrattan (1993) find that total factor productivity is roughly at its trend level during the war. See their Table 3.

family members: "civilians" and "draftees."[3] 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 at date t, with fraction a_t in the military, and fraction $(1-a_t)$ who are civilians.

The family optimally chooses consumption of both types which we denote as 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 $\bar{l}_d$. We now present the family's maximization problem. The family's problem is given by:

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

subject to

$$(1-a_t)c_{ct} + a_t c_{dt} + i_{pt} = (1-\tau_{kt})r_{pt}k_{pt} + (1-\tau_{lt})w_t(1-a_t)l_{ct} + \tau_{kt}\delta k_{pt} + T_t \tag{4}$$

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

where k_{pt} is the beginning of period capital stock at date 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 in t, respectively, and T_t are transfers in t. All quantities are in per-capita terms; the constant growth rate of the population is given by g_n. Processes for a_t, r_{pt}, w_t, τ_{kt}, τ_{lt}, and T_t are taken parametrically by the family and are specified later.

[3]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) preserved the representative agent construct by assuming separable consumption and leisure and by assuming that military labor income and private labor income were identical.

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:

$$(6) \qquad Y_t = F(K_{pt}, K_{gt}, Z_t L_{pt})$$

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 g_z: $Z_t = z(1+g_z)^t$.

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 Jaszi [1970], Gordon [1970], and Wasson et al. [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:

$$(7) \qquad G_t = C_{gt} + I_{gt} + N_t a_t w_t \bar{l}_d.$$

Since we treat military wage payments as a transfer payment, the period t government budget constraint is given by

$$(8) \qquad C_{gt} + I_{gt} + N_t T_t = \tau_{kt}(r_{pt} - \delta)K_{pt} + \tau_{lt} w_t L_{pt} + r_{gt} K_{gt}$$

where r_g is the rental rate for government capital, and $N_t T_t$ are total transfer payments, including the military wage bill. We assume that transfers net of the military wage bill residually balances the government budget each period.

Government capital evolves according to the following law of motion

$$(9) \qquad K_{gt+1} = (1-\delta)K_{gt} + I_{gt}$$

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

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 (8) and the wage rate in (4) are equal to the partial derivatives of the production function F in (6) with respect to K_p, K_g, and L_p, respectively. As we noted earlier, transfers T are defined residually from the government budget constraint (8); they depend on prices, privately chosen quantities, and several exogenous processes.

There are six exogenous processes in the model, five of which have already been discussed – the draft (a_t), the tax rates on capital and labor income (τ_{kt}, τ_{lt}), and government consumption and investment (C_{gt} and I_{gt}). The sixth exogenous process is related to the state of the postwar economy – which could be prosperous or depressed.

We allow for the possibility of a postwar depression because wartime surveys show that individuals as well as professional economists placed a significant probability on the event that the Great Depression would return following the end of the war. We model a postwar depression by (i) choosing values for taxes and spending at levels observed during

the 1930s and by (*ii*) introducing a restriction on the number of hours that civilians can work. We use $\bar{l}_{ct}$ to denote the upper limit on hours; this variable is our sixth exogenous variable. In a prosperous postwar, there is no constraint on work opportunities and $\bar{l}_{ct} = 1$. In a depressed postwar, there is a constraint with $\bar{l}_{ct} < 1$.

Our specification of the depression state is based on evidence in Cole and Ohanian (1999, 2001) and testimonies of professional economists during the war. Cole and Ohanian's (1999, 2001) evidence suggests that the post-1933 depression was caused by labor and industrial policies that restricted individuals' opportunities to work. In testimony to the U.S. Senate Special Committee on Post-War Economic Policy and Planning in May of 1944, economists before the committee clearly expected too few jobs and a high level of unemployment after the war.[4] 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.

We assume that the evolution of the six 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}, and $\bar{l}_{ct}$. The state variable s_t is modeled as a Markov chain. This specification allows for both tractability and flexibility. If individuals have perfect foresight, the process s_t is degenerate; for $t = 1941$, the values of the six exogenous variables are the actual U.S. values observed in 1941; for $t = 1942$, the value of the six exogenous variables are the actual U.S. values observed in 1942; and so on. In cases where expectations are not perfect, we assume some probability over levels actually observed in 1941, 1942, and so on.

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

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

$$(10) \quad K_{pt} = N_t k_{pt}$$

$$(11) \quad L_{pt} = N_t(1 - a_t) l_{ct}$$

(iv) the resource constraint

$$(12) \quad C_{pt} + I_{pt} + C_{gt} + I_{gt} = Y_t$$

holds where $C_{pt} = N_t[a_t c_{ct} + (1 - a_t)c_{dt}]$ and $I_{pt} = N_t i_{pt}$; and (v) transfers satisfy (8).

4. Parameter Values and Exogenous Processes

In this section, we describe functional forms, parameter values, and the Markov chains used in our numerical simulations. We study two types of simulations: deterministic and stochastic. In the single deterministic case, individuals know with certainty the path of the six exogenous variables. In the stochastic cases, we simulate many economies that satisfy certain prespecified restrictions. The values of all parameters and restrictions are summarized in Table 1.

Preferences are given by:

$$(13) \quad U(c, l) = \log(c) + \psi(1 - l)^{\xi}/\xi$$

and imply a compensated labor supply of $(1-l)/[l(1-\xi)]$. The parameter ψ is chosen so that postwar hours of work in the model are consistent with U.S. observations. The value changes as we change ξ. We chose a benchmark value for ξ of 0, which implies log preferences; we also evaluate the robustness of our results by conducting the analysis for ξ's that generate lower labor supply elasticities. 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. The quantitative results are not sensitive to this value. Period t preferences are discounted by β^t. The period length is assumed to be one year. For our numerical experiments, we chose values of β that generated rates of return to capital and investment shares consistent with U.S. observations.

