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*The Macroeconomics of War and Peace**

1. Introduction

This paper examines the effects of government purchases on economic activity. Among economists, there is a basic agreement about the effects of increased government purchases. A transient rise in government spending increases output, drives up interest rates, but crowds out private consumption and investment. There are a variety of theories that are consistent with these facts. Competitive models described by Hall (1980); Barro (1981); or Aiyagari, Christiano, and Eichenbaum (1992) predict these responses as do the imperfectly competitive models considered by Rotemberg and Woodford (1991, 1992). Other predictions of these competing explanations are at odds. Competitive models predict that the real wage should fall because of the negative wealth effect of higher tax liabilities. Imperfectly competitive models predict that real wages ought to rise.

Isolating the effects of government policy on gross national product and the labor market is generally difficult because of problems of simultaneity. But these problems may be resolved if the policy is sufficiently large to dominate other events. The two largest examples of government demand shocks in this century are the two world wars. At the peak of

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World War I, U.S. military expenditures absorbed about 16 percent of GNP and military outlays in Great Britain absorbed close to 40% of GDP. World War II resulted in even higher expenditures with U.S. military outlays absorbing about 40% of GNP, and British military expenditures absorbing about 50% of GDP. Events of this magnitude offer an interesting laboratory for establishing the facts about the effects of government purchases on economic activity and evaluating the plausibility of competing economic theories.

In the first part of this investigation, we document some of the basic facts about the United States and Great Britain. For both wars and both countries, we find that output rises and private investment and consumption are crowded out. We also find evidence of significant increases in government investment in fixed capital in both countries. During World War I, the British government financed expansions to critical manufacturing industries such as steel. In the United States, the government invested significant resources in the construction of a merchant marine. Government investment played an even larger role during World War II. In the United States, if government-owned, privately operated (GOPO) capital is added to the private capital stock, the total stock of capital increases during the war.[1]

Properly accounting for GOPO capital has a large effect on total factor productivity growth during the war. If GOPO capital is ignored, total factor productivity increases at annual rates of 4% per year between 1941 and 1944. Once GOPO capital is included in the capital stock, total factor productivity growth falls to 2.7% per year. After accounting for changes in utilization, we find that total factor productivity grows at 2% per year during the war.

In addition to the components of output, we report the responses of labor input and labor productivity for the two countries. In the United States, labor input increases during both wars. In Great Britain, on the other hand, the evidence suggests that labor input falls. In both countries, we find labor productivity increasing during the wars. The British experience of declining labor input and private investment at a time when output is increasing poses difficulties for both perfectly and imperfectly competitive models. In both frameworks, an increase in government purchases today requires an increase in labor input if output is to increase today. Thus, in terms of their prediction for labor productivity during periods of high military expenditures, both theories fail.

These features of the data may be reconciled with theory if the effects of conscription and government investment are explicitly modeled.

1. Gordon (1969) has estimated that the inclusion of GOPO capital results in a 30% increase in manufacturing capital stock between 1940 and 1945.

Conscription shifts the labor supply schedule left, thereby increasing labor productivity. Government investment shifts the labor demand schedule right in times of high government spending. With a shift in the labor demand schedule, it is possible to explain the fact that productivity rises in the United States during the wars as labor input increases. With conscription and government investment rising together, it is also possible to explain the British observation of increasing output in times when labor input is declining.

In the second part of our investigation, we ask the following question: Can a plausibly parameterized specification of preferences and technology deliver the U.S. and British observations? We consider a specification where government capital is an argument of the production technology. The production technology is assumed to be constant returns to scale in private capital, government capital, and labor input. Based on our finding that total factor productivity growth was about average during the war, we abstract entirely from fluctuations in the state of technology. Instead we focus on the effects of government activity. A Markov process is fit to data on government investment, military expenditures, and military employment. This process is used to simulate wars. We compute optimal decision functions for agents in the model and study their response to shocks of the magnitude of World War II.

We find that our simple framework does surprisingly well. The model captures a significant fraction of the movement of hours of work, productivity, and the components of GNP. We also find a positive correlation between productivity and government expenditures even when public and private capital are perfect substitutes in production. The rise in productivity comes one period after the increase in expenditures because the capital stock takes one period to adjust. Finally, we show that observations in Great Britain can be explained by including conscription in the model.

The remainder of the paper is organized as follows. Section 2 of the paper documents the U.S. and British wartime experiences. We focus on GNP and its components, the labor market, prices, and financial markets. In Section 3, we describe a simple model that takes into account government-owned privately operated capital. We relate the predictions of the model to the U.S. and British data. We conclude in Section 4.

2. *The Data*

In this section, we describe the effects of World Wars I and II on economic activity in Great Britain and the United States. We discuss the response of GNP and its components, the labor market, prices, and financial markets in the two countries. At the end of each section, we summarize the main findings.

2.1 GREAT BRITAIN'S ECONOMY DURING WORLD WAR I

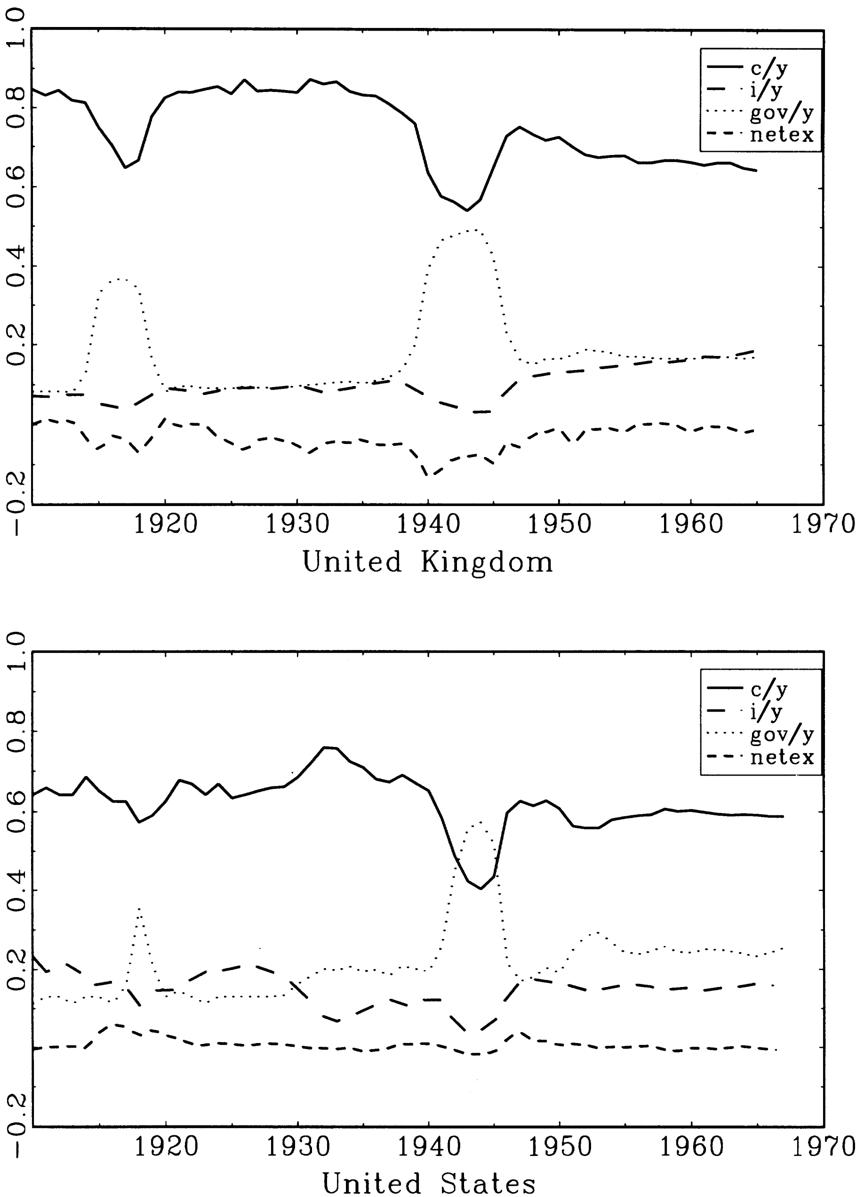
Great Britain on the eve of World War I had just passed through a period of prosperity. Unemployment, which was about 2%, was low by historical standards. With the Balkan war having been settled in the previous year, financial markets were calm and showed no evidence that war was anticipated. For instance, the assassination of Archduke Ferdinand in June 1914 was interpreted in early July as having had no effect on financial markets (Noyes, 1926, p. 54). Less than three weeks later, international markets were in a state of total collapse. On July 28, Austria declared war on Serbia. Three days later, Germany sent its ultimatum to France and Russia. On the same day, the London Stock Exchange closed for the first time ever in its history. The U.S. stock market suspended operations the same day.

The scale of the British war effort produced unprecedented demands on industry and the workforce, which led to rapid price increases. Between 1914 and 1918, commodity prices rose by over 100%. Early examples of profiteering led to the use of price controls, which by the end of the war covered "nearly everything that men could eat or drink without being poisoned" (Hancock and Gowing, 1949, p. 21). Price controls produced shortages that led the British to organize an administrative framework for systematically rationing food items. Although rationing was not imposed until the later stages of the war, lessons were learned that significantly facilitated the use of rationing in World War II.

During World War I, the British government made its first effort to control production systematically. Shortages of strategic materials led the government to restrict their export and requisition domestic stocks. The government imposed price controls on many intermediate goods and often directly controlled the allocation of these goods. The government also helped finance expansions to war-related industries.

2.1.1 British GDP and its Components in World War I In the upper panel of Figure 1, we plot the expenditure shares of the components of British GDP. The data that runs from 1910 to 1965 is taken from Mitchell (1988). From these diagrams, we see that the share of government purchases rose from less than 10% of GDP to a maximum of about 36% of GDP during World War I. This rapid transient rise in the size and scope of government activities is rivaled only by the events of World War II. The increase in government demand was accompanied by both an increase

Figure 1 EXPENDITURE COMPONENTS OF OUTPUT IN THE UNITED KINGDOM AND THE UNITED STATES.



in output and declines in private consumption and investment. Real GDP rose by 17% between 1913 and 1917, reaching levels that it did not exceed again for 20 years. The share of investment in output declined one half over the same period, and consumption's share in GDP fell by 20%. There were also large changes in the composition of consumption during the war. For instance, consumption of food items fell by only 3% between 1916 and 1917, while consumption of household durables declined by 20% (Mitchell, 1988). Finally, the war had significant effects on net exports. Between 1913 and 1917, net exports fell sharply as Britain increased imports of foodstuffs and other materials required for the war.

The demands of the war produced major changes in the composition of government purchases. Large fractions of the government's expenditure were used to purchase weaponry and to compensate and sustain military personnel. Evidence from the History of the Ministry of Munitions indicates that the government also played an important role in expanding productive capacity during the war. The British steel industry illustrates this point. At the outset of the war, the British government encouraged the steel industry to privately finance expansions in capacity. These appeals were successful early in 1915 but soon thereafter met with resistance. Producers pointed to uncertainties in the market for steel after the war and argued that the excess profits tax would make it impossible for them to achieve a reasonable return on their investment. After a series of negotiations in March 1916, the government settled on a formula for assistance that called for the producers to pay a minimum of 25% of the total cost of expansions to capacity (*History of the Munitions Ministry*, vol. 7, p. 58). By the end of the war, the government had provided financial assistance to 365 projects to expand steel production. The government's assistance of 23.4 million pounds amounted to 52% of the total cost of these projects.

The government also played a significant role in financing the development of a domestic optical glass industry, the domestic production of tungsten, and the expansion of copper production.

2.1.2 The British Labor Market in World War I The British war effort required a large increase in work effort at the same time that significant fractions of the work force were being drawn into the military. Panel A of Table 1 summarizes the effects of these competing demands on the labor market. Notice first that the size of the military increased from 400,000 in 1913 to over 4.4 million in 1918. This buildup in the size of the military is even more remarkable given that the unemployment rate of 2.1% was at a historically low level (Mitchell, 1980). During the war, unemployment dropped to a low of 0.4% in 1916. The figures in Table

1 show steady declines in civilian employment throughout the duration of the war. By 1918 civilian employment had fallen by over 2 million from its peacetime level of 19 million in 1913. This decline in civilian employment was accompanied by large changes in the composition of employment. Data in Mitchell (1988) on union membership show total membership rising by more than 50% between 1913 and 1918. Female membership rose by 179%. After the war both civilian employment and the unemployment rate rose as the size of the military was reduced. Female participation in the work force as measured by union memberships remained high through 1920 and then declined, leveling off at about twice its prewar level.

Data on hours worked is sketchy. Maddison (1989) reports that average hours per year in Britain in 1913 were 2,624, while Mitchell (1988) reports average annual hours were 2,753 in the same year. These figures suggest that average hours per week were somewhere between 53 and 56 on the eve of World War I. Bowley (1921) reports that weekly hours were reduced in 1919 by an average of 6.5 hours. If one uses prewar hours, this reduction implies postwar work weeks between 46 and 48 hours. While direct measurements of hours worked are not available during the war, days lost to labor disputes fell sharply, and anecdotal evidence points to an increased use of part-time employees, significant flows of labor from the agricultural sector to manufacturing, and extensive use of overtime. However, it appears unlikely that these factors could have produced a rise in total civilian hours during the war. If we assume that weekly hours were 53 and multiply this estimate by the 1913 civilian employment figure in Table 1, then total weekly civilian hours in 1913 are about 1 billion. In order for weekly civilian hours to maintain this level in 1918, per capita weekly hours would have had to increase by 9 hours.[2] An increase of this magnitude seems implausible. By way of comparison, in World War II, weekly hours increased by only about 3 hours per week. Moreover, in World War II, workers started from a lower base of 46.5 hours per week.

The difficulties in measuring labor input during World War I clearly affect our ability to measure labor's productivity. Feinstein (1972) reports output per worker using total employment (civilian and military), and his compromise factor cost measure of real GDP. This measure of labor productivity, which is reported in Table 1, rises by a total of 7% between 1913 and 1918.

Real wages during World War I decline between 1915 and 1917 and then recover in 1918, with net gains in real wages in 1919 and 1920. Bowley (1921, pp. 105–106) reports indices for a number of occupations

2. This calculation holds fixed the number of weeks worked per year.

Table 1 EMPLOYMENT, PRODUCTIVITY AND WAGES IN GREAT BRITAIN DURING WORLD WAR I AND WORLD WAR II

A. World War I

Year	*Civilian employment*[a] *(thousands)*	*Armed forces*[b] *(thousands)*	*Unemployment*[c] *(%)*	*Output per worker*[d] *(1913 = 100)*	*Real wages*[e] *(1913 = 100)*
1913	19,910	400	2.1	100	100
1914	19,440	810	3.3	101	100
1915	18,400	2,490	1.1	106	89
1916	17,700	3,500	.4	107	83
1917	17,100	4,250	.6	107	80
1918	17,060	4,430	.8	107	90
1919	19,030	2,130	3.4	97	102
1920	20,810	760	2.0	92	105

B. World War II

Year	*Civilian employment*[a] *(thousands)*	*Armed forces*[b] *(thousands)*	*Average weekly hours*[f]	*Output per worker*[d] *(1938 = 100)*	*Real wages*[e] *(1938 = 100)*
1938	20,986	432	46.5	100	100
1939	21,800	480	—	97	98
1940	20,800	2,270	—	103	96
1941	20,600	3,380	—	108	95
1942	20,700	4,090	—	108	95
1943	20,200	4,780	50.0	109	97
1944	19,700	4,990	48.6	106	99
1945	19,100	5,130	47.4	103	102

[a] Total civilian employment from Feinstein (1972, p. T126).
[b] Armed forces from Feinstein (1972, p. T126).
[c] Percentage unemployed from Feinstein (1972, p. T126).
[d] The ratio of real GDP from Feinstein (1972) to civilian employment plus armed forces expressed as an index.
[e] Index of weekly wage rates from Feinstein (1972, p. T140) divided by the Ministry of Labour Gazette index of retail prices, also from Feinstein (1972, p. T140).
[f] Average weekly hours, Hancock (1951, p. 204).

ranging from bricklayers to engineering artisans. If we use his cost of living index, increases in wage rates in 1918 offset the declines in the earlier years. Table 1 reports an index of real wages from Feinstein (1972). In constructing this index, nominal wage rates were deflated by the Labour Gazette cost of living index. Bowley (1921, pp. 63–75) documents several factors that lead this index to overstate increases in the cost of living during World War I. But the basic pattern of declines in 1915–1917 with subsequent rises from 1918 to 1920 is similar for both measures of real wages.

