Robert Gordon has argued that the case is “overwhelming” for the “economic miracle interpretation of World War II along every conceivable dimension…” In particular, he argues that the experiences of wartime production – learning by doing and process innovation – laid the supply foundations for output and productivity growth in the postwar period. Gordon’s claims have formed the basis of the conventional wisdom for decades. They are not novel and, as this paper will show, they are almost certainly wrong. The learning achieved in the extraordinary, and never to be repeated mass production of ships, aircraft, and military hardware between 1942 and 1945 had little relevance for the postwar period. The disruptions of war retarded a strong prewar trajectory of productivity advance. Aggregate TFP and labor productivity growth was substantially lower across the war years than it had been between 1929 and 1941. Within US manufacturing, productivity advance between 1941 and 1948 was negative, and substantially lower between 1949 and 1973 than it had been in the interwar period.
The Impact of World War II on the Growth of U.S. Potential Output

Robert Gordon’s *The Rise and Fall of American Growth* brings to a popular audience as well as many economists an interpretation of the broad contours of US economic growth since 1870. In this book Gordon considers the evolution of productivity, consumption, and more generally the standard of living in the United States from the end of the Civil War to the present day. Although his work is determinedly historical – sixteen of eighteen chapters focus principally on the past -- it is the pessimistic forecast for the future developed in chapters 17 and 18 that has generated the lion’s share of critical discussion and commentary. The debate has featured dueling TED talks from Gordon on the one hand and Eric Brynjolfsson and Andrew McAfee on the other, as well as optimist rebuttals to Gordon from his colleague Joel Mokyr, Deirdre McCloskey, and others.¹

Perhaps understandably, the historical sections – the bulk of the book -- have received less critical scrutiny. Skillfully blending qualitative and quantitative evidence, Gordon’s narrative brims with the enthusiasm of discovery and is enriched by personal anecdote and insights derived over a long career. Yet one aspect of his narrative remains particularly problematic: his interpretation of the economic impact of the Second World War, particularly its effect on US aggregate supply. This paper explores the difficulties with his argument and makes the case for a different interpretation.

Gordon originally settled on One Big Wave as his way of calling attention to the strong TFP growth that characterized the second and third quarters of the twentieth century in the United States. As a metaphor about levels, this never quite fit, since when a wave is past it leaves the water at its original level, whereas this wave left TFP levels and our standard of living permanently higher. It works somewhat better when applied to rates of growth rather than levels, although levels are what comes most readily to mind. In any case, Gordon has now dropped this catchphrase and adopted instead that of a Great Leap Forward. The idea of applying this language to TFP growth in the 1930s originated with Field (2011).

Gordon cites William Baumol as evidence that the idea of a ‘great leap’ was current in the literature a quarter century before Field published (Gordon, 2016, pp. 706-07). But Baumol’s ‘leap’ was quite different from Field’s. Baumol used the words to apply to a period after 1941, accepting the then conventional wisdom that productivity advance was below trend between 1929 and 1941 and above it thereafter: “It is noteworthy that the great leap above historical US productivity growth in the war and early postwar years were just about as great as the previous shortfalls during the Great Depression.” Baumol’s view epitomized what had for decades been the conventional view of the Depression and the war. Whereas Gordon accepts Field’s revisionism regarding (at least moderate) productivity advance between 1929 and 1941, he persists in retaining (but repackaging as new) the “economic miracle” interpretation of the supply side effects of the war, arguing that TFP growth across the war years greatly exceeded that during the Depression. While Field and Gordon agree that high TFP growth rates characterized the second quarter of the twentieth century of the United States, they disagree about the relative contributions of the depression and war years.
Gordon’s view of World War II is announced clearly at the start of his chapter 16: “The most novel aspect of this chapter is its assertion that World War II itself was perhaps the most important contributor to the Great Leap” (p. 537). That statement included the qualifier ‘perhaps’, but as Gordon warms to his argument, he abandons hedging: “In fact this chapter will argue that the case is “overwhelming” for the “economic miracle” interpretation of World War II along every conceivable dimension…” (Gordon, 2016, p. 537). Gordon’s claims have formed the basis of the conventional wisdom for decades. They are not novel and, as this paper will show, they are almost certainly wrong.