The production technology is given by the CES function

$$(14) \quad F(k_p, k_g, zl) = (bk_p^\rho + (1-b)k_g^\rho)^{\frac{\theta}{\rho}}(zl)^{1-\theta}.$$

We assume that government capital and privately capital are perfect substitutes, which implies that $\rho = 1$. We chose $\theta = .38$, which is consistent with the ratio of nonmilitary compensation to output. Our measure of output is GNP less military compensation and indirect business tax on sales.[5] The parameter b governs the relative productivities of private and public capital. We assume that these two types of capital are equally productive, which implies that $b = 1/2$.

The depreciation rate for both private and publicly owned capital (δ) is equal to 7 percent in all of our experiments. This value is consistent with long-run data on the fraction of output devoted to investment and the ratio of the capital stock to output. We choose the

[5] We subtract sales tax from GNP and consumption to make them consistent with our model accounts.

value of the technology parameter z so that model output in 1946 = 1. We set the growth rate of the technology parameter equal to its average value over this period, which implies that $g_z = 1.6$ percent. We also set the population growth rate equal to its average over this period, which implies that $g_n = 1.6$ percent.

Realizations of the exogenous processes for the deterministic economy are chosen so that they are equal to their counterparts in the data. These series are plotted in Figures 1-3. (The appendix describes the sources of these data and the transformations we make to the raw series.)

Figure 1 shows the components of government purchases. Note that government investment includes only plant and equipment expenditures used by either the private sector or the civilian government sector. This investment is primarily "GOPO" (government-owned, privately operated) capital. Government consumption is defined residually as total government spending less government investment and less military compensation. A large component of this government consumption residual is expenditures on military equipment. 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.

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

Figure 3 shows the average marginal tax rates for labor and capital income constructed by Joines (1981). This picture shows that both tax rates rose significantly during the war; the labor income tax rate more than doubled, and the capital income tax rate rose from

about 45 percent to about 60 percent.

Realizations of the exogenous processes for the stochastic economies are also chosen so that they are equal to their counterparts in the data (Figures 1-3). That is, individuals in the stochastic economies have the same experience as U.S. citizens during World War II. However, their expectations are not perfect; they are governed by some Markov chain over the state s_t. Our results are reported for many transition matrices of the Markov chain (drawn randomly from an urn) that satisfy certain restrictions.

Restrictions on the transition matrix in our stochastic simulations are motivated by the following facts about major U.S. wars prior to and including WWII: 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.[6] We consider transition matrices that generate similar histories of wars. To do this, we randomly generate probability matrices (500,000 in all) and use all that satisfy the criteria that (*i*) the average duration of wars is in the range of 2.6 to 4.8 years; (*ii*) the fraction of years a war is started is in the range of 2.9 to 5.3 percent; and (*iii*) the fraction of years in war is in the range of 10.6 to 19.8. (Thus, the range for each statistic is 70 percent to 130 percent of the U.S. value.)

Expectations about the postwar state are based on survey results in each of the years 1941 through 1945. 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 answered 'another depression.' In June of 1942 Gallup poll participants were asked, Which do you think the United States will have for the

[6]These statistics are based on the American Revolution, the War of 1812, the Mexican War, the Civil War, the Spanish American War, WWI, and WWII.

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 responded 'depression' in 1944 and 44 percent in 1945.[7] We use these wartime survey responses as the true expectations in our model.

The parameter choices summarized in Table 1 serve as our benchmark parameters. For key parameters we do sensitivity analysis after simulating our baselines.

5. 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. (Full details are given in our data appendix.) We then describe our numerical results. The first set of results are from a simulation for the deterministic economy in which individuals have perfect foresight about spending, taxes, the draft, and the postwar state. The second set of results are simulations of the stochastic economies.

A. The U.S. Data

In reporting our results, we compare six model variables to their counterparts in the U.S. data, namely GNP, consumption, investment, hours, wages, and returns to capital.

More precisely, we compare the models' output plus military compensation ($Y + Nal$) to real U.S. GNP (less indirect business taxes for sales). For both model and data, we report

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

GNP, consumption, and investment in per-capita, detrended terms, with output (Y) in 1946 equal to 1. Private consumption in the model is compared to U.S. personal consumption expenditures (less indirect business taxes for sales). Private investment in the model is compared to U.S. gross private domestic investment plus foreign net investment.

Total hours in the model is compared to Kendrick's (1961) manhours for the national economy – both series are reported relative to the working-age population and normalized by discretionary time.

The real wage rate in the model is compared to the wage rate of the U.S. manufacturing sector. We do not use a measure for the total economy for two reasons. First, to construct an economy-wide measure, we need to have a measures of labor income of proprietors, which we do not have. A large fraction of proprietors are farmers who saw their incomes soar during WWII. In Figure 4, we plot after-tax real wage rates for workers in the farm sector, the non-farm sector, and manufacturing. To compute these wage rates before tax, we summed compensation and 80 percent of proprietors' income and divided by total hours for the group multiplied by a growth trend of 1.016^t. To compute real wages, we deflate the nominal wage with the 1947 GNP deflator. For an after-tax measure, we multiply by one less Joines' (1981) labor tax rate. As a comparison, we also show after-tax wage rates for full-time equivalent employees, which includes no proprietors' income.