2.1.3 Prices in Britain During World War I Prices increased at unprecedented rates during World War I. The Labour Gazette index rose by 110% between 1914 and 1918. The Bowley index rose by 85% over the same interval. Mitchell (1919) reports even faster growth in commodity prices. Between 1914 and 1918, Mitchell's index of 150 commodity prices increased by 140%.

Incidents of hoarding and profiteering led the government to take direct control of key industries and impose price controls on many intermediate and final goods. These controls often took the form of cost plus formulas, which meant that production costs had to be calculated and reasonable markup margins determined. Excess profits taxes were also adopted that limited the gains from profiteering, but also dampened investment incentives.

Food supplies in Great Britain were not seriously affected until 1917. Price controls were first implemented on food items in the summer of 1917. However, it was not until food shortages arose in late 1917 and early 1918 that rationing was extended to items other than sugar. Initially, consumers were required to register with a particular retailer who then became the consumer's sole supplier of rationed items. Ration coupons were added to this registration requirement between February and July. These programs were largely successful in eliminating the queuing that had occurred in late 1917 for items like butter and meat.

Shortages of skilled labor produced bidding contests among employers at the start of the war. To control the upward pressure on wages, the Munitions Control Act of 1915 included a Code of Labour Regulation that prohibited workers from accepting new employment without written permission from their current employer. However, the Code of Labour Regulation provoked widespread resentment among workers and was abandoned in August of 1917.

2.1.4 Financial Markets in Britain During World War I The rapid inflation during World War I had a significant effect on real interest rates. Homer and Sylla (1991) report that nominal yields on consols rose steadily during the war from 3.46% in 1914 to 4.62% in 1919. Similarly, government issues rose from 3.96% in 1914 to about 6% in 1920. However, these increases in nominal yields were small relative to the price increases documented earlier. After accounting for the effects of inflation, ex post returns are negative for the duration of the war.

2.2 THE UNITED STATES ECONOMY DURING WORLD WAR I

The outbreak of war in Europe caused financial panic in the United States. The U.S. stock market suspended operations on July 31, 1914, to avoid facing an onslaught of panic sell orders from Europe. Expectations that trade flows would be disrupted produced steep declines in commodity prices for cotton and wheat. The prices of many other traded goods like copper, steel, meat, and oil fell as well. In contrast to the Europeans who placed embargoes on exports of gold at the outbreak of war, the United States continued to honor its gold obligations. The initial panic in the United States subsided rapidly as it became clear that the war would increase demand for many U.S. goods. After the United States entered the war in April 1917, further disruptions occurred as the country mobilized for war. The Armistice was signed on November 11, 1918, nineteen months after the United States' entry into the conflict.

2.2.1 U.S. GNP and its Components During World War I The U.S. experience in World War I was similar to the British experience in many respects. The lower plot in Figure 1 displays the shares of the expenditure components of GNP. As in Britain, World War I produced major changes in the composition of output. While the magnitude of the U.S. war effort was much smaller than in Britain, the pattern of responses of consumption and investment were quite similar. Increased government spending acted to crowd out private consumption and investment. Net exports, which were negative in 1913, rose rapidly after the outbreak of hostilities and peaked at 6% of GNP in 1916.

In the course of the war, the U.S. government devoted a small, but significant, fraction of its expenditures to activities that expanded the country's productive capacity. The disruption of trade flows in Europe and the neutrality of the United States created a demand for U.S. goods that quickly absorbed the resources of the entire U.S. merchant shipping fleet. To help meet the shortage of merchant shipping, the United States Shipping Board was established. The goal of this government enterprise was to provide a supply of merchant vessels that could support naval forces in the case of war and facilitate foreign commerce with other neutral countries. By the end of the war, the government had signed contracts to build 3,116 freighters with a deadweight tonnage of 16,914,047 tons. This was equal to one third of the world merchant tonnage in 1913 (Crowell, 1920). As of December 31, 1918, $2,769,337,500 had been authorized for ship construction under this program. This amount was twice the navy's ship building budget and about 4% of GNP in 1918. The U.S. government made further investments in munitions and industrial plants of about $600 million, and sold $2.2 billion of trucks and buses (original cost) after the war (Cook, 1948).

2.2.2 The U.S. Labor Market During World War I Panel A of Table 2 contains information on aggregate labor market statistics for the United States during World War I. Consider the patterns in civilian employment. Kendrick's measure of persons engaged increases from 1914 through 1917 and then declines in 1918, the year that conscription reached its peak. This pattern is different from Britain, where civilian employment dropped steadily throughout the entire war. One reason for this difference is the smaller migration of manpower into the armed services. At their peak the U.S. armed forces were only 65% of the size of the British forces. Table 2 also contains Kendrick's measure of man-hours divided by the population over 16. This measure shows an increase in labor input during World War I. Kendrick's measure of labor productivity is listed in column five. Labor productivity declines in 1917 and then recovers in 1918. Once trend growth is taken into account, these data show no strong pattern in labor productivity during World War I. Finally, note that real wages are basically constant until 1917, and then increase in 1918–1920.

2.2.3 Prices in the U.S. During World War I The evolution of prices in the United States during the war is similar to patterns already documented in Britain. Between 1913 and 1918, the CPI increased by 57% and by 1920 prices had risen by 133%. These increases are on a comparable scale with the British experience, although U.S. prices started rising somewhat later than in Britain. Commodity prices in the United States also closely mimic the evolution of British prices for comparable items. Commodity prices rose by 110% between 1913 and 1918. In both countries the sharpest increases in commodity prices occurred in 1916 and 1917 and then stabilized in 1918 as government price controls were extended.

Price controls were put into effect shortly after the United States entered the war in response to rapidly escalating prices. For instance, steel plates doubled in price during the first five months of war and food prices rose by 28% over the same period (see Mitchell, 1919). Price controls on food were effected by licensing requirements. Licenses were required for merchants who imported, manufactured, stored, or distributed specific items. Farmers, gardeners, and small businesses were exempted. Penalties were set for hoarding goods, destroying goods with the intent to drive up prices, or making excessive profits. Violators were subject to fines ranging from $5 to $10,000, the revocation of their licenses, and jail sentences for serious violations (Mitchell, 1919). In practice prices were not directly fixed: Rather markups were limited by "reasonable margin-of-profit" rules. Reasonable profit margins were initially based on prewar profit margins, but, as the war advanced, this was replaced by a two-tier system with distinct margins for high-cost and low-cost dealers. While price controls led to shortages of some items (e.g., sugar), a formal system of rationing was not used for consumer items in World War I. Instead the government relied on appeals to dealers to limit sales to each customer of items in short supply (Rockoff, 1984).

Wage controls were not applied in the United States during World War I. Instead the government took an active role in matching workers with employers and mediating labor disputes. In a few rare instances, the government seized key industries where labor problems were particularly acute. The most notable example was Smith and Wesson. Labor disputes also played a role in the government's decision to take over the railroads.

Taken together these measures were largely successful in bringing inflation under control by the beginning of 1918 (Rockoff, 1984, p. 69).

2.2.4 U.S. Financial Markets During World War I One result of war in Europe was that New York assumed London's position as the leading center of international finance. European powers floated large loans in the United States during the war, and by the war's end nearly half of the world's gold reserves were located in the United States. In the period from 1915 to 1917, (nominal) yields on bonds tended to decline (Homer and Sylla, 1991). However, the U.S. entry into war produced a decline in the bond market. Yields on prime corporate debt rose from 3.98 to 4.98% between January and October 1917. Commercial paper rates rose from 3.84% in 1916 to 5.07% in 1917. Yields on Liberty government bonds, which were tax exempt, rose quickly after their issue at 3.5% to 3.61%. These yields appear to be low given the rapid escalation of prices during this period. Ex post real rates on commercial paper were negative between 1915 and 1917 and in 1919.

Table 2 EMPLOYMENT, HOURS, PRODUCTIVITY, AND WAGES IN THE U.S. DURING WORLD WAR I AND WORLD WAR II

A. World War I

Year	*Persons engaged*[a] *(thousands)*	*Armed forces*[b] *(thousands)*	*Man-hours per capita*[c] *(1913 = 100)*	*Labor productivity*[d] *(1913 = 100)*	*Real wages in manufacturing*[e] *(1913 = 100)*
1913	36,285	155	100	100	100
1914	35,787	166	96	93	100
1915	35,916	174	94	97	99
1916	38,332	179	99	104	102
1917	39,004	644	100	99	99
1918	38,938	2,897	98	107	103
1919	38,990	1,173	94	114	107
1920	39,183	343	95	113	115

B. World War II

Year	Persons engaged[a] (thousands)	Armed forces[b] (thousands)	Man-hours per capita[c] (1941 = 100)	Labor productivity[d] (1941 = 100)	Real wages in manufacturing[e] (1941 = 100)
1938	40,718	323	88	89	88
1939	42,139	334	91	92	89
1940	43,874	458	93	95	90
1941	47,349	1,801	100	100	100
1942	49,885	3,859	107	100	112
1943	50,656	9,045	109	102	124
1944	49,513	11,452	106	108	128
1945	47,994	12,123	99	114	128

[a] Kendrick's measure of persons engaged as reported in *Long Term Economic Growth* (1973, p. 194).
[b] Armed forces from *Historical Statistics of the U.S.*, U.S. Department of Commerce (1975, p. 1141).
[c] Kendrick's total private man-hours as reported in *Long Term Economic Growth* (1973) divided by population over 16.
[d] Kendrick's index of output per man-hour as reported in *Long Term Economic Growth* (1973).
[e] Real wages in manufacturing defined as the ratio of average hourly earnings in manufacturing from *Historical Statistics of the U.S.* (1975, p. 168) divided by the CPI all items same source, p. 211.

2.3 A COMPARISON OF U.S. AND BRITISH EXPERIENCES IN WORLD WAR I

Our analysis of the British and U.S. economies shows three common features during World War I. First, the response of the major components of output was the same in both countries. The increased government demand for goods raised output and crowded out private consumption and investment in both countries. Second, significant fractions of government purchases were used to expand productive capacity during the war. For example, in Great Britain, the government helped finance expansions to the steel industry. In the United States, the government took a lead role in expanding the merchant marine. Third, labor productivity increased in both countries. In Great Britain, output per worker rose, and the available evidence points to increases in output per man-hour as well. In the United States, labor productivity fell in 1917 and then recovered in 1918.

The most striking difference between the United States and Great Britain was in the response of employment. In Great Britain, civilian employment fell steadily throughout the war. In the United States, civilian employment was steady in 1917 and 1918. This difference is most likely due to the fact that Great Britain lost a much larger fraction of its labor force to the armed forces.

2.4 GREAT BRITAIN'S ECONOMY DURING WORLD WAR II

The British government's actions in World War II were heavily influenced by its experience in World War I. For instance, rationing was widely viewed as having been successful in ending the queues that formed in the winter of 1917–1918. Thus, when war broke out again, rationing of food items was quickly reinstated. Wage controls, on the other hand, were considered to have been a failure and, thus, were not used in World War II. The experience of the First World War also influenced firms' actions. The severe recession that followed World War I penalized many of the firms that had responded to the government's pleas by expanding capacity with their internal funds. As a result, the British government was compelled to finance a substantially larger fraction of the expansions to productive capacity in World War II.

2.4.1 British GDP and its Components During World War II The scale of the "Great War" was dwarfed within 25 years by World War II. Figure 1 shows that at its peak, government purchases accounted for nearly half of Britain's GDP. This massive increase in government demand reduced private investment to levels not experienced since World War

I. Consumption fell to levels not seen in ten years. As in World War I, the decline in durable consumption was large. Real expenditures on household durable goods fell by 74% between 1939 and 1944, while real food expenditures fell by 13% (Hancock, 1951, p. 203). Net imports also surpassed levels in the first war, reaching a maximum of 13% of GDP in 1940, the year before the Lend-Lease Program began.

One of the more important distinctions between World War II and World War I is the increased importance of government assistance in financing investment. In the Second World War, firms were again willing to fund expansion of their facilities. With excess profits taxes of 100% and government regulation of prices, private operators argued that the return from investing in plant expansion was likely to be small or even negative. The steep recession that followed the First World War provided additional fuel for their arguments.

The government's investment in fixed capital fell into three categories: direct assistance to firms, investment in government agency projects that were government-owned but privately operated, and investment in government-owned, government-operated facilities. In cases where the government's needs could be met by expanding current facilities, it offered assistance in financing the project. This assistance had two forms: contributory schemes and 100% government financing. For contributory schemes, the government would offer to pay up to 60% of the cost of the project. Title of the project was given to the firm, and the firm paid rent on the government's share of the investment ranging from 4% to 6% per annum for the course of the war. Under the second form of assistance, the government contributed 100% of the costs and retained title to the project. In addition, the government limited the firm's return on the government-owned capital to an average of 2% although rates of return varied widely (Ashworth, 1953, ch. 12). Government investment in government agencies typically involved the construction of new plants. Private operators were then contracted to manage the operation of these facilities. The smallest of the three categories, government-owned, government-operated facilities, typically consisted of armaments factories, many of which had been built during World War I.

Total government investment in fixed capital amounted to 1.2 billion pounds between 1937 and 1945. Of this total, 50% fell in the category of government assistance to private firms, 25% went to agencies, and the remaining 25% was for government operations. Government expenditures on fixed capital were over 3% of GDP in 1940 and 1941 and then declined to about 1% of GDP after the United States entered the war (Ashworth, 1953, pp. 252–253).

2.4.2 The British Labor Market During World War II The British labor market in World War II bears many resemblances to the labor market in World War I. Panel B of Table 1 reports basic labor market statistics for the period 1938 through 1945. As in World War I, civilian employment fell steadily throughout the entire war period. Unemployment rates fell to the same levels observed in World War I. The availability of data on hours during World War II is only slightly better than for World War I. Hancock (1951) reports that average weekly hours increased from 46.5 in the last quarter of 1938 to a maximum of 50 in 1943. Given the measured decline in employment between 1939 and 1945, it appears unlikely that man-hours increased significantly during the war.