World War II confirms the fundamental Keynesian prediction that massive fiscal stimulus combined with expansionary monetary policy can bring a depressed economy to superfull employment within a very short time. There is little evidence, however, to suggest that production experience during World War II gave the economy a powerful permanent boost on the supply side. The learning by doing and process innovation resulting from the mass production of military hardware during the war was largely irrelevant given the product mix and factor prices prevailing after the war. The government funded expansion of war related plant and equipment (GOPO capital), to which Gordon has devoted much attention (Gordon, 1969), had much weaker long run effects on aggregate supply than did the streets and highways, bridge, tunnel, and hydro construction of the 1929-41 period.

Gordon suggests that the ‘economic miracle’ of the second World War propelled total factor productivity to a permanently higher level, and was largely responsible for setting the stage for the golden age of labor productivity growth (1948-73). He explains why: “The most obvious reasons why productivity remained high after the war was that technological progress does not regress. People do not forget. Once progress is made… it is permanent” (Gordon,
2016, p. 550. After the war, “As they struggled to fill orders that seemed almost infinite, they adopted all that they had learned about efficient production in the high pressure economy of World War II” (p. 550).

Gordon adduces no data in support of this view. He repeats the oft cited examples of learning by doing building Liberty ships and aircraft, and then argues that “the shipyard example can be generalized to the entire manufacturing sector” (p. 549), and that “Every part of the postwar manufacturing sector had been deeply involved in making military equipment or its components, and the lessons learned from the war translated into permanent efficiency gains after the war” (p. 550). The involvement of US manufacturing firms in wartime production was indeed broad. The second part of the statement, as we will see, is questionable.

The effects of learning by doing on productivity in shipbuilding, aircraft, and other military ordnance are well known to economists (Arrow, 1962; Alchian 1963). What has not been demonstrated are the effects of wartime production experience on levels and rates of TFP growth in the postwar period. These effects should have been most apparent within manufacturing, a sector which reached its peak in terms of share of value added and labor force employed in the 1940s. Productivity advance in the private nonfarm economy did not cease between 1941 and 1948. But the main contributors to it were sectors other than manufacturing, in particular wholesale and retail distribution, railroad transportation, and electric and gas utilities. War did inspire process innovation, but in many cases the innovation was in response to, and especially suited to a highly unusual set of input availabilities and implicit factor prices, conditions which would disappear with the end of the war. Construction firms, for example, faced with shortages of structural steel, developed kiln dried wood forms called, due to their shape, thunderbirds. These served as effective roof bearing substitutes in many of the one story factory buildings.
hastily erected by the federal government (Walton, 1956, p. 214). This innovation, however, was a response to a materials shortage that would not persist. It was of little relevance in the postwar period.

What of the effects of learning by doing? The argument that World War II production experience had positive persisting effects on aggregate supply almost always begins with the Liberty ships and goes on to cite examples of the inverse relationship between cumulated output and the unit labor requirements for B-24s, C-47s, or Oerlikon antiaircraft guns. These gains, while real, did not generalize to the rest of the economy during the war, and did little to boost either civilian or military production capability after it. The manufacture of most of these products had ceased by V-J day. In contrast to what was true during the war, postwar military hardware had limited production runs and much higher costs per unit.

There is also good reason to doubt that the wartime diversion to military production advanced the production of consumer durables after the war. Following Pearl Harbor, the government prohibited, effective January 1, 1942, all sales as well as the delivery of previously ordered cars, trucks and parts. Effective February 22, 1942, the production of all US passenger vehicles, commercial trucks, and auto parts ceased. Half-finished assemblies, along with many specialized dies, were sent to salvage to be melted down and recycled. Car dealers retained an inventory of 520,000 vehicles produced but not yet sold; these with a special permit could purchase one during the war. Design work on new models ceased completely for thirty months. It resumed again in the fall of 1944, subject to the restriction that it not interfere with still ongoing war work. Production of new vehicles recommenced in October of 1945. The situation

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2 Guns and (military) ships were in fact the biggest ticket hardware items in the US war effort (Smith, 1959, p. 7).
with respect to truck technology is somewhat more nuanced. The US produced close to 2.4 million light, medium, light-heavy, and heavy-heavy trucks between 1942 and 1945 (Smith, 1959, p. 9).