Although the measured wage rate for farmers shown in Figure 4 rises significantly, measures of farm output per manhour reported by the Department of Agriculture rise only modestly. (See *Historical Statistics*, Series 430.) In our theory, the two are the same. Part of the rise in farm incomes may be due to the fact that foreign supplies of agricultural products were cut off. Accounting properly for both the large rise in farm proprietors' income and

the small decline in nonfarm labor income is beyond the scope of this paper. Since it is a small sector, we exclude from our wage rate measure. Any other measure implies basically the same thing: real wages fell with the fall in the range of 0 to 10 percent between 1941 and 1944.

There is a second and more important reason for using the U.S. manufacturing wage rate when we assess the success or failure of neoclassical theory. Those who have critiqued the neoclassical model use the manufacturing wage rate when comparing the model predictions to the data. However, there is disagreement about the facts. Mulligan (1998) argues that real wage rates fell significantly, and Rotemberg and Woodford (1992) argue that real wage rates rose significantly.[8] (Compare Mulligan's Table 1 with Rotemberg and Woodford's Figure 11.[9])

The discrepancy between Mulligan and Rotemberg and Woodford is due to two differences in their wage measures. First, Mulligan computes wages after taxes, while Rotemberg and Woodford compute wages before taxes. Labor taxes rose significantly during World War II. Second, Mulligan uses the consumer price index (CPI) to deflate nominal wages, while Rotemberg and Woodford (1992) use the GNP deflator. Changes in the CPI exceeded changes in the GNP deflator. If Rotemberg and Woodford (1992) followed Rotemberg's (1993) recommendation to use a private value added deflator – which behaved similarly to the CPI during WWII – and took into account changes in taxes, then they would have a similar wage series to Mulligan, which in turn is similar to the manufacturing wage series

[8]Burnside et al. (2000) also argue that wages fall during wars, but they look only at the post-WWII period.

[9]Rotemberg and Woodford have the wrong labels on their real wage and GNP series; they need to be interchanged. This implies less of a discrepancy between Mulligan and Rotemberg and Woodford than their Table 1 and Figure 11 suggest.

plotted in Figure 4.

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.

B. Results from the Deterministic Model

We turn now to the results from simulating the deterministic economy. In Figure 5, we plot time series for the model and data in six panels, which we refer to as Figures 5A-5F. In the graphs, the solid line is the actual variable and the dashed line is the model variable.

With the exception of the beginning of the war, the time series for the model and data line up well. 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 data fall 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 – rises close to 40 percent in both the model and the data.

There is a significant rise in model investment and hours (and hence GNP) at the beginning of the war because here we are assuming that individuals know for sure that they will be facing higher tax rates in the future. (See Figure 3.) For them, 1941 is a good year to work hard and invest. We will see in Section 6, that increased uncertainty about the size of future governments can eliminate this initial mismatch of theory and data.

Figures 5E and 5F show the after-tax factor prices for both the model and the data. Figure 5E shows the after-tax wage rates. Both model and actual wages fall below their

1941 levels during the war and rise steadily in the postwar. Figure 5F shows the after-tax returns to private physical capital. Both returns fall initially and then rise in 1945. The model return falls initially faster as households quickly increase their capital investment.

Mulligan has argued that the neoclassical theory cannot account for both the large increase in the wartime labor input *and* the decline in the after-tax real wage. The results of Figure 5 indicate that standard theory can indeed account for these facts. The reason the theory is consistent with both higher labor input and lower wages is because the fiscal shock also generates lower consumption in the model, which in turn raises the marginal utility of consumption and the labor input. For example, both model and actual consumption fall about 6 percent between 1941 and 1944.

The key to understanding the difference between our quantitative findings and Mulligan's view is that Mulligan's analysis does not include a simulation of a general equilibrium model in response to the wartime fiscal shock. It is difficult to assess how well the model captures wartime economic behavior without this type of a quantitative experiment because evaluating the model requires computing the equilibrium wage, labor input, and consumption.

Burnside et al. (2000) study post-WWII wars and, like Mulligan, argue that the evidence is inconsistent with neoclassical theory. They estimate a vector autoregression and compare its empirical impulse responses with theoretical impulse responses for a version of the neoclassical growth model. To do this, they must make assumptions about the interaction of fiscal and non-fiscal shocks. The advantage of World War II over post-WWII wars is its size – the fiscal shocks dominate non-fiscal shocks and the event provides a strong test of the theory. Our finding is that the theory passes the test – the model is quantitatively consistent

with observed World War II changes in quantities and after-tax factor prices.

We turn next to a stochastic version of our model to see if adding in uncertainty significantly changes the findings.

C. The Results from the Stochastic Version of the Model

This section introduces uncertainty into the model. We follow the same format as in the previous section; Figures 6A-6D compare the quantity variables in the model to the data, and Figures 6E-6F compare the factor price variables in the model to 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).

Our main finding is that our results are robust to adding uncertainty; the stochastic model captures the main changes in both the quantity and the factor price variables. In fact, adding uncertainty reduces some of the deviations between the perfect foresight model and the data, particularly for investment and labor input. To see this, we compare Figures 6C to 5C for investment in the two models, and 6D to 5D for labor input in the two models. These figures show that for many of the simulations the labor input and investment in the stochastic model increase less at the start of the war compared to the perfect foresight model. This is because households do not perfectly anticipate the large increase in government spending that occurs later in the war. In the next section, we explore this further by considering alternative expectations of future government size.

Overall, we find that the stochastic versions of our model are also quantitatively

consistent with World War II macroeconomic activity.