Finally, note that real wages and output per worker moved in opposite directions during the war. Feinstein's (1972) measure of output per worker shows an initial dip in 1939, followed by increases through 1943. Real wages, on the other hand, declined from 1939 until 1942 and did not exceed their prewar level until 1945.

2.4.3 Prices in Great Britain During World War II Price increases during World War II were more moderate than in World War I. The Labour Gazette's cost-of-living index increased by 43% between 1939 and 1945, which was less than half of the increase observed in World War I. The smaller growth in prices during World War II reflects the success of government price control and rationing programs. Responsibility for price controls on consumer goods was divided between two agencies: the Ministry of Food and the Board of Trade. The Ministry of Food was given exclusive control over food imports and used this authority, e.g., to purchase virtually the entire sugar crop produced in the British Empire in 1939. The Ministry of Food also was responsible for setting maximum prices for food products at the wholesale and retail levels and for rationing staples such as sugar and meat. Rationing was imposed on butter, bacon, sugar, and meat shortly after war was declared. As the war progressed, piecemeal rationing of particular items was replaced by a point system. The Ministry of Food also subsized items ranging from milk to meat and flour. Controls for nonfood consumer goods were the responsibility of the Board of Trade. Price increases were controlled by limiting markups to prewar levels plus an additional percentage to cover their increased costs. Wages were one of the few items not controlled. On the basis of its experience with labor market controls in World War I, the government decided to let wage differentials draw laborers into sectors where their services were needed most.

2.4.4 Financial Markets in Great Britain During World War II The outbreak of World War II was widely anticipated and, thus, did not produce the panic selling that occurred in World War I. Stock market prices in Great Britain started falling in 1937, reaching a low point in June 1940 during the Dunkirk evacuation. After the evacuation, prices started a recovery that lasted until the end of the war. New security issues fell dramatically during the war because of controls imposed by the government. The yield on consols rose from 2.65% in 1935 to a high of 4.1% in 1939 and then fell steadily through the second war, falling to a low of 2.51% in 1946. The average yield of bonds of maturity 30 years or longer fell from a high of 3.62% in 1939 to a low of 2.53% in 1946. The bank rate was fixed at 2% during the war, and government bonds were issued at 3% (Homer and Sylla, 1991).

2.5 THE UNITED STATES ECONOMY DURING WORLD WAR II

The United States declared war on Japan and Germany on December 7, 1941. Preparations for war, however, had begun 18 months earlier. During the Second World War, the government adopted many of the same strategies used by Britain. Price controls were widespread, and government mandates curtailed production of many consumer durables. Rationing of food items was introduced in 1943. The marshaling of resources achieved by the United States during the Second World War is unprecedented. It took ten years for real GNP to exceed its wartime peak.

2.5.1 U.S. GNP and its Components During World War II As in World War I, the outbreak of hostilities in Europe brought an initial period of prosperity to the United States. Real GNP grew at about 7% per year in 1939 and 1940 before it started accelerating in 1941. Between 1941 and 1944, real GNP increased by 52%. The responses of aggregate expenditures shown on the lower plot of Figure 1 are familiar: a massive increase in government purchases that is associated with large increases in GNP, and significant crowding out of private investment.

An interesting property of this data is the positive growth in consumption between 1943 and 1945. Real consumption expenditures fell between 1941 and 1942 and then increased during the remainder of the war. There were also large changes in the composition of consumption during the war. In 1942 production of automobiles for nonmilitary purposes was halted, and production of many other consumption durables was curtailed. These actions produced a large decline in the share of durables in total consumption.

Government purchases also exhibited significant compositional shifts during World War II. Before the war, government purchases of goods and services were dominated by services, which accounted for 65% of federal purchases in 1938. In 1938 durable goods constituted 5% of federal purchases and structures added another 10%. The share of nondurables was 9%. By 1942 the composition of purchases had shifted sharply toward durables and structures. Durable goods had risen by a factor of 8 and accounted for 24% of total purchases, while structures had risen by a factor of 12 and made up 17% of total purchases. Spending on durables and structures started rising in 1940 as the country began preparing for the possibility of war. Nondurables and services rose later as the costs of raising and maintaining the armed forces mounted. Approximately 80% of the increase in the services component between 1938 and 1943 was due to increases in total wages and salaries paid to military employees.[3]

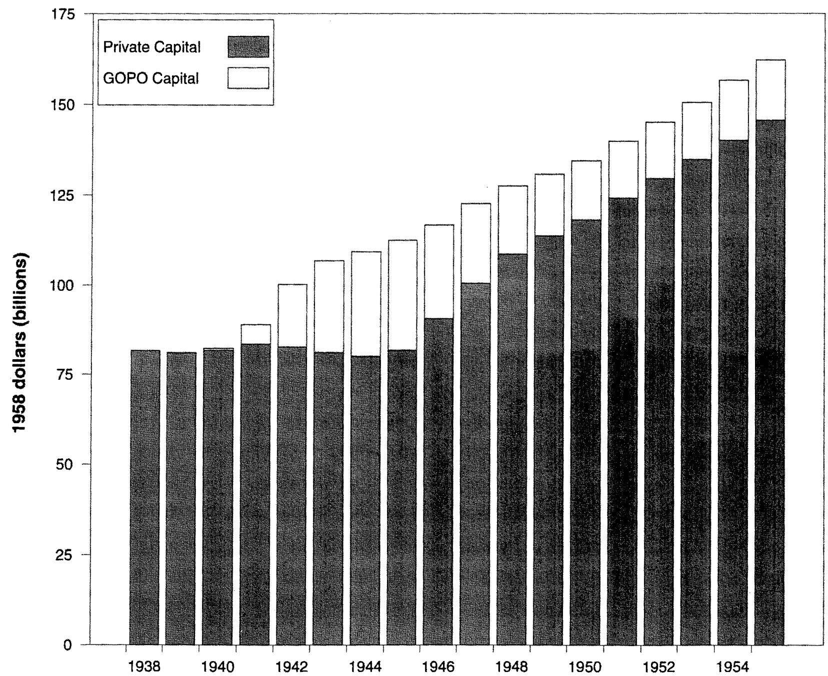
One problem with the National Income and Product Accounts data on government purchases is that it fails to show the uses of the investment components. During World War II, the investment component was large. The federal government financed large increases in industrial construction and producer's equipment that increased the productive capacity of the automotive, aircraft, and aluminum industries. In addition, large fractions of the government's investment in fixed capital was used by private industry after the war. Gordon (1969) estimates that $12 billion (valued at historical cost) worth of structures and equipment financed by the government during the war was used by postwar private operators (see also Jaszi, 1970, and Gordon, 1970). For purposes of comparison, total private investment over the same period was $11.4 billion.

Figure 2 shows the private gross manufacturing stock of equipment and structures, and the gross stock of GOPO equipment and structures from 1939 to 1954 expressed in 1958 dollars. The data is from Wasson, Musgrave, and Harkins (1970). Note that the inclusion of GOPO capital provides an entirely different picture of the war. If GOPO capital is left out, the capital stock falls during the war. If government capital is included, then the war is a period in which significant additions were made to the country's productive capacity.

Some general information on the types of investments that the government undertook are recorded in the October 1944 issue of *Survey of Current Business*. The *Survey* estimated that 90% of magnesium capacity, 65% of aluminum capacity, 20% of blast furnace capacity, and 10% of steel-making furnaces was government owned at that point in time. Cook (1948) and Gordon (1969) provide more details on the nature of projects in which the government invested. Some of the larger invest-

3. These calculations are based on figures reported in *The National Income and Product Accounts of the United States, 1929–1982* (1986).

Figure 2 PRIVATELY OWNED CAPITAL AND GOVERNMENT-OWNED, PRIVATELY OPERATED CAPITAL IN MANUFACTURING.



ments include $1.3 billion to expand steel capacity, $3.8 billion in aircraft plants, $704 million in aluminum plants, and $700 million in synthetic rubber plants. After the war, significant amounts of GOPO capital were sold to the private operators at an average of 27% of the historical cost. However, as Figure 2 illustrates, GOPO capital continued to constitute an important fraction of the manufacturing capital stock through the postwar.[4]

Correctly accounting for the investment component of government purchases has a large effect on the properties of Solow's residual. Table 3 summarizes the average growth rate of total factor productivity between 1938 and 1947. Results are reported for three subperiods, 1938–1941, 1941–1944, and 1944–1947. The percentages reported in Table 3 are total growth for the subperiod. The upper panel contains results for the entire U.S. economy. In the upper panel, output is measured using real GNP in 1982 dollars net of government compensation of employees. The measures of labor input and capital are varied as we move across

4. Many of these facts have been documented previously by Gordon (1969).

Table 3 U.S. TOTAL FACTOR PRODUCTIVITY DURING WORLD WAR II[a]

Subperiod	*Private capital (percent)*	*Private plus GOPO capital (percent)*	*Capacity utilization (percent)*
1938–1941	4.3	4.3	3.7
1941–1944	4.0	2.5	1.8
1944–1947	−1.2	−1.0	0

[a]The figures in this table are average annual growth rates in total factor productivity.

the columns. In column one labor input is measured using Kendrick's (1961) index of labor input in the private economy and the capital stock using data on the stock of capital of equipment and structures for all industries measured in 1982 constant dollars as reported in *Fixed Reproducible Tangible Wealth in the United States* (1987). Column two uses the same measure of labor input and augments the capital stock to include GOPO capital as reported in Wasson, Musgrave, and Harkins (1970).

The third column uses private capital plus GOPO capital to measure the total capital stock and makes adjustments for utilization of capital. In Appendix B we describe a model that allows for variation in the workweek of capital. This specification yields the following aggregate production technology:

$$y_t = k_t^{\theta} n_t^{(1-\theta)} h_t z_t,$$

where n_t represents the fraction of the population employed, h_t is hours per worker, k_t is the capital stock (per capita), y_t is per capita output, and z_t is the technology shock. Results in column three use Kendrick's (1961) measure of private-sector employment divided by civilian population over sixteen from U.S. Historical Statistics to measure n_t, and h_t is constructed by dividing our previous measure of labor input by private-sector employment. The variables y_t and k_t are also expressed in per capita terms. In this representation hours per worker indexes the intensity of utilization of the two inputs: capital and labor. Finally, note that all columns assume a capital share of $\theta = 0.25$.[5]

Looking first at the period from 1941 through 1944, we observe that the productivity calculation in column one suggests that a large positive technology shock occurred during the war. Total factor productivity growth in the peacetime averages about 2% per year. Subtracting this

5. The capital share parameter value here is lower than the values used by Prescott (1986) or Christiano (1988), who add an imputed service flow of consumer durables to output.

from the reported growth of 4.3% leaves 7% unexplained between 1941 and 1944. In column two GOPO capital is added to the capital stock. This adjustment reduces total factor productivity growth to 2.5% per year, thereby reducing the unexplained growth of 2% over this three-year period. Once the effects of changes in utilization are accounted for, productivity growth between 1941 and 1944 is about average at 1.8% per annum.

The nine years from 1938 to 1947 covers the period between the last prewar trough to the first postwar trough. In this period, if GOPO capital is ignored, total factor productivity exhibits strong growth before the war and slows considerably after the war. Overall, total factor productivity increases by 20% over this period or about 2% above trend. Accounting for GOPO capital attenuates the swings in total factor productivity and reduces the growth in total factor productivity over the period to 17% which is slightly below trend. Adjustments for changes in capacity utilization reduce the growth during this period further to 16%.

2.5.2 The U.S. Labor Market During World War II A second important factor explaining the remarkable growth in GNP during World War II was growth in labor input. Panel B of Table 2 shows some of the main features of the labor market during the second war. Employment started rising as Europe began to prepare for war and rose further after war broke out in 1939. One of the more remarkable features of World War II was the strong growth in employment after the United States entered the war. Civilian employment continued to increase steadily through 1943 even as armed forces were increased from four to nine million. The changing composition of government demand is also reflected in more disaggregated labor market statistics. For instance, employment in durable goods manufacturing increased by over 150% between 1938 and 1944, while employment in nondurable manufacturing increased by only 30%.

Per capita man-hours also grew strongly, increasing by 9 percent between 1941 and 1943. While some of this growth came from the increases in employment documented earlier, weekly hours increased significantly as well. The National Industrial Council Board's index of weekly hours increased from 41.7 hours per week in July 1941 to 47.9 hours per week in July 1944. In some vital industries like machine tools, the average workweek increased by as much as ten hours during the war.[6]

6. See various issues of the *Survey of Current Business* (1941–1944).

Labor productivity growth is not very strong during World War II. Kendrick's measure is essentially flat in the first two years of the war and then increases. If we assume average growth of about 2% per year, Kendrick's measure is below trend in 1942 and 1943 and above trend in 1944 and 1945. It is interesting that the strongest growth in average productivity coincides with the periods when conscription rates reach their maximum.

Finally, as Rotemburg and Woodford (1992) have emphasized, wages in manufacturing increased rapidly during the Second World War. Underlying this growth was a sharp increase in wages in durable goods industries. In other sectors of the economy, wage rates fell. Bry (1961, p. 316), for instance, reports steady declines in real wage rates for skilled construction workers during World War II.

2.5.3 Prices in the United States During World War II General price controls were introduced in March 1942 in the form of a price freeze. Over time, this freeze gave way to cost-plus rules similar to those used in Great Britain. Merchants were allowed to pass on cost increases as long as their markup was not altered. As in Britain, price controls slowed but did not halt inflation. Between 1941 and 1945, the CPI rose by about 22%. Food rationing was introduced in 1943. Rockoff (1984) reports that average values of nutrition under rationing exceeded prewar nutrition levels. In addition, large black markets existed for more expensive food items like meat. As noted earlier, many consumer durables were rationed by government edicts curtailing or halting production of items like typewriters and stoves. Wages were controlled by the National Labor Board, which prohibited wage growth rates in excess of the CPI growth rate. However, these controls were frequently circumvented by offering inducements like vacation, medical insurance, and promotions.

2.5.4 The U.S. Financial Market in World War II Bond yields were low before the start of the war. In 1938, bond yields averaged 2.94%. Homer and Sylla (1991) report instances in 1938 where nominal treasury bond yields sold at negative yields because of the tax status of these issues. Between 1938 and 1940, the yield on corporate bonds, municipal bonds, and treasury bonds declined even further and then stabilized after the United States entered the war. During the war, the Treasury and Federal Reserve coordinated their policies in order to maintain a constant price schedule for government debt issues. The U.S. stock market during World War II experienced a gradual decline from 1937 to 1942 and then started to climb again midway through 1942.