Refrigerator and appliance production likewise ceased during the war. Commercial television had been introduced at the 1939 New York World’s Fair, but the war delayed large scale production and take up for at least six years. Production of TV sets was completely prohibited between April of 1942 and August of 1945. Learning by doing in each of these commodity classes ceased, and there were few spillovers from experience gained building B-17s or Sherman tanks.

Even M&Ms, originally sold only to the military during the war, had been patented in 1941 with production beginning prior to Pearl Harbor.

Undoubtedly the war propelled forward many military technologies, including the beginnings of the move from piston driven to jet aircraft, the supplanting of the battleship by the aircraft carrier, the development of rocketry, and of course the atomic bomb. On the other hand, aircraft design was advancing rapidly during the 1930s, and jet aircraft might well have arrived as quickly in the absence of the conflict. Similarly, the B-29, the one combat aircraft that had not already flown by 1941, advanced monocoque technique – the external skin of the plane contributed to its structural integrity – but the design concept went back decades—and the last generation of propeller driven bombers likely would have had it with or without the war. Nuclear power is a tougher call, but its benefits in the postwar economy were mixed: the technology never delivered on its early promise of electricity too cheap to meter. On balance, a stronger case can be made that learning by doing producing automobiles and refrigerators during the 1920s and 1930s enabled the mass production of military hardware during the war, as opposed to
the claim that the latter laid the groundwork for advances in producing automobiles, refrigerators, and televisions in the postwar period.

The war did leave significant institutional and economic legacies for the United States. Experience with high tax rates and the introduction of withholding gave the federal government expanded fiscal capacity. Controls on wages led inadvertently to our system of largely employer provided health care insurance. And the war presaged, after a brief lull, permanently higher levels of military spending, which had persisting regional economic effects (Wright, 2017). It is unlikely, however, that it contributed to a large jump in potential output or productivity. The United States was at war for less than four years during the 1940s. Full scale war production was concentrated in an intensive 16 month period. This experience did not magically transform the doom and gloom economy of the 1930s so that in 1948 the US stood astride the world economy like a colossus. Most of the foundations for that dominance were already in place by 1941.

The Macro Evidence

Gordon’s book contains many useful and informative charts and figures. His figure 16-5 is an exception in this sense. Although it appropriately highlights the generally strong TFP growth between 1920 and 1970, as compared with the years prior to and following these years, its identification of the 1940s as the locus of peak TFP growth is problematic. According to this figure, TFP growth in the 1940s was almost twice as high as during the 1930s: 3.4 vs 1.8 percent per year.

We know that there are strong cyclical effects on productivity, which is why it is so important to measure TFP growth rates between years where the economy is at or close to potential. It is a principle to which Field (2003, 2011) and Abramovitz/David (2000) adhered, as
for the most part has Gordon. Figure 16-5 violates this rule by simply reporting decadal growth rates of TFP. 1940 was considerably below potential: unemployment was close to 15 percent. 1941 is the closest we can get to potential prior to the distortions of the economy associated with full scale war mobilization. For the postwar peak 1948 is preferable to 1950 – since the unemployment rate was lower in 1948 than in 1950. And 1929 is preferable to Gordon’s sometime preference for 1928; since unemployment was lower in 1929 in the absence of any evidence of goods and services price inflation. Either should be preferred to 1930, which had an 8.7 percent unemployment rate.
But the choices of 1948 vs. 1950, or 1928 or 1929 in lieu of 1930 are relatively minor issues. The bigger problem with the story told by figure 16-5 is the use of 1940 as a benchmark. Because of the procyclicality of TFP, measured productivity levels were substantially lower in 1940 than in 1941, reducing a calculated growth rate to 1940 and increasing a calculated growth rate from 1940-50, as compared with calculations that measure to and from 1941.

Gordon has a long history of making various adjustments to labor and capital input that change measured TFP growth rates between benchmark years. He originally identified 1928-50 as evidencing peak TFP growth, and it is this chronology that he featured in several editions of his macroeconomics textbook, beginning in 1993 and extending through the eighth edition in 2000. Sometime around 2000 he made a new set of adjustments that tipped the balance towards 1950-64.