6. Sensitivity Analysis

We now evaluate whether the findings are robust to plausible variations in parameter values and the specification of the stochastic process. In particular, we allow for lower labor elasticities, alternative assumptions about the postwar economy, and the possibility of returning to lower pre-war levels of taxes and spending. The results of this section are summarized in Table 2 and Figure 7.

In Table 2, we report values for U.S. aggregates and their model counterparts for the year 1944. For the model, we report the range of model bounds. Thus, the benchmark simulation corresponds to the results of the stochastic model shown in Figure 6. The parameters for this case are reported in Table 1. For the other simulations reported in Table 2, we use these benchmark parameters unless otherwise noted.

Consider varying the labor supply elasticity. For the benchmark case we use logarithmic preferences with $\xi = 0$ and $\psi = 2.3$. The implied labor elasticity is 2.7 percent, which is typical in the real business cycle literature. In Table 2, we report two cases with lower elasticities, namely 1.5 percent and 0.5 percent. Not surprisingly, as we lower the elasticity, GNP and total hours of work rise by less than in the benchmark case. But, the elasticity has to be very low before civilian hours are roughly constant or falling. An elasticity of 1.5 percent actually implies a better fit of the hours and GNP data – and only a slight degradation of the fit of other variables.

For our benchmark stochastic economy, we used survey results to model individuals' postwar expectations. In Table 2, we report two alternatives of interest. The first assumes

that individuals' expect a postwar depression for sure. The second assumes the opposite: individuals' expect postwar prosperity. With certain postwar depression, individuals increase their hours and investment, with GNP higher as a result. With postwar prosperity, there are fewer incentives to work hard and invest right away. But, quantitatively, the changes in the variables across these examples are small.

It turns out that the initial investment and hours booms that we found for our benchmark economies are not reduced by much when we change our assumptions about the postwar state. What is critical for the initial periods (that is, 1941 and 1942) is the assumption that the future government is in all states of the world much larger than it has ever been in the past.

To explore this further, we consider a different stochastic environment in which there is a fifty-fifty chance in 1941 that we either (*i*) enter the new regime (i.e., one with higher government) defined by the stochastic process of our benchmark economy or (*ii*) return to 1929 (pre-war, pre-depression) levels of spending and tax rates. We show results of simulations of this case in Figure 7 for investment and hours alongside the results of the benchmark stochastic economy (from Figure 6). Notice that we do not have a boom in the initial periods when there is a significant chance of returning to earlier levels of government spending and tax rates. In fact the model and data, in this case, are in very close agreement.

7. Summary and Conclusion

We have found that standard neoclassical theory can successfully account for the World War II economic boom. In particular, we have 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 and/or quantities.

Our main finding has both positive and normative implications. The main positive implication is that the analysis supports the simple neoclassical explanation of World War II, and suggests that the non-standard factors suggested by Mulligan (1998) and Rotemberg and Woodford (1992) may be quantitatively unimportant for understanding wartime economic activity. Given the success of the positive analysis of the theory, the main normative implication is that the standard neoclassical optimal fiscal policy (Barro (1979), Chari, Christiano, and Kehoe (1994)) is a useful tool for evaluating how best to finance wars or other large public finance shocks.

Appendix

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

A1. Sources

- *National Income and Product Accounts of the United States, 1929-82* (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* (1987) is the source for real government investments in equipment and structures in 1982 dollars (Table B12).
- *National Income and Product Accounts, 1929-2000* (2001) and *Fixed Assets and Durable Goods, 1925-1999* (2001) 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* (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* is the source for the population over 16 (series A39) and military wages (series F167).
- Joines (1981) is the source for labor and capital tax rates (Series MTRL1,MTRK1).
- *A Supplement to the Survey of Current Business* (1954) is the source of the GNP implicit price deflator for the 1947 base year (Table 41).

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 $(1+g_z)^t$. 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 four groups of workers: farm; nonfarm; full-time equivalent employees; and manufacturing. The wage rate for a group is defined to be real income in that group divided by manhours in that sector. With the exception of income for full-time equivalent employees, real income is defined to be compensation plus 80 percent of proprietors' income divided by a price deflator. For full-time equivalent employees, real 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 wages, we use the 1947 GNP deflator because the basket of goods has changed dramatically over time.[10] For after-tax wages, we multiply the wage rate by one minus Joines' 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.[11] The capital stock divisor is the sum of net stocks of (*i*) total

[10]The series is very similar if we use the private value added deflator as suggested by Rotemberg (1993) or the CPI as in Mulligan (1998).

[11]Roughly half of net interest payments are imputed intermediate financial services and are not included.

private fixed assets; (*ii*) total government fixed assets; (*iii*) consumer durable goods; (*iv*) inventories.

See McGrattan and Prescott (2000) for details on imputed net interest.