2.6 SUMMARIZING THE EFFECTS OF THE WORLD WARS ON ECONOMIC ACTIVITY

The economic responses that we have documented in the previous subsections are the largest economic events of the twentieth century. Consider the correlations reported in Tables 4(a) and 4(b) for Great Britain and the United States. The two panels report correlations of various aggregate variables with output and military expenditures. The sample period extends from 1910 to 1965 for Great Britain and from 1910 to 1968 for the United States. Results are reported for variables expressed in terms of deviation from trend. Definitions of the series can be found in the data appendix. Note that many of the patterns described earlier are reflected in the correlations of Table 4(a). For Britain, military purchases (Mil) are positively correlated with output (GDP), and government expenditures (G-EXP) and negatively correlated with consumption (C), investment (I), and net-exports (Netx). As we noted earlier, civilian employment (Emp-Civ) and wages (Wage) are negatively correlated with military expenditures, and output per worker (GDP/Emp) is positively correlated with expenditures. Finally, ex post and real returns on interest rates (RR-long) are negatively related to military outlays. The pattern of output correlations also reflects the dominant effects of the

Table 4a CORRELATIONS OF DETRENDED DATA FOR GREAT BRITAIN, 1910–1965

	Cross-Correlation with GDP (t + i)			*Cross-Correlation with Mil (t + i)*		
	−1	*0*	*1*	*−1*	*0*	*1*
GDP	0.92	1.00	0.92	0.38	0.59	0.70
C	0.16	0.27	0.36	−0.49	−0.46	−0.39
I	−0.11	−0.03	0.07	−0.53	−0.61	−0.60
Netx	−0.09	−0.15	−0.11	−0.27	−0.47	−0.61
Gov	0.69	0.71	0.61	0.66	0.90	0.99
Mil	0.70	0.59	0.39	0.90	1.00	0.90
G-EXP	0.47	0.33	0.10	0.88	0.92	0.76
G-REV	−0.16	−0.38	−0.54	0.59	0.37	0.12
Emp-Civ	0.14	0.18	0.28	−0.27	−0.29	−0.17
Emp-mil	0.59	0.53	0.36	0.84	0.96	0.94
GDP/Emp	0.91	0.99	0.91	0.39	0.58	0.68
Wage	−0.51	−0.57	−0.51	−0.38	−0.56	−0.63
RR-long	−0.49	−0.58	−0.55	−0.34	−0.56	−0.66

Table 4b CORRELATIONS OF DETRENDED DATA FOR UNITED STATES, 1910–1965

	Cross-Correlation with GNP (t + i)			*Cross-Correlation with Mil* (t + i)		
	−1	*0*	*1*	*−1*	*0*	*1*
GNP	0.88	1.00	0.88	0.65	0.73	0.68
C	0.62	0.58	0.47	0.05	−0.04	−0.12
I	0.47	0.44	0.40	0.02	−0.11	−0.15
Netx	0.03	−0.12	−0.06	0.05	−0.20	−0.25
Gov	0.51	0.66	0.59	0.67	0.89	0.89
Mil	0.67	0.73	0.66	0.90	1.00	0.90
G-EXP	0.40	0.48	0.42	0.82	0.91	0.81
G-REV	0.72	0.73	0.61	0.89	0.88	0.75
H	0.84	0.92	0.84	0.50	0.54	0.52
N	0.83	0.92	0.85	0.52	0.55	0.52
Emp-mil	0.66	0.75	0.68	0.86	0.98	0.93
GNP/H	0.77	0.90	0.77	0.69	0.81	0.74
GNP/N	0.53	0.64	0.49	0.56	0.72	0.67
Wage	0.31	0.27	0.12	0.04	0.09	0.05
RR-short	−0.05	−0.12	−0.20	−0.54	−0.50	−0.40
RR-long	−0.17	−0.24	−0.32	−0.57	−0.53	−0.43

two wars. Consumption is only weakly procyclical, and investment, real wages, and interest rates are all countercyclical.[7]

With a few exceptions, the co-movements in the United States mimic those for Britain. For example, the correlations between military expenditures and the components of output have the same signs for the two data sets. On the other hand, the measure of the labor input (N) in the United States is positively correlated with military expenditures (Mil). With respect to correlations with output, the United States has a positive correlation between investment (I) and GNP. This result is due, in part, to the fact that our sample includes nonwar periods when other shocks (e.g., technology shocks) are important.

What general lessons can we draw about the effects of large increases in government purchases? First, the response of output and its components is similar in both countries. The large increases in government expenditures increased output and crowded out consumption and investment in both countries during both wars. Second, both governments took an active role in directing investment into activities that

7. Correia, Neves, and Rebelo (1992) have documented this property of British data previously.

were vital to the war effort and financing these expenditures directly when firms could not be induced to do so. The evidence suggests that the two governments were more active in financing investment in World War II than in World War I. In the United States, the picture of a contracting capital stock during the Second World War that emerges from the National Income and Product Accounts ignores the significant expansions in capacity financed by the U.S. government. Third, labor productivity increased in both countries during the two world wars.

Other labor market patterns vary across time and the two countries. In Great Britain there appears to be a fall in labor input in both wars, whereas labor input increases in the United States. This difference is most likely due to the effects of conscription. British armed forces at their peak accounted for about 20% of the total labor force in both world wars. The United States armed forces did not reach this rate until 1944, which is the first year that labor input declines. In Great Britain, civilian employment plus the armed forces constituted 50% of total population in 1943. In the United States, civilian employment plus armed forces at their peak were only 44% of the total population.

Some of these facts are consistent with the predictions of neoclassical theory. Hall (1980), Barro (1981), and Aiyagari, Christiano, and Eichenbaum (1992) have found that the neoclassical framework predicts temporary increases in government purchases should increase output, crowd out consumption and private investment, and raise employment. However, this framework also predicts that labor productivity and wages should fall. Negative wealth effects in conjunction with intertemporal substitution effects lead households to work harder today and consume less today. In the labor market, these effects shift labor supply out along an (essentially) stable labor demand schedule.

Conscription may resolve the productivity puzzle and the patterns of employment observed in Great Britain. In isolation, conscription reduces households' time endowment. This in turn shifts labor supply left in the civilian sector, which results in a rise in labor productivity and lower civilian employment.

Government investment may also explain the measured increases in productivity in the two countries. Increases in government investment can shift out the labor demand schedule and thereby increase labor productivity. With the labor demand schedule shifting out, the contemporaneous increase in labor input and labor productivity observed in the United States is no longer a puzzle. Moreover, when government investment is modeled in conjunction with conscription, the British experience of increased output and productivity in a period where labor input and private capital input are declining is less puzzling.

In the next section we will examine the effects of conscription and government investment in a neoclassical framework. The central focus of this analysis will be to investigate the role of conscription and government investment in explaining the basic facts we have documented for Great Britain and the United States.

3. The Model

To isolate the effects of government consumption, conscription, and government investment during wartime, we focus on a very simple abstraction.[8] Let h_t be the number of hours spent producing goods in period t, and let a_t be the number of hours in the army in period t. If there is one unit of time to allocate, then leisure in period t is given by

$$l_t = 1 - h_t - a_t. \tag{1}$$

We assume that the preferences of a typical household depend on their consumption of goods and leisure, e.g.,

$$E\left[\sum_{t=0}^{\infty} \beta^t u(c_t, l_t) | x_0\right], \tag{2}$$

where c_t is consumption in period t, β is a discount factor, x_0 is the state of the world in date 0 which is taken as given by households, and E is an expectation operator conditioned on the initial state.

There is a technology available to the households that requires inputs of labor and capital. Households can invest and, thus, accumulate private capital. They also receive public capital for private production. The resource constraint for the economy is

$$c_t + i_t + i_{g,t} + b_{g,t} = y_t = f(k_t, k_{g,t}, h_t), \tag{3}$$

where i_t is private investment in period t, $i_{g,t}$ is government investment in t, $b_{g,t}$ is government consumption in t, k_t is the private capital stock in t, $k_{g,t}$ is the stock of government capital in t, y_t is output for the private sector in t, and f is the production function that exhibits constant returns to scale with respect to all three inputs. Note that the production

8. We include hours in the army and abstract from distortionary finance, public services, and shocks to technology. Related papers are by Aiyagari, Christiano, and Eichenbaum (1992), Barro (1981), Baxter and King (1990), Hall (1980), and Ohanian (1993).

function does not depend on an exogenous technology shock. Both the private and the public capital stock are assumed to depreciate at a rate of δ per period, e.g.,

$$\begin{aligned} k_{t+1} &= (1-\delta)k_t + i_t \\ k_{g,t+1} &= (1-\delta)k_{g,t} + i_{g,t}. \end{aligned} \tag{4}$$

In period t, all agents know the history of the state. Thus, current consumption, labor, and investment decisions will depend on the history $\{(k_s, k_{g,s}, a_s, i_{g,s}, b_{g,s}), s = 0, \ldots, t\}$. Assume that military hours, government investment, and government expenditures are Markov processes (of order q) that are known to the agents. Then consumption, investment, and labor decisions are functions of current values of the state, for example, $(k_t, k_{g,t}, z_t, \ldots, z_{t-q})$ in period t where $z_t = (i_{g,t}, b_{g,t}, a_t)$.

Let $x_t = [k_t, k_{g,t}, z_t, \ldots z_{t-q}]$ be the vector of state variables at date t. An equilibrium for this economy is a set of decision functions $c(x_t)$, $i(x_t)$, and $h(x_t)$, and a law of motion for the state, $x_{t+1} = \gamma(x_t)$, such that households maximize Equation (2) subject to Equations (1), (3), (4), and processes for government consumption, investment, and military employment.

This model can be used to quantify the effects of government consumption, investment, and conscription on the economy during wartime. This involves choosing a parameterization of preferences and technology, solving for the equilibrium decision functions, and using the decision functions and some process for the exogenous shocks to simulate time series.

The functional forms that we use for utility and production are as follows:

$$u(c_t, l_t) = \frac{(c_t^{\gamma} l_t^{1-\gamma})^{1-\omega} - 1}{1-\omega}$$

$$f(k_t, k_{g,t}, h_t) = \lambda(bk_t^{\rho} + (1-b)k_{g,t}^{\rho})^{\theta/\rho} h_t^{1-\theta},$$

where

$$\beta = 0.96, \gamma = 3, \omega = 1, \lambda = 3/2, b = 1/2, \rho = 1, \text{and } \theta = 1/4. \tag{5}$$

For the discount factor, we choose $\beta = 0.96$, which corresponds to a 4% annual interest rate if consumption is not growing over time. A value of 3 for γ implies weights of 1/4 and 3/4 on consumption and leisure in utility. With $\omega = 1$, the utility function has a logarithmic form. To calculate the annual depreciation rate, we projected $i_t - (k_{t+1} - k_t)$ onto k_t using U.S. data. The resulting estimate of δ is 6.54%. This rate of depreciation is also used for Britain. A value of $1/4$ for θ implies that the capital share of income is 25%. The values of $\rho = 1$ and $b = 1/2$ for technology imply that private and government capital are perfect substitutes in production. The constant λ determines the scale of the components of output. A value of $3/2$ was chosen so that the steady state values of these variables lie between 0 and 1. For the most part, our choices of the utility and technology parameters and the parameters of the Markov chain imply that the first moments of c_t/y_t, i_t/y_t, k_t/y_t, and h_t in the model are approximately equal to the sample means of the U.S. data during the postwar period. The differences between the first moments of the U.S. and British data are due primarily to differences in government expenditures and conscription. Therefore, we use the parameters of Equation (5) for both countries. In our final remarks, we describe how the above choices affect our results.

To compute the equilibrium decision functions, we assume that the vector of exogenous variables is a Markov chain. Let $\bar{z}^j$ be the value for $z_t = (i_{g,t}, b_{g,t}, a_t)$ if the jth state occurs in period t. Assume further that z_t takes on n possible values and denote the transition matrix by π. In this case, the decision rules for consumption, investment, and hours are indexed by the state and defined on $\mathbb{R}^2$, e.g., $c^j(k_t, k_{g,t})$, $j = 1, \ldots, n$. The algorithm used to compute the decision functions is described in Appendix A.

To simulate the model, we also need to specify the conditional means and transition probabilities for government investment, government consumption, and military hours. Unfortunately, in the case of the exogenous state variables, we have very few observations and a large number of parameters to identify. Our strategy is to choose a specification that reproduces the magnitude and timing of $b_{g,t}$, $i_{g,t}$, and a_t during World War II for the United States and the United Kingdom. For the United States during World War II, we assume that the vector of exogenous variables (z) takes on seven possible values (i.e., $n = 7$). The seven vectors are chosen by matching realizations of $i_{g,t}/y_t$, $b_{g,t}/y_t$, and a_t/h_t in the model with observations in the United States between 1939 and 1945. In Figure 3(a), we plot these ratios for the United States during World War II. To make the ratios in the data and the model comparable, we subtract compensation of government employees, net exports, and inventories from GNP when constructing y_t. To construct $b_{g,t}$, we take total government purchases and subtract the compensation of government employees and government investment. Government investment is constructed from GOPO capital stock using Equation (4).[9] The year 1939 is assumed to be peacetime. Between 1938 and 1939, there was little, if any, preparation for war in the United States. Once the war began in Europe, the United States began investing in privately operated projects and increasing the number of troops. At that point, the involvement of the United States was still uncertain. By 1941, the level of investment of the government in projects operated by the private sector was one third of its peak level. On the other hand, in 1941, the share of government consumption in output, (b_g/y), was at its 1939 level. At the end of 1941, the United States declared war, and non-GOPO government expenditures and conscription rose significantly. By 1943, the fraction of output used for GOPO investment had hit its peak, while other expenditures continued to rise. The pattern of military hours relative to private hours is similar to that of government consumption. Both lag government investment, and both are high at the end of the war. It is this pattern that we model when specifying the exogenous processes.

Our assumption about the timing of government expenditures and conscription is important. From the perspective of the private sector, government investment is a signal of future increases in conscription and future increases in government expenditures. In effect, it is a signal of future taxes. The private sector, seeing government investment increasing today, updates its forecast for the likelihood of war and, therefore, for the likelihood of a large fiscal shock. Their response to this government investment and expected future spending is an increase in hours of work and, in some cases, an increase in *private* investment.[10] The increase in hours of work leads to an immediate fall in labor productivity because capital cannot adjust immediately. However, if a sufficiently large increase in government expenditures is projected, the total capital stock increases. The increase in capital can lead to a rise in productivity in the period following the increase in government investment. The increase in capital can, therefore, produce a positive correlation between government consumption and labor productivity. Conscription can also increase labor productivity. An increase in conscription leads to a decrease in private hours of work and, therefore, to an increase in labor productivity.

To parameterize the Markov chain for the British experiment, we again assume that the vector of exogenous variables (z) takes on seven

9. Emp-mil and H, which are defined in the data appendix, are used to construct the ratio of military hours to private hours of work.