Field (2003; 2011, pp. 27-30) expressed skepticism about the net effect of these adjustment and the then newfound enthusiasm for 1950-64. Gordon has now shifted back to locating his great leap in the second quarter of the century. Nothing in Figure 16-5 now suggests that 1950-64 evidenced peak TFP growth. The questions remaining are when during the second quarter of the century peak advance occurred and whether wartime production experience had persisting beneficial effects on TFP growth in the postwar period. Gordon quotes Abramovitz and David: “the war … imposed restrictions on civilian investment, caused a serious reduction in private capital accumulation and retarded normal productivity growth.” (p. 547). Gordon states that
because of his ‘new’ interpretation, that view is “called into question.” Field and Abramovitz/David, in contrast, have contrary views on the effects of the war.³

**Is Gordon’s estimate of TFP growth in the 1940s plausible?**

Chain indexed real output growth between 1940 and 1950 was 5.6 percent per year (Bureau of Economic Analysis, NIPA Table 1.1.6). Gordon has TFP growth between 1940 and 1950 at about 3.4 percent per year (figure 16-5). That leaves 2.2 percent per year for the combined contribution to growth of increases in labor and capital input. That’s possible. But we were well below potential in 1940. We do not want to measure from trough to peak.

Real output growth between 1941 and 1950, from the BEA, was 4.2 percent per year, which means, if Gordon’s 1940-50 TFP growth rate of 3.4 percent is an acceptable proxy for its growth rate between 1941 and 1950, that only .8 percent per year is left for the combined contribution to growth of increases in capital and labor input.

Kendrick (1961, Table A-XXII) has private domestic economy labor input growing at 1.07 percent per year between 1941 and 1950.⁴ The BEA’s Fixed Asset Table 1.2, line 3 shows private sector fixed assets growing at 2.09 percent per year over the same period. Weighting labor input growth by .7 and capital input growth by .3, we have growth of conventional inputs at about 1.4 percent per year. TFP could not have been growing at 3.4 percent per year between 1941 and 1950, simply because $3.4 + 1.4 > 4.2$. Given these estimates of the growth of real

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³ Field, however differed with Abramovitz/David’s interpretation of the twentieth century as reflecting a reliance on knowledge based growth fundamentally distinct from the nineteenth. Field argued that Abramovitz/David generalized from the high TFP growth of the first half of the century, a generalization which the data from the second half did not support. In particular, he argued that TFP growth in the last third of the twentieth century was lower than it had been during the comparable period in the nineteenth.

⁴ Labor input is ‘quality adjusted’: Kendrick weighted different categories of labor by their respective wage rates. Unweighted manhours grew at .56 percent per year.
output, capital services, and quality adjusted labor input, the highest that total factor productivity growth between 1941 and 1950 could have been was 2.8 percent.

But that is before a cyclical TFP adjustment for 1941. Unemployment was still just under 10 percent for that year. Because of TFP procyclicality, a cyclical adjustment will raise the TFP estimated growth rate for 1929-41 and lower it for 1941-50 (or 1941-48). Field (2010) estimated, based on more than a century of data, that each one percentage point reduction in the unemployment rate adds roughly 1 percentage point to the growth of TFP, above and beyond trend (Field’s law). A cyclical adjustment based on this regularity adds close to a half a percentage point to the 1929-41 growth rate of TFP, and subtracts even more from the 1941-48 or 1941-50 rate.