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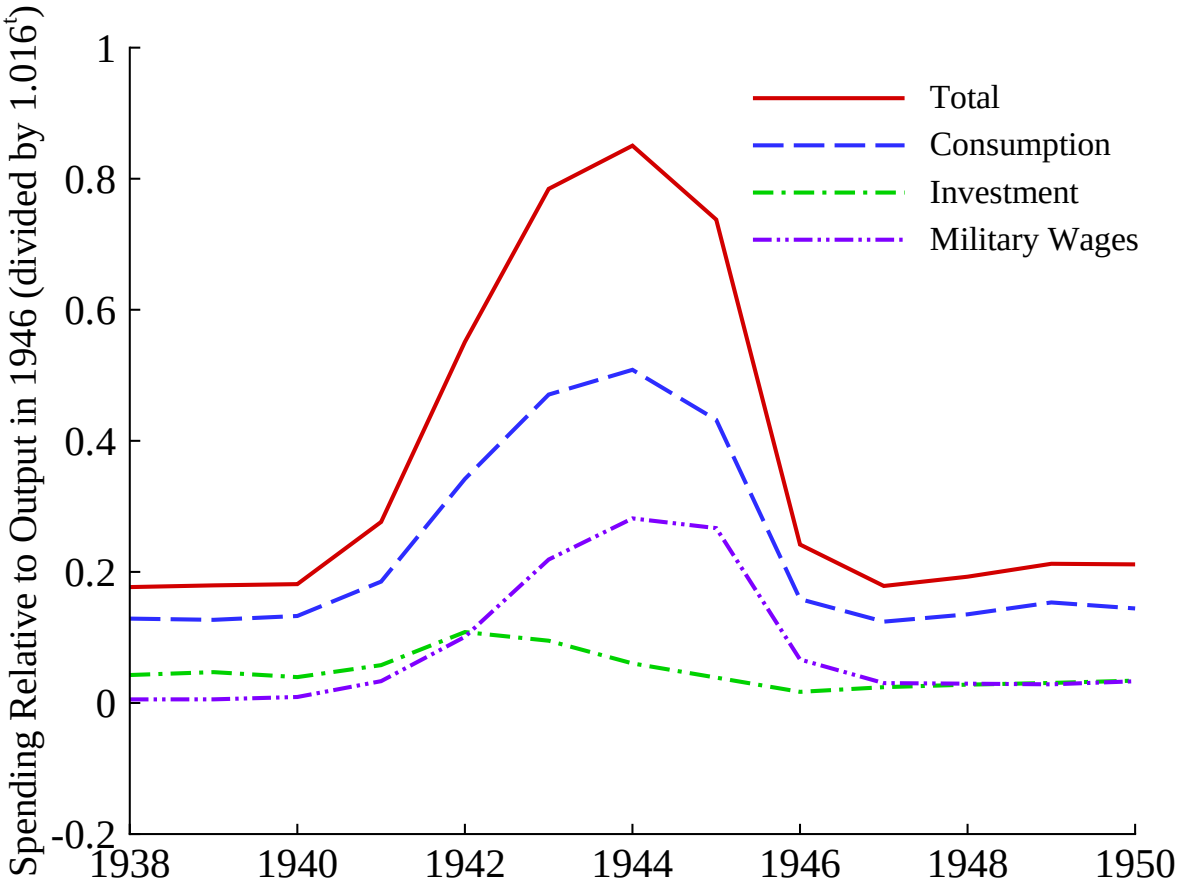


Figure 1. Components of U.S. Government Spending, 1938-50.

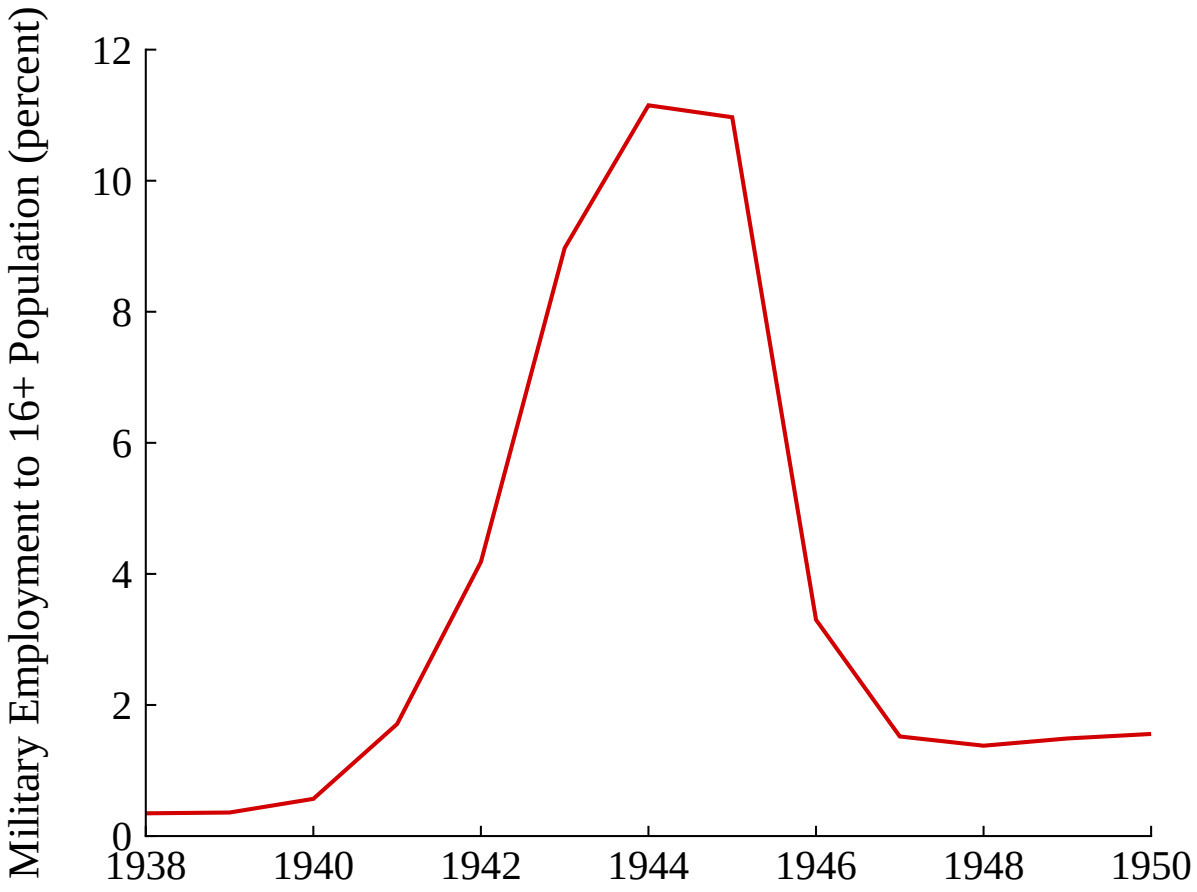


Figure 2. Fraction of U.S. Population over 16 in the Military.