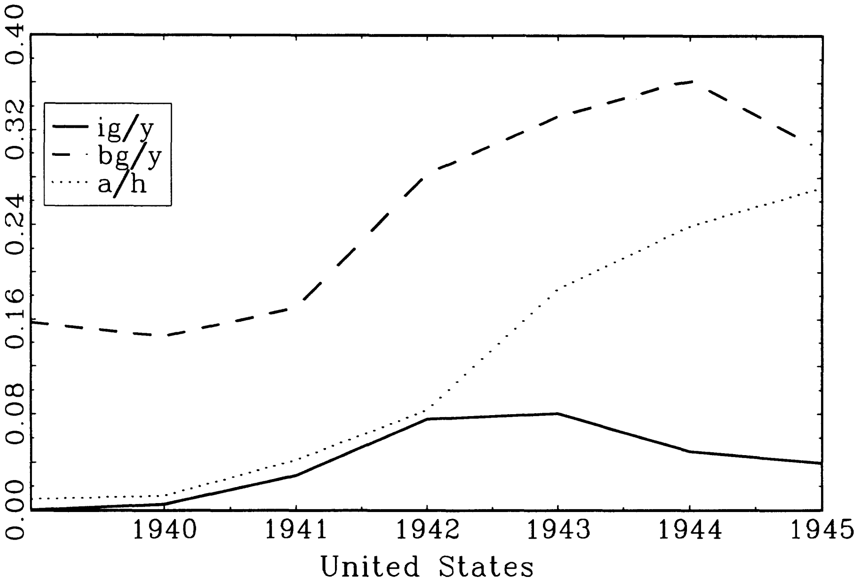
10. We will later show that increases in private investment can occur even if private and public capital are perfectly substitutable.

possible values. The war in Europe started two years earlier than in the United States, but the changes in government investment, government consumption, and military hours during 1944 and 1945 were relatively small in Britain. Thus, to economize on parameters, we assume that these two periods represent the same state for the Markov chain. In Figure 3(b), we plot the ratios $i_{g,t}/y_t$, $b_{g,t}/y_t$, and a_t/h_t for Britain for the years 1938–1945. To construct y_t, we subtract the compensation of military employees, net exports, and inventories from GDP. To construct $b_{g,t}$, we take total government expenditures and subtract the compensation of military employees and Ashworth's (1953) measure of government investment ($i_{g,t}$). The year 1938 is assumed to be peacetime. In 1939, they started investing in some projects but not to the extent that the United States had been investing before it entered the war. However, as in the United States, there was little change in other government expenditures before the war. The largest increases in government consumption and conscription occurred after the British declared war. The pattern of shocks that we see for Britain is very similar to that of the United States. At the midpoint of the war, the fraction of output used for government investment hit its peak while other expenditures and conscription continued to rise. Government consumption and military hours lag government investment but are high at the end of the war when government investment is low.

In Table 5, we report the conditional means and transition probabilities for government investment (i_g), government consumption (b_g), and the fraction of time in the military (a) for our two experiments. These values of the three exogenous shocks imply that the ratios of government expenditures to output, $i_{g,t}/y_t$ and $b_{g,t}/y_t$, and military hours to private hours, a_t/h_t, for the model are equal to those in the data if we observe a war with the same pattern and duration as World War II. We choose the transition probabilities so that the ergodic probability of state 1 (peace) is 0.82. Thus, if the duration of war, including periods for preparation, is on average six years, there would be three wars per century. The probability for being in each of the other states is approximately equal to 0.03. The only difference between the United States and the United Kingdom is the specification of π_{71} and π_{77}. We increased the likelihood of being in state 7 because we assume that both 1944 and 1945 constitute state 7 for the United Kingdom.

In Figure 4, we plot ratios of consumption, investment, and spending to output for the United States and the model. The U.S. ratios for 1937 through 1968 are in the top panel (Figure 4a). In Figure 4(b), we display a simulated war of the magnitude and duration of World War II. This simulation is based on the parameters of Equation (5) and Table 5. Al-

Figure 3 GOVERNMENT INVESTMENT, GOVERNMENT CONSUMPTION, AND CONSCRIPTION DURING WORLD WAR II.



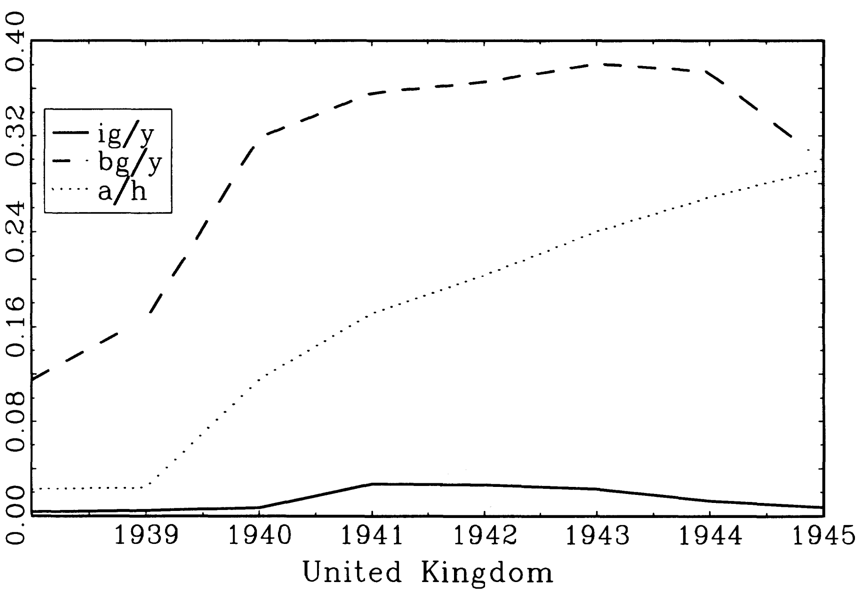


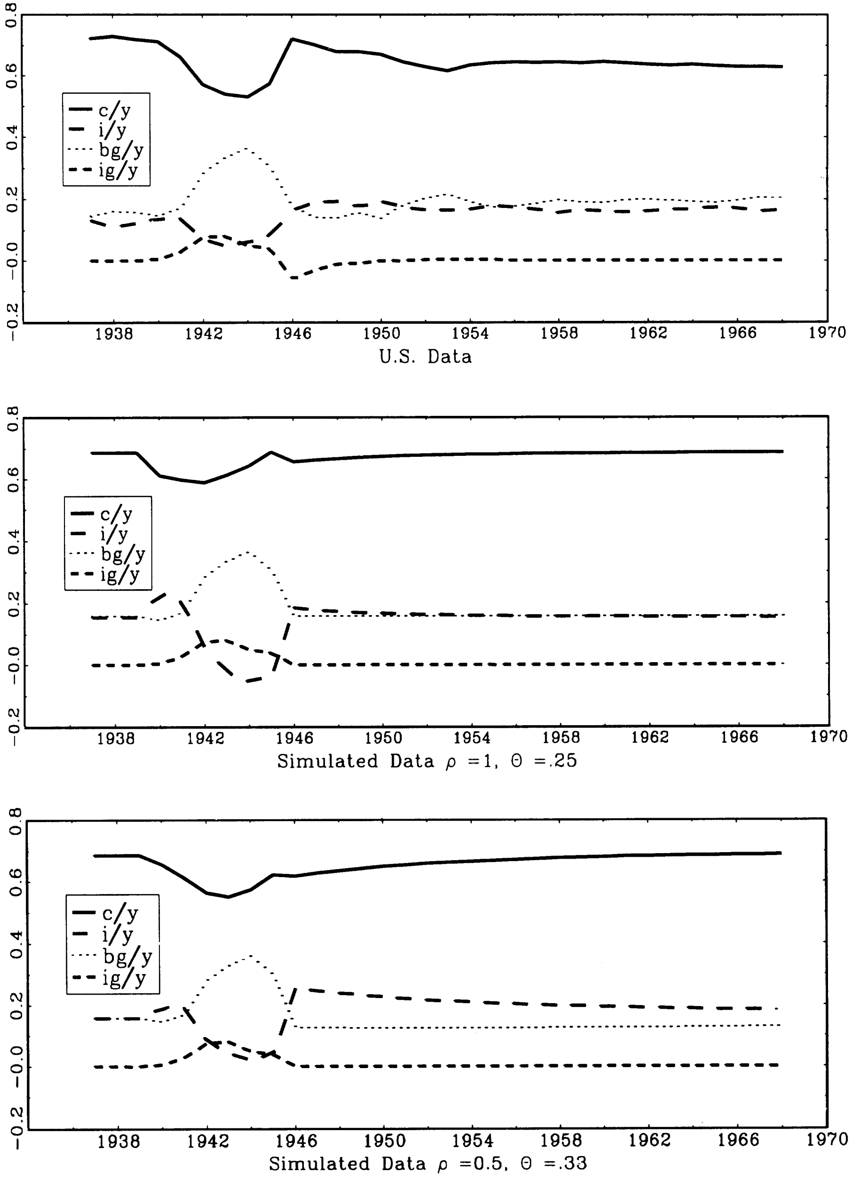
Table 5 CONDITIONAL MEANS AND TRANSITION PROBABILITIES FOR GOVERNMENT INVESTMENT, GOVERNMENT CONSUMPTION, AND MILITARY HOURS

	United States			*United Kingdom*			
	i_g	b_g	a	i_g	b_g	a	π^a
1	0	.0762	.0024	.0010	.0534	.0057	π_{11} = .97, π_{12} = .03
2	.0024	.0751	.0033	.0024	.0858	.0069	π_{21} = .05, π_{22} = .20, π_{23} = .75
3	.0153	.0892	.0121	.0036	.1705	.0348	π_{33} = .25, π_{34} = .75
4	.0401	.1497	.0241	.0145	.1853	.0502	π_{44} = .25, π_{45} = .75
5	.0406	.1678	.0510	.0131	.1830	.0570	π_{55} = .25, π_{56} = .75
6	.0235	.1750	.0626	.0105	.1850	.0625	π_{66} = .25, π_{67} = .75
7	.0177	.1384	.0674	.0056	.1635	.0660	π_{71} = .9, π_{77} = .1
							(.75) (.25)

[a] All of the transition probabilities for the United States and Great Britain are the same except for state 7 where the British probabilities are in parentheses.

though we report only one realization, any war with the same duration and sequence of states would exhibit the same pattern shown in Figure 4(b). As in the U.S. series, we find that increases in government consumption and investment crowd out private consumption and investment and increase output. However, relative to the United States, the model's prediction of the decline in the ratio of consumption to output is too small. The result is due to the fact that the predicted rise in output is too small. The U.S. output was 17% above trend at its peak in 1943 and 1944. The peak of output in the simulations occurs in state 4. State 4 corresponds to 1942 when output in the United States was 12% above trend. In the simulations, output is only 9% above trend in state 4. What drives the increase in output in the model? In our model, both hours and the total capital stock are increasing. In Figure 4(b), we observe a rise in private investment in 1940 (or state 2). This increase leads to an increase in the capital stock in the following year. In 1941 and 1942, total investment is still high because of increases in government investment. Significant declines in the total capital stock do not occur until 1944 or 1945 (i.e., states 6 and 7). Hours growth, on the other hand, is rapid from 1939 to 1940 but then stops as conscription picks up. This suggests that the problem is not the response in capital but the response in hours. Theory predicts that hours rise in response to expectations of large fiscal shocks. However, because we assume that hours must be used for the military, expected increases in military service at the end of the war lead the private sector to increase hours of production in the initial periods when conscription is low.

Figure 4 SIMULATED AND ACTUAL CHANGES IN THE COMPOSITION OF OUTPUT.



The simulations for Britain show a pattern in the shares of consumption and investment that is similar to that of Figure 4(b). In particular, the low point in the consumption to output ratio occurs too early. However, for the British experiment, we come close to matching the maximum response of output to the wartime shocks. The model predicts that in state 3 (1940) output is 16% above its peacetime level. In 1940, output in the data was 15% above trend. In 1941, output in the data reached its peak at 17% above trend. Because of the large increase in output, we see a large decline in the consumption to output ratio. In the data, this ratio falls 39%, and in the model it falls 33%.

The simulation displayed in Figure 4(c) assumes that the capital stocks are not perfectly substitutable ($\rho = 0.5$). For values of ρ less than 1, we find a larger increase in output during war. This is not surprising given the fact that an increase in i_g leads to high returns in subsequent periods and, therefore, larger responses in hours of work. What we do find surprising is that the consumption and investment ratios are in much better agreement with the data than in the case of perfect substitutes. In Figure 4(c), we plot these ratios for the parameterization of Equation (5) and Table 5 with $\rho = 0.5$ instead of $\rho = 1$. In addition, we set $\theta = 1/3$ and reset the parameters of Table 5 so as to maintain the same steady-state ratios for c_t/y_t and i_t/y_t and the same realizations of $i_{g,t}/y_t$ and $b_{g,t}/y_t$. The ratio of consumption to output does not hit its low point too early and falls to about the same level as that observed in the data. More important, we do not see a negative ratio of private investment to output. However, a choice of $\rho < 1$, or imperfect substitutability, may have problems if our model is to be used for predicting the effects of fiscal shocks during peacetime. During peacetime, the stock of government capital, k_g, is small. If $\rho < 1$, the marginal product can be very high but depends on the value of b. Unless we assume that the government ignores the fact that it could achieve a high return from subsidizing investment, this choice of technology does not make much sense. But the results do suggest that some technological distinction between public and private capital may be warranted.

In Table 6, we report the time paths of hours and productivity for the U.S. and U.K. experiments. Both experiments use the parameters of Equation (5) and Table 5. First consider the results for the United States. As we noted earlier, hours rise in the first few periods of the war but fall once conscription increases significantly. If we compare this column to "Man-hours per capita" in Table 2, we see a similar rise between 1939 and 1941 in the model and the data. However, after 1942, hours rise in the data and fall in the model. For productivity, we find good agreement between the model and data during the war. Notice that the

Table 6 HOURS AND PRODUCTIVITY FOR MODEL SIMULATIONS OF WORLD WAR II[a]

	United States		United Kingdom	
Year	*Hours (1941 = 100)*	*Labor productivity (1941 = 100)*	*Hours (1938 = 100)*	*Labor productivity (1938 = 100)*
1938	91	95	100	100
1939	91	97	121	97
1940	99	97	119	101
1941	100	100	114	104
1942	100	103	110	106
1943	94	106	105	108
1944	90	108	99	111
1945	85	110	102	110

[a]Note that we have added 2% annual growth to labor productivity to facilitate comparison with Tables 1 and 2.

simulation captures the 8% increase in productivity found in the data between 1941 and 1944. (See Table 2.) Furthermore, the model's predictions for labor productivity also compare favorably with the data on real wages. Both decline early and then rise strongly at the end of the war. Note, however, that an increase in labor productivity implies a decrease in capital productivity when technology shocks are absent. A declining marginal product of capital can explain the fall in stock market returns observed during the later part of World War II but cannot account for the decrease in the capital-output ratio.

Our U.K. simulation produces a much larger increase in hours of work than the U.S. simulation. This explains why we see a larger increase in output in the U.K. experiment than in the U.S. experiment. In other respects, the pattern of hours is similar in the two countries: a sharp rise followed by a steady decline. There is a slight increase in hours of work for the United Kingdom at the end of the simulation, but this increase is due to the fact that 1944 and 1945 are assumed to be the same state when we are calculating the Markov chain. If an eighth state is added for 1945, then the predicted increase disappears. Note that much of the decline in hours for the two countries is due to conscription. Average weekly hours for the United Kingdom are reported in Table 1 for 1938 and 1943 through 1945. As in the simulation, we see a decline in hours at the end of the war with hours of work in 1938 at about the same level as in 1945. The pattern of productivity in the U.K. simulation is similar to that of the United States. Productivity falls initially with capital fixed and hours of work rising. As the capital stock increases, labor productivity rises. Thus, we find productivity positively correlated with government expenditures in both countries.

To see if these results are robust to changes in the parameterization of Equation (5) and Table 5, we tried some alternative specifications. Consider first the parameters of preferences. For the weight on consumption in utility, we use $\frac{1}{4}$. If we increase γ to $\frac{1}{3}$, the value used by Kydland and Prescott (1982), we find a larger steady-state value for hours of work but a similar pattern in the response of hours to the shocks during the war. With a larger value of hours in the steady state, it is necessary to increase the values of a in the Markov chain. Then the increase in military hours produces a larger decline in hours toward the end of the war. The value of ω chosen for our experiments is 1. To significantly change our results, we must assume either that agents are very risk averse (ω large) or risk neutral (ω close to 0). For most values used in the business cycle literature, we do not find much of a difference from what we reported earlier. The discount factor, which we set at 0.96, affects the consumption versus saving decision. When we change this parameter, we find differences in the steady-state values but little difference in the responses to shocks.