It makes a big difference whether we measure to 1941 as opposed to 1940. Real chained output growth between 1929 and 1940 is 1.64 percent per year; between 1929 and 1941 it is 2.87 percent per year. Gordon has TFP growth for the 1930s at about 1.8 percent per year. Let’s explore whether that could plausibly be a good proxy for the 1929-41 rate. Between 1929 and 1941, private sector quality adjusted labor input was basically unchanged, declining at .06 percent per years (hours decreased at -.26 percent per year (Kendrick, 1961, table XXII)). Private fixed assets increased at .22 percent per year (BEA). Weighting capital growth by .3 and labor growth by .7 we have inputs conventionally measured increasing at .07 percent a year. Given the BEA data which indicate output growing at 2.87 percent per year, we have TFP advance between 1929 and 1941 growing at about 2.8 percent per year. This is already a percentage point higher than suggested by Gordon’s table 16.5. And this is before a cyclical adjustment.
Based on Field’s law, we can ask what the level of 1941 TFP would have been had unemployment been 3.8 percent (as in 1948) as opposed to the actual 9.9 percent. The 1941 level would have been about 6 percent higher, which adds about .5 percentage points to a TFP growth rate calculated over the period 1929 – 1941 (3.3 = 2.8 + .5). At the same time, a cyclical (upward) adjustment for 1941 TFP reduces 1941-50 TFP growth from the previously calculated 2.82 percent per year to 2.15 percent per year. Using the adjusted 1941 level and calculating growth to 1948, we have TFP growth across the war years of 2.15 percent. Gordon’s table 16.5 suggests TFP growth in the 1940s almost twice the rate of the 1930s: 3.4 vs 1.8 percent per year. The above calculations suggest that it was actually at least a third lower: 2.15 vs 3.3 percent per year.

These numbers do not include any of Gordon’s capital service flow adjustments. In The Rise and Fall of American Growth, Gordon makes several adjustments to capital input, including adding government capital that is complementary to civilian production, making an adjustment for variable depreciation rates, and reweighting the equipment and structures capital stocks as proxies for service flow. The rationale is that equipment has a higher user cost of capital because a higher proportion of it depreciates each year. Whatever the merits of these adjustments (the case for the first is the most compelling), they are too small to alter this basic inequality. They add 20.9 log percentage points to 1941 levels of capital compared to 1928, and 24 log percentage points to 1950 levels compared with 1928 (Gordon, 2016, table A-2, p. 666).

These data imply an upward adjustment of 1.6 percent per year in the growth rate of capital between 1928 and 1941. Assuming a capital share of .3, this adjustment would chop .48 percent percentage points off our estimate of 3.30 percent per year between 1929 and 1941, bringing it down to 2.82 percent. Gordon’s proposed capital input adjustments would also
reduce TFP growth between 1941 and 1948, although not by as much, reducing the 2.15 percent per year estimate to 2.05. We would still have TFP growth between 1929 and 1941 38 percent higher than between 1941 and 1948.

These are not just games with numbers. They fundamentally influence our interpretation of the economic consequences of the war. Gordon’s figure 16.5 is the statistical underpinning of his interpretation of the Second World War. It is deeply misleading. The war introduced temporary and quite wrenching changes in the economy’s product mix and in the explicit and implicit factor prices producers faced. From the standpoint of aggregate supply, it was highly disruptive. It produced technological advance in the form of both process innovation and learning by doing, but much of this was irrelevant in the postwar period.

Learning by Doing

The next section of this paper explores in more detail the plausibility of the conventional argument (which Gordon has resurrected as new) that the success of military production during the war laid the foundations on the supply side for postwar prosperity. It is worth repeating Gordon’s case for this: “The most obvious reasons why productivity remained high after the war was that technological progress does not regress. People do not forget. Once progress is made… it is permanent” …After the war, “As they struggled to fill orders that seemed almost infinite, they adopted all that they had learned about efficient production in the high pressure economy of World War II” (p. 550).

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5 Subtract 20.9 from 24 and divide by 9 (the number of years between 1950 and 1941) = 3.3. Multiply 3.3 by .3, capital’s share, = .10.
To determine whether there is merit in this claim we must identify a) where the technological progress is alleged to have been most concentrated, and b) whether it is likely to have benefited production in the postwar period. The most frequently cited examples of such success involve stories of the declining cost per unit of ships, planes, tanks, and other ordnance. The ‘miraculous’ effects of learning by doing during the war are well known to economists largely as the result of Kenneth Arrow’s 1962 article in the Review of Economic Studies and Armen Alchian’s 1963 article in Econometrica. Citing work by Wright, Verdoorn, and Lundberg, Arrow noted that it was well established that the number of labor hours required to complete an airframe dropped predictably with the number of previously completed airframes, that the Horndal iron works in Sweden had experienced a 2 percent annual increase in labor productivity over a fifteen year period in the absence of any new physical investment. He then explored the theoretical implications of this. Alchian also took the effects of learning by doing as well established, and explored how reliable were statistically estimated learning parameters in predicting the decline in labor requirements per pound as a function of cumulated output in airframe production.