Figure 3. Effective U.S. Tax Rates, 1938-50.

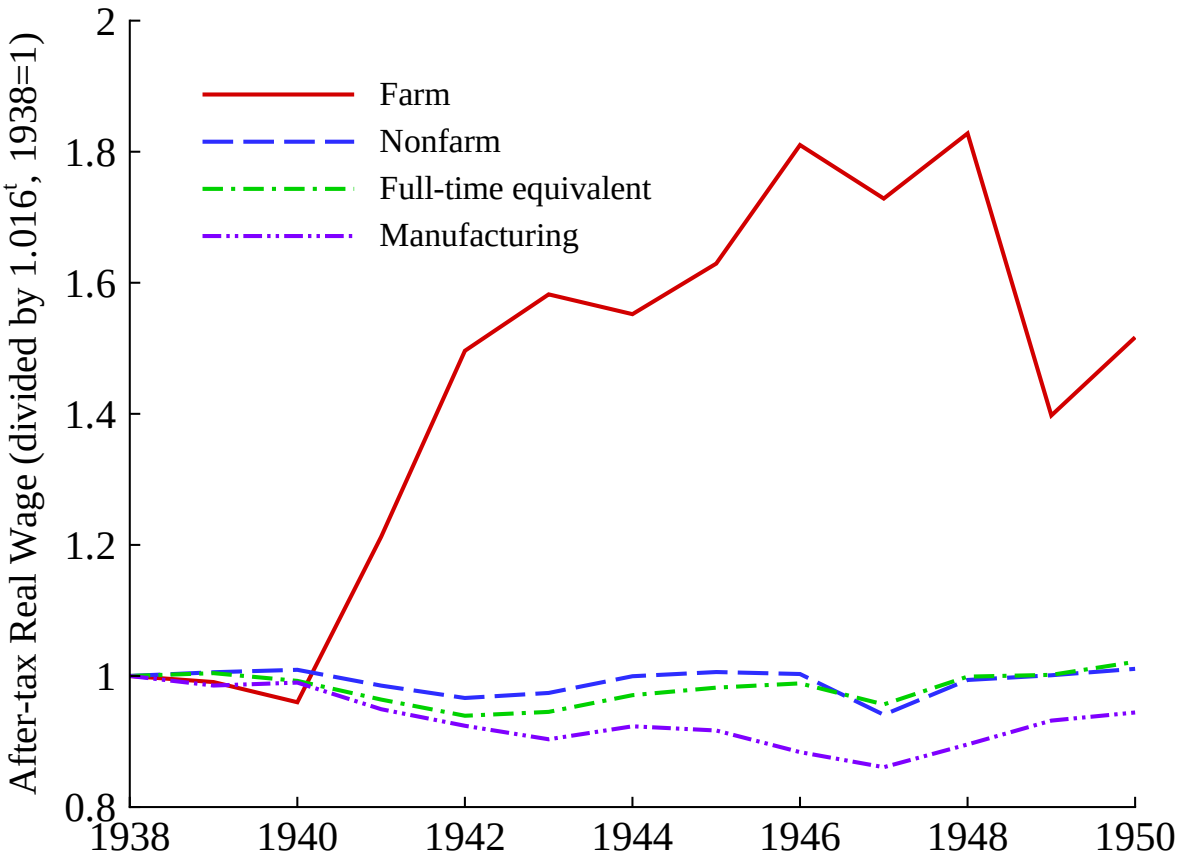


Figure 4. Real U.S. Wage Rates, 1938-50.