Consider next the parameters of technology. As we noted earlier, the choice of ρ significantly affects our results. We use $\rho = 1$ because we want a theory of the effects of government purchases that can be applied in both peacetime and wartime. However, improvements in the responses of consumption and investment suggest that alternative specifications of technology should be explored. For the share of capital in income, we use $\frac{1}{4}$. If we increase the value of this parameter, we increase the level of investment in periods of peace, but we do not find a significant reduction in the response of investment to fiscal shocks. Finally, consider changes in the transition probabilities. To significantly affect our results, we would need to choose values for π that imply very different ergodic distributions. Our current specification assumes that most of the time is spent in peacetime. If we increase the time spent in any of the prewar or war periods, we change the decision functions, but we also simulate wars that last too long from a historical standpoint.

In summary, we have presented a simple model that we use to quantify the effects of changes in government investment, government consumption, and military hours. We have shown that, although the model abstracts from shocks to technology and to taxes, the model does capture a significant fraction of the movement of GNP and its components, hours of work, and productivity. We have also shown that it is not necessary to include imperfectly competitive markets to get a positive correlation between productivity and government expenditures. But it is important to distinguish the uses of government expenditures and the timing of different expenditures during the war. Finally, we have shown that our theory can more easily account for observations of the labor market in Britain than in the United States. With all agents forced to put time into the military, we find a significant decline in hours in periods when the rate of conscription is high. In the United States, during World War II, we saw large increases in both private and military hours. In Appendix B, we explore an extension of this model that distinguishes civilian and noncivilian employment as well as variations in hours of work and employment.

4. *Conclusions*

In this paper we have documented the responses of the British and U.S. economies to the two World Wars and proposed a simple model that allows us to quantify the roles of government investment, conscription, and government consumption. Our model captures a significant fraction of the movement in GNP and its components and is consistent with the U.S. observations of rising hours and average productivity. We find further that the British experience of declining employment and increasing productivity can be explained by Britain's high conscription rates.

There are a number of features of the data that the model cannot explain. Both countries exhibited large increases in hours per worker during World War II, yet the pattern of employment differed in the two countries. Our model makes no distinction between these two margins. In addition, our model predicts that an increase in government purchases has opposite effects on the output-capital ratio and labor productivity. Thus, it is difficult for our model to reconcile the large decrease in the capital-output ratio and concurrent decline in interest rates that occurred in the United States during World War II.

Our analysis raises other questions as well. For instance, does the large buildup of GOPO capital that occurred during the war have implications for peacetime? Between 1939 and 1945, the private output-capital ratio increased by 33% (see, e.g., Blanchard and Fischer, 1989). Since the war, this ratio has remained relatively stable. The increase in GOPO capital during the war certainly offers a partial explanation for the increase in the ratio of output to private capital. But why has the ratio not fallen back to its prewar level in the postwar period as the stock of GOPO capital has fallen? The Cold War has resulted in continuing

GOPO investment in the postwar period, but the magnitude of this investment has been small. In Figure 2 we can see that by 1955, GOPO capital constituted less than 10% of the total capital stock in manufacturing. To explain the high output-capital ratio in the postwar period requires us to look beyond GOPO capital. Aschauer (1993) and Gordon (1969) have argued that other forms of government investment like infrastructure are important for understanding growth in the postwar period. The postwar transition from privately operated railways to a public highway system and air transit system with government-owned airports may be one plausible explanation for the fact that the output-capital ratio has remained high in the postwar period.

Changes in the participation rates may offer an alternative explanation for the high output-capital ratio. During the Second World War, participation rates of women increased rapidly. After the war many women remained in the work force. Participation rates of women rose by 60% between 1930 and 1950, with most of this increase occurring during and after World War II. Higher participation rates may have resulted in a more intensive use of capital in the postwar period.

Data Appendix

1. BRITISH DATA SOURCES

- GDP: Gross Domestic Product in constant 1980 prices, per capita. The source for this time series is Mitchell (1988), pp. 831–841; GDP at market prices, current prices and GDP at market prices constant prices various base years. The population measure is described below. Note that between 1910 and 1920, GDP and its components include Ireland; after 1920 they exclude the Republic of Ireland.
- C: Consumers' Expenditure in constant 1980 prices, per capita from Mitchell (1988), pp. 831–841.
- I: Gross Domestic Fixed Capital Formation in constant 1980 prices, per capita from Mitchell (1988), pp. 831–841.
- Netx: Exports less Imports in constant 1980 prices, per capita from Mitchell (1988), pp. 831–841.
- Gov: Public Authorities' current expenditures on goods and services in constant 1980 prices, per capita from Mitchell (1988), pp. 831–841.
- Mil: Gross Public Expenditure of the United Kingdom on army and navy and air force plus votes of credit during the war years deflated by the GDP-deflator, per capita from Mitchell (1988), pp. 587–594.
- G-EXP: Gross Public Expenditure of the United Kingdom deflated by the GDP-deflator, per capita from Mitchell (1988), pp. 587–594.

- G-REV: Total Gross Public Income of the United Kingdom deflated by the GDP-deflator, per capita from Mitchell (1988), pp. 587–594.
- Emp-Civ: Total civilian employment, per capita from Feinstein (1972), pp. T126–T127.
- Emp-Mil: Armed Forces, per capita from Feinstein (1972), pp. T126–T127.
- GDP/Emp: Output per worker from Feinstein (1972), pp. T52–T53. The numerator is Feinstein's GDP-compromise constant factor cost estimate, and the denominator is total civilian employment plus armed forces.
- Wage: Index of weekly wage rates, divided by the Labour Gazette's retail price index from Feinstein (1972), p. T140–T141.
- RR-long: Yield on 2.5% Consols Mitchell (1988), p. 678, deflated using the GDP-deflator from Mitchell (1988).
- Population: Estimated Mid-Year Home Population for England and Wales plus Scotland plus Ireland through 1920. For 1921 through 1965, population is for England and Wales, Scotland and Northern Ireland. The source is Mitchell (1988), pp. 13–14.

2. U.S. DATA SOURCES[11]

- GNP: Gross National Product in 1982 constant dollars per capita. From 1910 to 1928, the source is Romer (1989). For 1929–1969, the source is *National Income and Product Accounts* 1929–1982.
- C: Consumer expenditures in 1982 constant dollars per capita. From 1910 to 1928, the source is Romer (1987), Table 3. From 1929 to 1969, the source is the NIPA.
- I: Fixed Investment in 1982 constant dollars per capita. From 1910 to 1928, the source is Romer (1987), Table 3. From 1929 to 1969, the source is the NIPA.
- Netx: Net Exports in 1982 constant dollars per capita. From 1910 to 1928 the fraction of net exports in 1929 constant dollar GNP as reported in Kendrick (1961), pp. 293–297, was applied to Romer's GNP time series to produce estimates of constant dollar net exports.
- Gov: Government purchases of goods and services in constant 1982 dollars, per capita. From 1910 to 1928, the source is Romer (1987), Table 3. From 1929 to 1969, the source is the NIPA.
- GOPO capital and private capital reported in Figure 2 are gross stocks of equipment and structures in manufacturing and government-owned gross stocks of equipment and structures in manufacturing

11. The data used in this paper were made available in part by the Inter-University Consortium for Political and Social Research. The data were originally collected by the NBER.

from Wasson, Musgrave, and Harkins in *Survey of Current Business* (1970) expressed in 1958 constant dollars. For some of the model simulations, we needed 1982 constant dollar estimates of GOPO. These were calculated by expressing total net GOPO capital (all industries) as a fraction of 1958 dollar net total private capital (all industries). Then this fraction was applied to 1982 constant dollar estimates of net total private capital (all industries) in *Fixed Reproducible Tangible Wealth in the U.S., 1925–1985* (Dept. of Commerce) to produce 1982 constant dollar estimates.

- Mil: Military outlays of the federal government on the army, navy, and air force, in constant 1982 dollars, per capita. Current dollar figures are from *Historical Statistics of the U.S.*, series Y-458:60. These were converted to constant dollar values by deflating by the GNP-deflator.
- G-EXP: U.S. Federal Government expenditures from *Historical Statistics of the U.S.* (1975), series Y336 and Y457, converted into constant dollars by deflating using the GNP-deflator, per capita.
- G-REV: U.S. Federal Government Revenues from *Historical Statistics of the U.S.* (1975), series Y336 and Y457, converted into constant dollars by deflating using the GNP-deflator, per capita series Y335,Y339,Y343.
- H: Total Man-hours from Kendrick as reported in *Long Term Economic Growth* (1973), Dept. of Commerce, p. 1141, divided by population over 16. This series is reported as an index with a 1958 base. The index was scaled by hours worked in 1958 in private industries from NIPA 1929–1982 (1986), p. 287, to convert its units into billions of hours.
- N: Labor input from Kendrick as reported in *Long Term Economic Growth* (1973), Dept. of Commerce, p. 1141, divided by population over 16. This series is reported as an index with a 1958 base. The index was scaled by hours worked in 1958 in private industries from NIPA 1929–1982 (1986), p. 287, to convert its units into billions of hours.
- Emp-mil: Military personnel on active duty from *Historical Statistics of the U.S* (1975), series Y904, converted into an hours measure assuming annual hours worked are 2,500, per capita.
- GNP/H: Labor Productivity measured using man-hours.
- GNP/N: Labor Productivity measured using labor input.
- Wage: Real wages in manufacturing. From 1910 to 1919 they are measured using payroll average hourly earnings in manufacturing from *Historical Statistics of the U.S.*, p. 168. The 1920 observation is the average of this time series and average hourly earnings in all manu-

facturing industries, p. 170. From 1921 to 1969, the p. 170 average hourly earnings numbers are used. Real wages are then calculated by deflating by the CPI all-items as reported in *Historical Statistics of the U.S.*, p. 211.

- RR-short: Yield on commercial paper from NBER tape, deflated using the GDP-deflator.
- RR-long: Moody's AAA bond yields from NBER tape series number a13108, deflated using the GDP-deflator.
- Population: U.S. population over 16 from *Historical Statistics of the U.S.* (1975), p. 10. The observations 1917–1919 have been augmented with armed forces (p. 1141 in Colonial Statistics) using (0.53 × Emp-mil) + pop to account for the fact that the pop dataset does not include forces overseas during World War I. The fraction 0.53 is reported in Colonial Statistics, p. 1140, as the average fraction of armed forces overseas during World War I.

Appendix A

In Section 3, we defined an equilibrium to be decision functions that maximize households' utility subject to certain resource constraints. In this Appendix, we describe the algorithm used to compute the equilibrium decision functions.[12] The general formulation of our problem is as follows: find $G : \Omega \subset \mathbb{R}^n \rightarrow \mathbb{R}^m$ that satisfies

$$F(G; \mathbf{x}) = 0,$$

where $F : \Psi_1 \rightarrow \Psi_2$, Ψ_j, $j = 1, 2$ are function spaces, and $\mathbf{x}$ is an n-dimensional vector and is some point in Ω. In our case, the function G is the vector of consumption functions that are indexed by the state of the Markov chain governing exogenous states. The first element of the vector $\mathbf{x}$ is private capital, and the second is public capital. The mapping F is the first-order necessary condition that relates current marginal utility to the expectation of the marginal utility next period weighted by the return from holding capital. Given the consumption function, the remaining first-order conditions can be used to determine the hours and investment decision functions.

Thus, we are looking for m functions that (approximately) satisfy a set of functional equations. To do this, we apply a finite element method with piecewise linear shape functions. Define the approximation to G,

12. A more detailed technical appendix is available upon request. See Hughes (1987) for a general description of the method applied here.

i.e., $G^h(\mathbf{x})$, as follows:

$$G^h(\mathbf{x}) = \sum_{a=1}^{nnodes} \gamma_a N_a(\mathbf{x}),$$

where γ_a, $a = 1, \ldots, nnodes$ is a vector of constants and $N_a(\mathbf{x})$, $\mathbf{x} = (x, y)$ for the two-dimensional case is given by the hat-shaped functions,

$$N_a(\mathbf{x}) = \begin{cases} \dfrac{x - \underline{x}_a}{x_a - \underline{x}_a} \cdot \dfrac{y - \underline{y}_a}{y_a - \underline{y}_a} & \underline{x}_a \leq x \leq x_a, \underline{y}_a \leq y \leq y_a \\ \dfrac{\overline{x}_a - x}{\overline{x}_a - x_a} \cdot \dfrac{y - \underline{y}_a}{y_a - \underline{y}_a} & x_a \leq x \leq \overline{x}_a, \underline{y}_a \leq y \leq y_a \\ \dfrac{x - \underline{x}_a}{x_a - \underline{x}_a} \cdot \dfrac{\overline{y}_a - y}{\overline{y}_a - y_a} & \underline{x}_a \leq x \leq x_a, y_a \leq y \leq \overline{y}_a \\ \dfrac{\overline{x}_a - x}{\overline{x}_a - x_a} \cdot \dfrac{\overline{y}_a - y}{\overline{y}_a - y_a} & x_a \leq x \leq \overline{x}_a, y_a \leq y \leq \overline{y}_a \\ 0 & \text{elsewhere,} \end{cases}$$

where $x_a = (x_a, y_a)$ is the vector of coordinates associated with node a and $[\underline{x}_a, \overline{x}_a] \times [\underline{y}_a, \overline{y}_a]$ is the rectangle for which $N_a(x)$ has a positive value. Note that $N_a(x)$ is equal to 1 at $x = x_a$. The constants, γ_a, are chosen to satisfy the following equations

$$H(\gamma) = \int_{\Omega} F(G^h(\mathbf{x}); \mathbf{x}) N_a(\mathbf{x}) d\mathbf{x} = 0, \qquad a = 1, \ldots, nnodes \tag{A.1}$$

where $\gamma = [\gamma_1', \ldots, \gamma_{nnodes}']'$ is a vector of length $m * nnodes$ and H has $m * nnodes$ elements. Equation (A.1) is the weak formulation of our problem.

The main computational task is to find γ such that $H(\gamma) = 0$. If we use a Newton-Raphson algorithm to find γ, then we choose some initial guess, say γ^0, and iterate as follows:

$$\gamma^{k+1} = \gamma^k - J(\gamma^k)^{-1} H(\gamma^k),$$

where J is the Jacobian of H. Because $G^h(x_a) = \gamma_a$ where a is some node on the grid, starting guesses can easily be obtained. For the examples of Section 3, we started with an increasing, linear function that is equal to steady-state consumption when evaluated at the steady-state values of private and public capital. Note that the Newton iterations require algorithms for solving linear systems, $Au = b$, where $A = J(\gamma^k)$, $b = H(\gamma^k)$. For large n or $nnodes$, A is a large, sparse matrix; in such cases, we use an iterative method to solve the linear system. (For more detail, see Saad, 1993).