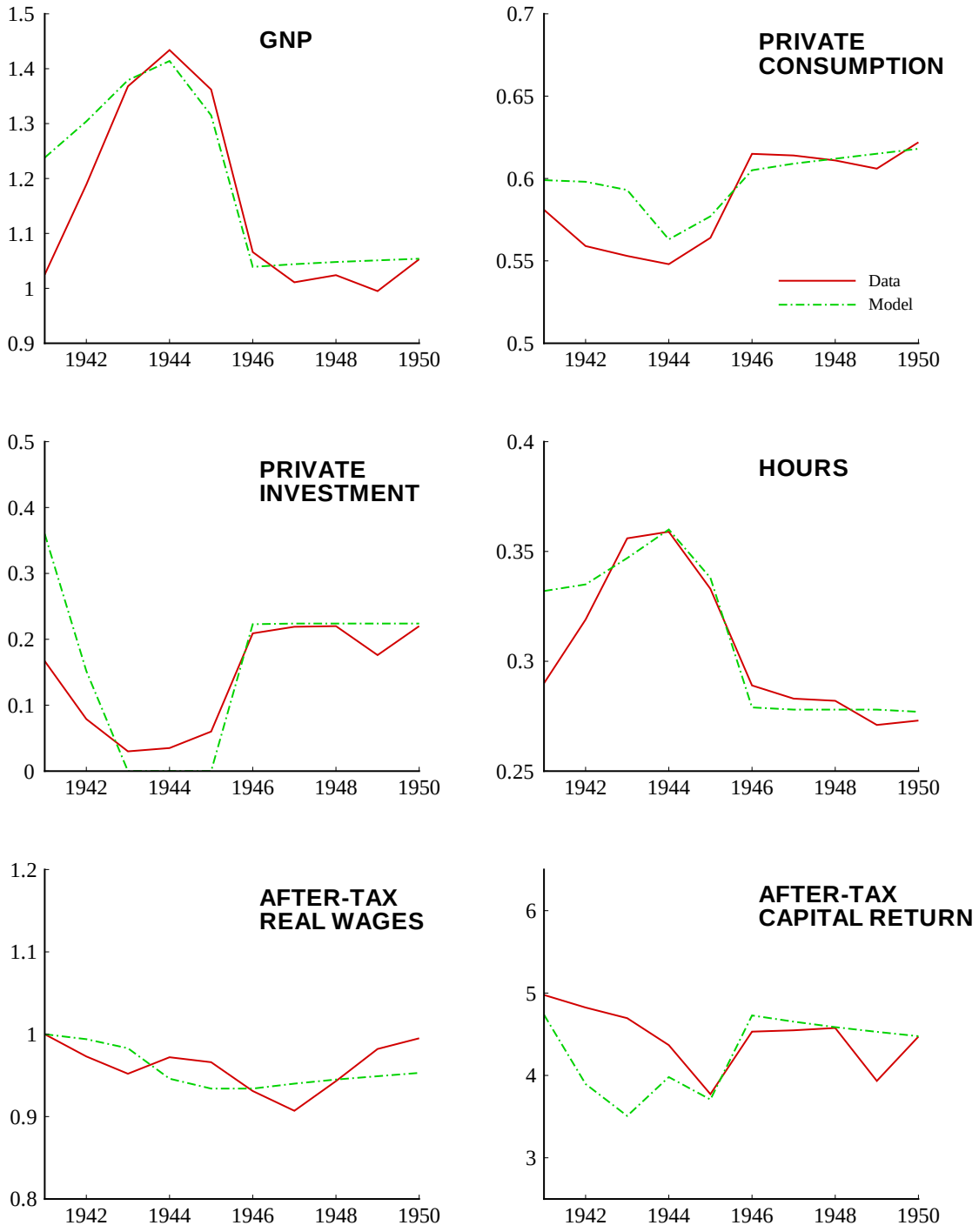


Figure 5. Results for the Deterministic Model Economy

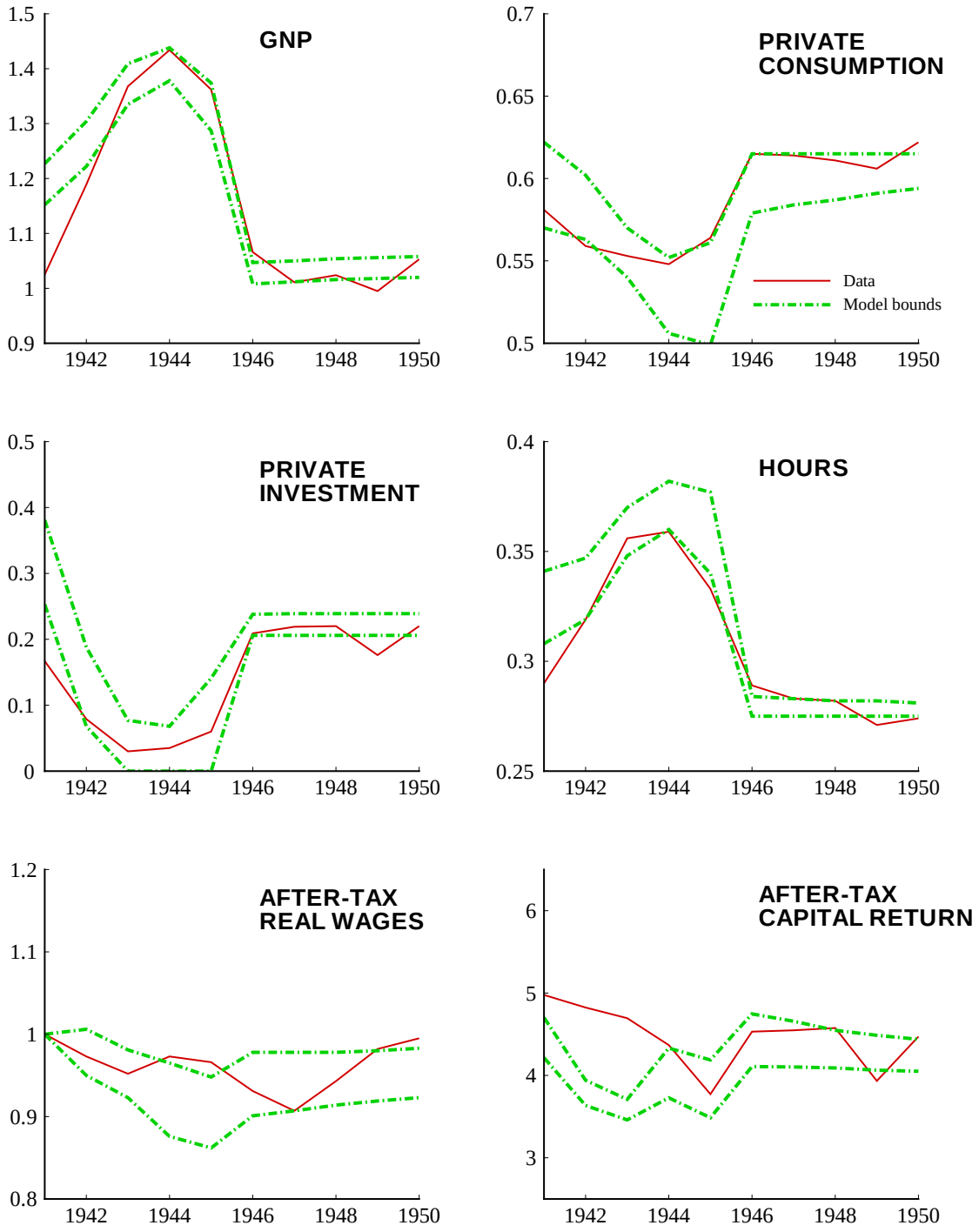
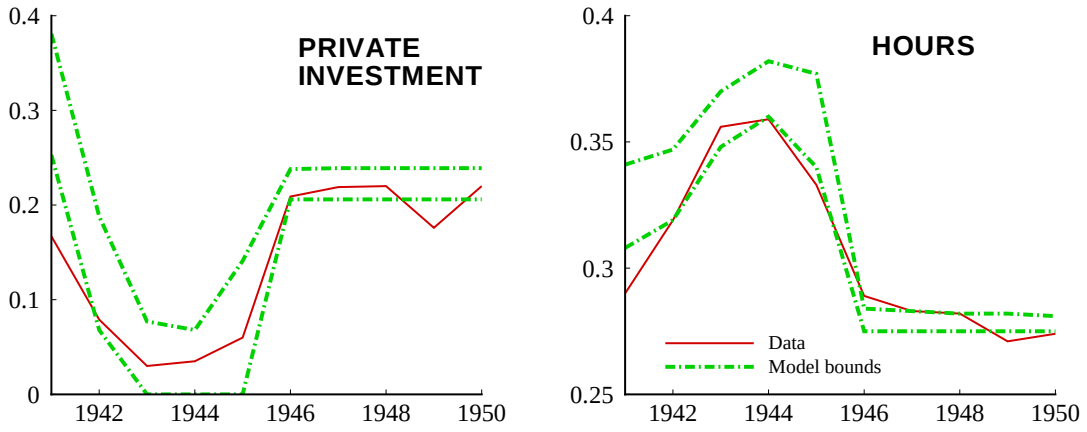
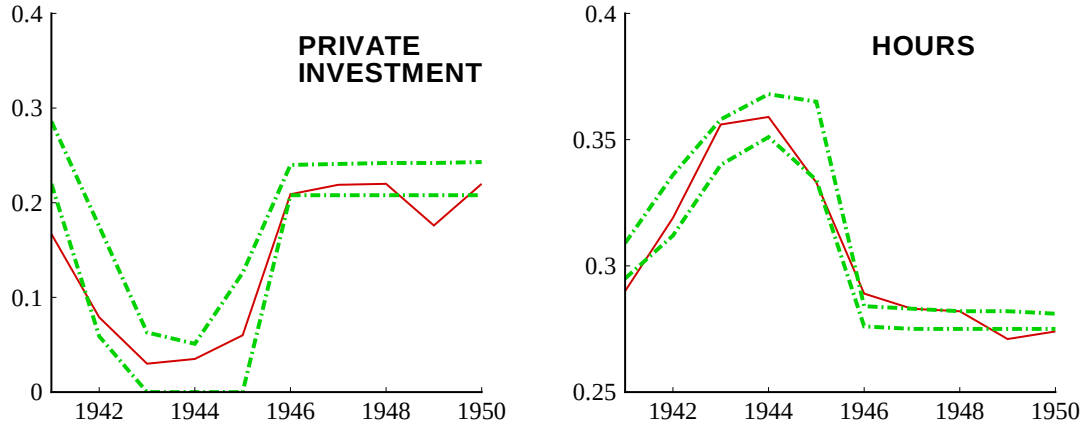


Figure 6. Results for the Stochastic Model Economies



A. Zero probability of small government; higher labor elasticity



B. Nonzero probability of small government; lower labor elasticity

Figure 7. Investment and Hours for Two Stochastic Environments

Table 1

Parameter values for Model Simulations

Preferences	$\psi = 2.3$, $\xi = .0$, $\bar{l} = 50/84$
Deterministic economy	$\beta = .977$
Stochastic economies	$\beta = .971$
Technology	$b = 1/2$, $\rho = 1$, $\theta = .38$, $\delta = .07$
Growth	$g_n = .016$, $g_z = .016$
Hours limit†	$\bar{l}_c = 80\%$ (.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 first year	78%
in second year	43
in third year	47
in fourth year	51
in fifth year	44

† Only relevant for stochastic simulations.

‡ The probability is conditional on the war ending.

Table 2

Sensitivity Analysis

	Range of 1944 Values for:					
	GNP	Consumption	Investment	Hours	Wage Rate	Capital Return
Data	1.43	.55	.04	.36	.97	4.37
Models:						
Benchmark	[1.38,1.44]	[.51,.55]	[.00,.07]	[.36,.38]	[.88,.97]	[3.73,4.33]
Lower labor supply elasticities:						
1.5% ($\xi = -0.8$, $\psi = 1.80$)	[1.35,1.41]	[.49,.54]	[.00,.05]	[.35,.37]	[.88,.96]	[3.66,4.19]
0.5% ($\xi = -4.4$, $\psi = 0.55$)	[1.31,1.35]	[.46,.51]	[.00,.03]	[.33,.34]	[.90,.95]	[3.51,3.94]
Alternate views on depression:						
Certain postwar depression	[1.42,1.47]	[.51,.54]	[.03,.10]	[.37,.39]	[.89,.98]	[3.73,4.18]
No postwar depression	[1.36,1.42]	[.50,.55]	[.00,.05]	[.36,.38]	[.85,.96]	[3.77,4.49]