Appendix B

In Section 2 we calculated Solow's residual for a production technology that included government capital and variation in capacity utilization. We found that, once we accounted for changes in government capital and changes in utilization, the growth in total factor productivity during World War II was equal to its average postwar rate. In Section 3, we decribed a model that explores the effects of changes in government investment. In this appendix, we describe a model that allows for variation in the workweek of capital as well as variations in government capital.[13]

Assume that there are a large number of ex ante identical agents with preferences

$$E \sum_{t=0}^{\infty} \beta^t u(c_t, l_t), \qquad u(c, l) = \frac{(c^{\gamma} l^{1-\gamma})^{1-\omega} - 1}{1 - \omega}, 0 \leq \beta, \gamma \leq 1, \omega > 0,$$

where c_t is consumption at date t, l_t is leisure at date t, and $h_t = 1 - l_t$ is hours spent working at date t. An agent that works h_t hours with k_t units of private capital and $k_{g,t}$ units of public capital produces a homogeneous good, y_t, with the following production technology:

$$y_t = \lambda \{k_t + k_{g,t}\}^{\theta} h_t.$$

The good can be consumed or invested, e.g., $c_t + i_t + i_{g,t} + b_{g,t} \leq y_t$. In specifying the production technology, we assume that private and public capital are perfect substitutes.

Note that the production technology exhibits increasing returns to scale. However, if we assume that agents buy and sell lotteries over bundles of goods, hours, and capital, as in Prescott and Townsend (1984), then we can convexify the commodity space. Suppose that agents, in date 0, enter into contracts which specify the number of hours to work and the number of units of capital to provide. In return for hours and capital, the agents receive consumption goods. To compute their equilibrium decisions, we can exploit the fact that the competitive

13. The model is similar to that of Kydland and Prescott (1991). We include conscription, government investment, and heterogeneity in preferences over agents' employment status but ignore moving costs.

equilibrium is Pareto optimal and solve the social planner's problem:

$$\max_{\{c_{1,t}, c_{0,t}, h_t, n_t\}} E \sum_{t=0}^{\infty} \beta^t \{n_t u(c_{1,t}, 1 - h_t) + (1 - n_t) u(c_{0,t}, 1)\}(1 - a_t)$$

subject to

$$n_t c_{1,t} + (1 - n_t) c_{0,t} + i_t + i_{g,t} + b_{g,t} \leq \lambda \left(\frac{k_t + k_{g,t}}{n_t}\right)^{\theta} h_t n_t,$$

and subject to the constraints on capital, i.e., Equation (4) of Section 3, where c_1 is consumption of those working in the private sector, c_0 is consumption of those not working, i is private investment, i_g is government investment, b_g is government consumption, k is private capital, k_g is government capital, a is the fraction of the population in the military, n is the fraction of the civilian population employed in the private sector, and h is the number of hours that the plant is operated. The terms of the resource constraint are per capita.

In posing the planner's problem, we have imposed some restrictions. Hornstein and Prescott (1993) show that for the class of problems that includes ours, the equilibrium consumption vector places mass on only two points. The first has zero hours and zero units of capital, and the agent receives c_0 consumption goods. The second has a positive value for hours and capital and the agent receives c_1 consumption goods. Thus, we need not search over all possible lotteries. To compute an equilibrium, we again use the procedure outlined in Appendix A. In this case, we find a function for consumption of the fraction working, $c_{1,t}$. The consumption function is chosen to approximately satisfy the intertemporal first-order condition of the maximization problem. The remaining functions are derived from the intratemporal first-order conditions and the solution for the consumption function of the working agents.

One advantage of this model over that of Section 3 is that it allows us to explore the role of capacity utilization. In Section 3, we assumed that the only way to increase current output was to change the number of hours that the stand-in consumer worked. In the environment described here, both hours per worker and the number of workers can be varied. During war, we observe large changes in both margins. In addition, during wars we see the output-capital ratio rising at the same time average productivity rises. Our previous specification was inconsistent with this fact. With variations in capacity utilization, both average products may rise concurrently. Another advantage of this model is its differential treatment of workers in the military and the private sector. Because all agents in Section 3 are ex post identical, we assume that the representative agent spends some fraction of his time in production, some fraction of his time in the military, and some fraction of his time in leisure activities. We do not distinguish civilian and noncivilian employment. As a result, we find that the hours of work decision is very sensitive to the rate of conscription since hours of work in the private sector and hours of work in the military have the same effect on utility.

In the course of analyzing this model, we have uncovered the following peculiar property. In equilibrium, hours of work *do not* vary over time. To see this, consider the first-order necessary conditions for consumption, employment, and hours of work:

$$\frac{\partial u(c_{0,t}, 1)}{\partial c_{0,t}} = \frac{\partial u(c_{1,t}, 1 - h_t)}{\partial c_{1,t}}$$

$$n_t \frac{\partial u(c_{1,t}, 1 - h_t)}{\partial l_t} = \frac{\partial u(c_{1,t}, 1 - h_t)}{\partial c_{1,t}} \lambda(k_t + k_{g,t})^{\theta} n_t^{1-\theta}$$

$$u(c_{1,t}, 1 - h_t) - u(c_{0,t}, 1) = \frac{\partial u(c_{1,t}, 1 - h_t)}{\partial c_{1,t}} \times (c_{1,t} - c_{0,t} - (1 - \theta)\lambda(k_t + k_{g,t})^{\theta} n_t^{-\theta} h_t).$$

The first condition equates the marginal utilities of the two types of agents. The second condition equates the ratio of the marginal utility of leisure of the working agent to the marginal benefit of running the plant an extra hour. The third condition equates the change in welfare caused by one more person working to the additional output produced by having an additional employee. With some manipulation of these three equations, we have the following condition:

$$-\psi^{-1}(1 - h_t)\frac{\{(1 - h_t)^{\psi}\}^{1-\omega} - 1}{1 - \omega} = (1 - \theta)h_t, \qquad \psi = \frac{1 - \gamma}{\gamma(1 - \omega) - 1}. \tag{B.1}$$

Notice that this formula involves only h_t and the parameters of the utility and production functions. Therefore, h_t must be constant in equilibrium. Furthermore, there are only two fixed points of Equation (B.1), $h_t = 0$ and $0 < h_t < 1$. This follows from the fact that the left-hand side of the equation is a concave function that is equal to 0 if $h_t = 0$, 1 if $h_t = 1$ and has a derivative equal to 1 at 0. If $0 < \theta < 1$, then the right-hand side has a slope that is between 0 and 1. Therefore, the linear function $(1 - \theta)h_t$ crosses the concave function twice, once at 0 and once at some point in (0,1). We can exclude the $h_t = 0$ outcome because it is not an optimum. Therefore, to calculate the equilibrium hours decision, we find the positive fixed point of Equation (B.1).

The prediction that hours per worker are constant is at odds with the data. At the aggregate level, hours per worker rose 20% between 1939 and 1942. Large increases were also observed in many industries. For example, the average hours worked per week in the machine tools industry rose 22.6% between 1939 and 1942.[14] Thus, while this model can account for the growth in total factor productivity during World War II, its predictions for hours per worker do not match up with the observations in the data.

One way of resolving this problem is to allow for differential costs of entering the labor force. It is unlikely that the disutility of a woman with six children who enters the labor force is equal to that of a woman with no children. Suppose that individual preferences are given by

$$E \sum_{t=0}^{\infty} \beta_t \{u(c_t, 1 - h_t) - \eta \chi_{\{h_t > 0\}}\},$$

where η measures the disutility of entering the work force, and χ is an indicator function. If the utility costs of entering the work force vary, η will have a nondegenerate distribution. If civilians are aligned with points on the interval $[0, 1 - a)$, then we can construct a cost function. For example, suppose that agents are aligned in such a way that costs are represented by a linear, increasing function. Then, in the aggregate, the costs of increasing employment are given by

$$-(1 - a) \int_0^n (\xi_0 + 2\xi_1 s) ds = -(1 - a)\{\xi_0 n + \xi_1 n^2\}, \xi_1 > 0,$$

where a is the fraction of people in the military, and n is the fraction of civilians who work. If preferences are redefined with this additional term, it is no longer true that hours per week remain fixed in response to large fiscal shocks. If the costs of increasing employment are high, it may be optimal to vary hours. The magnitude of costs required to produce plausible variation in hours per worker is an open question.

14. See the December 1942 issue of the *Survey of Current Business* for average hours in other industries.

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Comment

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During World War II in the United States, real production boomed. The sudden surge in aggregate demand from government wartime spending was accompanied by a surge in production and employment. Private consumption and investment fell. Real interest rates fell to less than zero. Real wages and labor productivity rose significantly.

I have never thought that economists should try to account for the World War II experience using a market-clearing, competitive model. The government did much to create false prices, shortages, and market failures during the war: Episodes of rationing and indicative planning, negotiations between corporatist groups of executives and Galbraith's OPM, and direct control of resources—primarily labor through the draft and its pattern of exemptions, but also capital—fill administrative histories of World War II. Moreover, the government tried to operate its war economy by changing tastes themselves: They tried to create a taste among women and other secondary workers for defense work, and they tried to create a taste for holding government debt independent of the coupon it paid. Looking at the speed of the shifts in employment patterns, and at the willingness of U.S. investors to hold government bonds during the war, I think the government was relatively successful.

Nevertheless, Braun and McGrattan try to account for the U.S. World War II experience (and for the British experience and World War I experience) using a market-clearing, competitive model. They focus on an anomaly that Rotemberg and Woodford (1992) pointed out: In a competitive model, increased labor input is associated with lower labor productivity and lower real wages. But labor productivity and real wages were high during World War II—between 30 and 40% higher than one would have expected before the war. Rotemberg and Woodford interpret increased productivity (and real wages) as employment expands as a sign that the representative firm is operating at less than efficient scale, and following Hall suggest that the representative firm is best modeled as an imperfect competitor.

With this point Braun and McGrattan take issue. They argue that a competitive model is perfectly capable of generating an increase not only in output and employment but also in productivity and real wages as a consequence of an increase in government purchases. "Suppose," Braun and McGrattan say, "the government is providing firms with capital to be used in production . . . [W]ages and productivity . . . will eventually rise [in response to a demand shock] if government investment produces a large enough shift in the labor demand schedule." Productivity rises with a government spending demand shock because the government spending demand shock is associated with an increase in the capital-labor ratio and, thus, in the productive capacity of the economy. They calibrate the model and find that "historical fluctuations in government investment during World War II are of a sufficient magnitude to predict a positive correlation between hours and productivity during periods of war."

On reading this, my first thought was skeptical. In 1958 dollars, pre-World War II GDP was about $200 billion. Braun and McGrattan report that the U.S. government had invested $25 billion (in 1958 dollars) in government-owned but privately operated (GOPO) capital by 1943. If one assumes this capital yielded a gross return of 20% per year, the U.S. government's investments would have boosted 1943 output by $5 billion—2.5%. But between 1938 and 1943, real wages in manufacturing and labor productivity rose between 30 and 40%. It is hard to see how the government's investments could have more than a second-order impact on the cyclicality of labor productivity during World War II.

How, then, do Braun and McGrattan manage to conclude otherwise: that GOPO capital is of first-order importance in explaining procyclical productivity during World War II? One part of the answer is that their capital stock measures appear too low. The capital stock aggregate that they use, which is shown in Figure 2, is equipment and structures in manufacturing—a much smaller aggregate than the total capital used to produce GDP. They have implicitly assumed a very high marginal return to investments in manufacturing capital—their 36% capital share combined with a capital output ratio of 0.4 implies a *private* return on investment of 90% per year.

Moreover, there appears to be an additional, more important factor. The \$25 billion 1958 dollar investment in capital by the government between 1938 and 1943 has, in Braun and McGrattan's production function with $\rho = 0.5$, the same effect on productivity as a 2.5-fold multiplication—from \$80 to \$194 billion—in the private manufacturing capital stock. The rate of return on GOPO capital in Braun and McGrattan's model appears to be four times the rate of return on private investments—360% per year. In Braun and McGrattan's model with $\rho = 1.0$, the return is only one fourth as much but is still very large relative to the returns to privately owned and operated capital.

Thus, in Braun and McGrattan's setup, government investments in capital are the ultimate free lunch. Their model implies that an activist U.S. government should strain every nerve to create GOPO capital—and would be enormously successful if it did so.

The implication, of course, is that Braun and McGrattan's calibration is badly awry. The government did invest substantially in capital during World War II, and it did lease this capital out to private firms to operate. But when Braun and McGrattan write of what GOPO capital was, they write of increases in "the productive capacity of the automotive, aircraft, and aluminum industries." They write of how producers, uncertain of postwar demand, demanded that the government finance a share of their expansion of capacity—not of how producers asked that the government provide special types of capital that it alone could make that would make private investments more productive.

Why is GOPO capital so productive in Braun and McGrattan's setup? In one model they simply assume that private and GOPO capital are strong complements. In another model in which government-owned and privately owned capital are perfect substitutes, high productivity during the war cannot be attributed to a high level of government-owned capital because the correlation of government-owned capital and output is negative.

Why do Braun and McGrattan get caught in this particular trap? I think (and here let me beat my own drum) that the reason is that they are not economic historians. An economic historian telling the story of increased productivity during World War II would find it difficult to avoid discussing the details of at least one industry. And for historians, God is in the details. Braun and McGrattan write of how GOPO capacity is important in the aircraft, aluminum, and automobile industries. But they do not go back to the details of any one industry—do not even think of returning to the aircraft production industry, and showing how private productivity was significantly enhanced by government-owned capital. They remain at the level of the macroeconomist. They do not descend to the level of the economic historian, where complementarity of capital goods calls for demonstration that the productivity of each kind of capital good was greatly multiplied by the presence of the other.

So I conclude that Braun and McGrattan have not made a case that procyclical productivity in World War II is consistent with a competitive model. Labor productivity increased by 30% in the United States during World War II—an extra gain in output of roughly 60 billion 1958 dollars a year. If this had been generated by additional capital yielding 20% per year, the investments would have to be on the order of 300 billion 1958 dollars. But Braun and McGrattan have only 25 billion dollars of GOPO capital. The effects they point to are there but are only one tenth the size needed to account for the World War II experience.

What about the other 90% of the productivity gains of World War II? What accounts for them? Some part is surely generated by increased work effort: People work harder if the job is not just to earn money but is worth doing for its own sake to defeat Hitler. Some part is surely generated by the imperfect competition mechanisms of Hall, and Rotemberg and Woodford. Some part is surely the high valuation we place on military goods—whose value is determined not by consumers but by governments. But we do not have a good breakdown. It is good to have a good account of even 10%.

Comment

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This paper is in three parts. The first part is my favorite. It lays out a great number of interesting facts concerning the two world wars in both the United Kingdom and the United States. There are clearly some similarities between the two experiences because output and productivity rose in all four episodes. But, what is probably even more interesting are the differences between the U.S. and the U.K. behavior of employment and real wages.

The second part of the paper presents a general equilibrium model that captures Braun and McGrattan's theory of why productivity and output rose in the first place. Their theory of the initial expansion in output is traditional: Output rose because there was an increase in labor supply, which was itself the result of the wealth reduction brought about by the war. What is more novel is their theory of why productivity rose. They attribute this to an increase in government-owned privately operated (GOPO) capital. In calling for increased focus on GOPO, the authors are surely right. GOPO capital is, as pointed out initially by Robert Gordon (1969), a very large component of capital by the end of the war.

The third part of the paper argues that the model and, thus, GOPO capital, can explain the behavior of productivity and real wages in the aftermath of increases in military spending. This is the weakest part of the paper. I feel that much more effort needs to be spent analyzing the specific consequences of the GOPO program before we will know its contributions to productivity and real wages.

I will start my discussion by talking about the model. Then I will talk about the evaluation of the contribution of GOPO capital. Then, finally I will have some comments on the difference between the U.S. and the U.K. behavior of real wages.

1. *The Model*

Their model is one where output is produced with a production function that depends on the aggregate labor input, the aggregate private capital stock, and GOPO capital. The model assumes that, except for the choice of GOPO capital, the other economic decisions are made by a central planner who maximizes expected discounted utility. I must say that I preferred the previous version of this paper where the outcome was decentralized and production decisions were made by firms.[1] In that earlier version, the firms were perfect competitors who had each been given an endowment of GOPO and sold their output at marginal cost.

Both versions suffer from the problem that output in the model differs from measured GNP. In the current paper, the value of output is the value of what is produced with all three inputs. That would correspond to measured GNP only if all this output were sold in the market. In the previous version, this was even clearer because the firms did indeed sell all their output to the government at marginal cost.

1. One advantage of dealing with a market equilibrium is that there it gives a rationale for aggregating the outputs of different goods by using their prices as weights as is done in the National Income Accounts. The reason is that, in a competitive equilibrium a good that gives ten times as much utility as another will have a price ten times as large. There is then some basis for saying that one unit of this good adds ten times as much to consumption, investment, or government purchases. By contrast, prices don't need to play any role in a centrally planned economy.

But, at least in the United States, the government was also the sole purchaser of the output produced with GOPO. This matters because there is no reason for the government to pay the firms the entire value of the output. Indeed, if the output is sold at marginal cost even though the firms have been given a GOPO endowment, then the firms will make positive profits.

In the United States, plants with GOPO were operated under two regimes. In one regime, the government hired the private company as a contractor and made a payment for the services provided by the contractor. In another (called "Cost Plus Fixed Fee"), the government reimbursed the contractor for its cost and added a prespecified profit. In either case, we would not expect the firms to make any unusual profits; there would be no reason for the government to pay for the services of the capital that it had itself provided. Thus, the payments from the government would fall well short of what it would have to pay to buy the same goods in the open market. But, it is only these payments from the government, rather than the value of total output, that are counted in GNP. (The reason is that GNP does not include the services provided by government-owned capital.) Thus, the authors overstate the theoretical effects of government purchases on GNP.

2. *The Evaluation of the Model*

The existence of price controls and rationing make it unlikely that any general equilibrium model is exactly right, and this may well be the reason why the authors moved to a specification where prices play no role. It would have preferred it if, instead, they had made a larger effort in specifying which parts of the model can be tested even in the presence of rationing. Given the widespread rationing of consumer goods, it seems reasonable to believe that the marginal rate of substitution between consumption and leisure could well be different from the published ratio of the nominal wage to the CPI. My sense is that, instead, Braun and McGrattan are mainly concerned with explaining the behavior of productivity and real wages with a model where price is always equal to marginal cost and where there are diminishing returns to labor. Insofar as firms were not rationed in the amount of inputs that they could buy or in the amount of output they could sell, the validity of this part of the model can be ascertained with productivity and real wage data for the period.

Braun and McGrattan are surely right that GOPO contributed to productivity growth and to the rise in real wages during the World War II period in the United States. The question they have not settled is how

Table 1 OUTPUT AND THE AVERAGE PRODUCT OF LABOR IN SELECTED INDUSTRIES[a]

	Stone, clay, and glass		*Food and food products*		*Tobacco products*	
Year	*Output*	*APL*	*Output*	*APL*	*Output*	*APL*
1940	100	100	100	100	100	100
1941	125.97	104.57	112.40	105.04	110.33	105.76
1942	125.48	104.25	126.19	105.83	120.50	109.67

[a]The output series is the industrial production index from the Federal Reserve Bulletin. The hours series needed to construct the average product of labor are constructed by multiplying "Factory Employment" with "Average Hours Worked per Week" from the same source.

much GOPO contributed. It appears from their discussion that they think GOPO explained a very large fraction of the increase in productivity and real wages. That seems unlikely to me. First, this view is inconsistent with the post-World War II facts. As Hall (1988) and Rotemberg and Woodford (1992) have shown, productivity and real wages also rose together with military purchases after World War II even though GOPO did not exhibit unusual growth during the Korean or Vietnam Wars. Whatever led productivity and real wages to rise in this other period must have been at work in World War II as well.

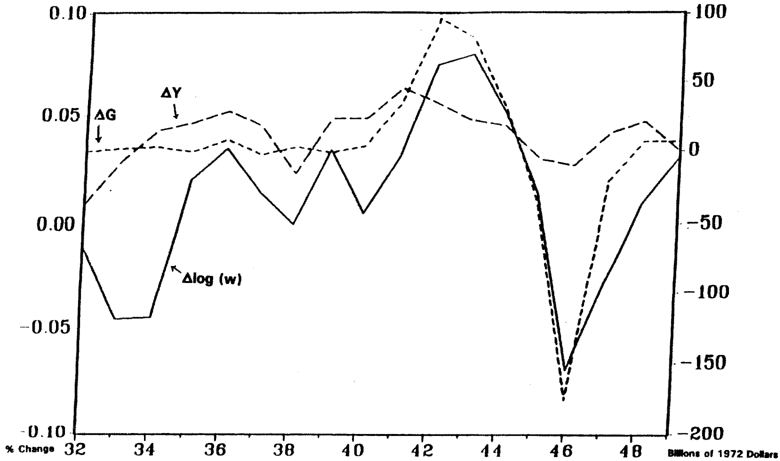
There is also some more direct evidence that GOPO can't be the whole story. First, I analyzed the behavior of output and average labor productivity in industries where GOPO was not important. Table 1 shows the behavior of output and the average product of labor in Stone, Clay, and Glass; Food; and Tobacco for the years 1940–1942.

The output and the productivity of all three industries rose from 1940 to 1941. The Food and Tobacco industries became important suppliers for the war effort, and their output continued rising from 1941 to 1942. What is interesting is that, in spite of the absence of significant GOPO in these industries productivity rose as well. From 1941 to 1942, the Stone, Clay, and Glass industry contracted because construction slowed down considerably. As we would expect from Hall's findings for the postwar era, productivity in this industry fell as well.[2]

Figure 1 shows evidence that GOPO does not explain the entire increase in real wages either. This figure, which was part of early drafts

2. If one takes the view of Rotemberg and Woodford (1992) that increases in military purchases raise economic activity by raising labor demand, then the fall in construction activity also rationalizes the fall in the real wages of skilled building workers documented in Bry (1960) and cited in Braun and McGrattan's paper.

Figure 1 WAGES, FEDERAL PURCHASES, AND PRIVATE VALUE ADDED IN THE UNITED STATES



of Rotemberg and Woodford (1992), shows the changes in real military purchases, in privately produced real value added and the changes of the logarithm of real wages. Real wages are deflated by the deflator for private value added, which is what is relevant if one is asking about the relationship between the marginal product of labor and the real wage.[3] We see that there was already a substantial increase in real wages between 1940 and 1941, even though GOPO capital at the end of 1940 (i.e., capital we would typically view as available for 1941 production) was trivial.[4] It also shows that real wages declined together with private output and military purchases in 1944–1946. While this is not shown in Figure 1, productivity declined as well at the end of the war. But, GOPO capital rose significantly from 1942 to 1945 and stayed high thereafter. Thus, I think it is impossible to explain either the timing of the increase in real wages and productivity or their subsequent fall at the end of the war by attributing them exclusively to the changes in GOPO.

3. Braun and McGrattan use the real wage deflated by the CPI. This is the wage that would be relevant if they were looking at the first-order condition relating the real wage to the marginal rate of substitution of consumption for leisure.

4. According to the BLS *Fixed Reproducible Capital in the United States, 1925–1979* (1982), there was less than $1 billion 1972 dollars of GOPO capital at the end of 1940. This compares with $8 billion at the end of 1941, $28 billion at the end of 1942, and $47 billion at the end of 1944.

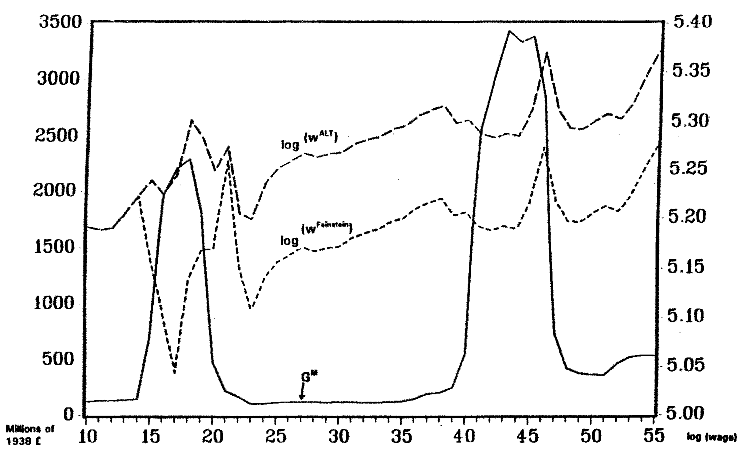
3. *The United Kingdom versus the United States*

I want to close by commenting on the difference in the behavior of real wages in the United Kingdom and the United States. This difference has been noted before by Correia, Neves, and Rebelo (1992), who argue that the negative correlation between real wages and military purchases in the United Kingdom provides evidence for the standard neoclassical model of government spending. This negative correlation is principally due to the behavior of British real wages during World War I. The problem is that measuring British real wages in this period is apparently subject to great difficulty.

For the period with which I will be concerned, i.e., that from 1914 to 1924, the authors use the index of wages presented in Feinstein (1972). As pointed out by Dowie (1975), this index is identical to that which Bowley first published in 1921 and then supplemented in monthly issues of the *London and Cambridge Economic Service Bulletin*. Dowie (1975) criticizes this index and recommends that for the period 1914–1924, one use instead Feinstein's (1972) index of weekly earnings. The use of this alternative index makes a big difference.

Figure 2 presents data on both real expenditures on national defense and two series for British real wages. The first is the wage series in Feinstein (1972) that Braun and McGrattan use, though I have deflated it by the GDP deflator. The second, alternative series, uses the Feinstein wage series up until 1914. From 1914 to 1924, it uses instead the percent-

Figure 2 WAGES AND NATIONAL DEFENSE PURCHASES IN THE UNITED KINGDOM



age changes in the Feinstein *earnings* series, which it applies to the 1914 base. Finally, I follow the authors and use the percentage changes in the Feinstein *wage* index from 1924 on. Because the alternative series grows 20% more between 1914 and 1924, the line representing the alternative wage remains above the original series after 1924. If one uses this alternative wage series, real wages rise together with military purchases during World War I.

As Dowie (1975) shows, the problem with the original Bowley (1921) series, which is the basis of the Feinstein (1972) wage series, is that Bowley himself later changed his mind about the growth rate in nominal wages from 1914 to 1924. While his original index grew by 74% in this period, he concluded in Bowley (1952) that earnings for a "normal week" grew by 94% in this period. Moreover, Bowley is quite explicit that this growth in weekly earnings does not involve any changes in hours worked. He says, "The intention throughout has been to measure the change in wages paid for unchanged work in the number of hours that at each date constitute a normal week without overtime or short time" (Bowley, 1952, p. 500). As further confirmation that he viewed hourly wages as having risen by 94%, Bowley (1952) provides a new wage series that grows by that amount between 1914 and 1924. The problem with this newer Bowley series is that, as pointed out by Dowie (1975), it is quite arbitrary. It simply spreads evenly over the 1914–1919 period the difference between the 74% increase of the original series and the 94% that he ultimately deemed accurate.

These problems lead Dowie (1975) to prefer the Feinstein (1972) series on weekly earnings. In principle, changes in this series could be due not only to wage changes but also to changes in hours worked. However, as Dowie reconstructs this series, changes in hours worked appear to play no role in the measurements between 1914 and 1924. In particular, Feinstein's (1972) earnings series grows by 94% from 1914 to 1924 as the hourly wage series is supposed to. Moreover, the movements in the series from 1920 to 1924 are based on the movements of published wage data that are not affected by changes in hours.

My conclusion from this is not that I am sure that real wages really did indeed rise with military purchases during World War I. It is rather, as Dowie (1975) also concludes, that we have very little reliable information on this question. The data do seem more reliable for World War II. British real wages also rose in World War II although, admittedly, only well after military purchases became substantial. What is striking is that, as in the United States, real wages fell together with military purchases at the end of the war.

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Discussion

Bob Gordon, "Mr. GOPO himself" according to Olivier Blanchard, had several remarks. First, he agreed with the basic idea expressed in the Comment by Brad De Long, which is that at $25 billion GOPO was just too small to explain why real GDP in 1958 dollars increased by more than $100 billion. Second, Gordon noted that the experience in the U.S. economy immediately following World War II is also instructive. Per capita GDP fell substantially after the war until around 1950. Similarly, productivity growth declined before picking up during the period 1948–1951. The reason for these movements, Gordon suggested, is the Korean War: Much of the GOPO capital sold to private operators after the war was specifically tailored to wartime use. Military expenditures as a share of GDP jumped to 10% during the Korean War, and this post-World War II variation may be useful in pinning down the contributions of GOPO capital.

Finally, Gordon emphasized the importance of capacity utilization in understanding the procyclicality of labor productivity. Capital services rather than the capital stock is the correct input into the production function, and if the number of worked shifts increased during the war, this difference can be important. In terms of separating this effect from the contribution of GOPO capital, Gordon suggested that examining the nonfarm, nonmanufacturing sectors, which employed very little GOPO capital, could be used to control for utilization-related jumps in productivity.

Braun remarked that GOPO capital is only one of the factors driving the results. Much of the dynamics arise from the standard models of the response of the economy to a temporary rise in government purchases. The contribution of GOPO is to produce an increasing capital stock during the war, which can help to explain the rise in hours worked and productivity.

Several participants including Geoff Carliner and Inderjit Singh wondered about the role of rationing and patriotism during wartime. In particular, Carliner noted that the results of the competitive model ignoring rationing predict consumption fairly accurately. Does this mean that rationing played no role? McGrattan responded that the paper abstracts from many things, including rationing, patriotism, learning by doing, and capacity utilization. The purpose of this abstraction was to focus on a simple model in which the government extracts hours through conscription and output for investment to see how successful such a model would be. Responding to Carliner's specific point, McGrattan suggested that rationing would likely change the results, but it is not clear exactly how they would change.

Carliner also asked why people stored their wealth in government bonds during the war. Shouldn't they have anticipated that the repayment of the postwar debt would occur through seignorage as well as taxation when the wartime price controls were released? Bob Hall noted that traditionally the government induced bondholding and an increased labor supply by promising, contingent on winning the war, postwar deflation. For example, this was the approach taken in the United States during the Civil War and, to some extent, after World War I. World War II was the first clear situation in which the government failed, opportunistically in fact, to deliver on the implicit promise of a high return on its wartime debt. In so doing, the federal government probably lost the ability to induce the labor supply response through this traditional mechanism.

Singh suggested that the discussion of the effects of large increases in government expenditure on the economy led naturally to the question of what would happen if government expenditures were to fall drastically, as is currently the case in much of Eastern Europe and the former Soviet Union. Would a similar analysis apply, or would the difference in organizational structure be overwhelming?