There is no questioning the productivity gains experienced in the manufacture of military goods – not just airframes but also Liberty Ships, Oerlikon antiaircraft guns, and other ordnance. In some cases, as in the substitution of welding for riveting in ship construction, there were process improvements. But the gains derived largely from improvements in the organization and coordination of production resulting from prior experience. Let’s consider the possible effects of learning by doing in aircraft production both during the war and thereafter. Learning by doing might generate three types of advance that would show up in the residual as ‘technological’ progress: 1) gains in producing a particular type or model of aircraft; 2) broader gains in the
understanding of how to produce large quantities of aircraft, and 3) gains that might have applicability to manufacturing more generally.

It is uncontroversial that gains in category 1 were very high. The United States produced 276,000 aircraft between 1942 and 1945; over 300,000 between 1940 and 1945. The question is how much relevance this had for manufacturing – either civilian or military – after the war. Wikipedia has compiled a list of most-produced aircraft, enumerating those with production runs greater than 5,000 (Wikipedia, 2017a,c). There were twenty-one World War II aircraft in the United States that met this criterion: five bombers (two heavy, two medium, one light), eight fighters, three dive or torpedo bombers, three trainers, a transport aircraft, and a glider. These are described below, with production totals in parentheses, along with information on the year in which production ceased.

The two heavy bombers were the Boeing B-17 Flying Fortress (12,731) and the Consolidated B-24 Liberator (18,482), the two medium bombers were the North American Mitchell (9,984), and the Martin B-26 Marauder (5,288). The light bomber/intruder aircraft was the Douglas DB7 (A-20 Havoc) (7,478). Production of all of these aircraft ceased in 1945, with the exception of the Douglas, for which production ceased in 1944. Each of these aircraft had been fully designed, tested, and flown prior to Pearl Harbor (Wilson, 2016, p. 58). 6

Eight World War II fighters had production runs of more than 5,000: the Grumman F4F Wildcat (~7,800), the Curtiss P-40 Warhawk (13,738), the Chance-Vought F4U Corsair (12,571), the Grumman F6F Hellcat (12,275), the Lockheed P-38 Lightning (10,037), the

6 The only heavy bomber that had not flown by December 1941 was the B-29, 3,970 of which were produced. Production ceased in 1946. This was the aircraft that delivered atomic bombs to Hiroshima and Nagasaki.
Republic P-47 Thunderbolt (15,660), the North American P-51 Mustang (15,586), and the Bell P-39 Airacobra (9,584). Production of all of these aircraft had ceased by the end of 1945, with the exception of the Mustang and the Corsair, which remained in production until 1951 and 1952 respectively. All of these aircraft had been designed before the war. With the exception of the P-47, F4U, and F6F, all had flown prior to Pearl Harbor.

The Douglas SBD Dauntless dive bomber (5,936) and the Curtiss SB2C Helldiver (7,140) ceased production in 1945; the Grumman TBF Avenger torpedo bomber (9,837) in 1944. All three had flown prior to Pearl Harbor.

The Douglas C-47, the military transport version of the DC3, remained in production until 1952, but the rate of production slowed greatly after the war. Total production was 16,079, including 607 civilian versions (DC3s completed in 1942 or earlier), 10,048 C-47’s built in the United States during the war, and 4,937 under license by the Soviets.

Three small training aircraft also continued to be built after the war. The North American T-6 Texan (15,495) remained in production into the 1950s. The Vultee BT13 Valiant (11,537) ceased production in 1947, and the Fairchild PT-19 (~7,700) in 1948. Finally, ~13,900 Waco CG-4 gliders were produced, with production ceasing in 1945.7

Constructing over 276,000 aircraft between 1942 and 1945 was, without qualification, an extraordinary achievement. During 1944, the United States completed an airplane on average once every five and a half minutes (Walton, 1956, p. 540).8 But none of the experience acquired

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7 Many of these aircraft were used almost exclusively by the Army. See Smith (1959, p. 27) for production statistics very slightly lower but in very close agreements with these statistics from Wikipedia.
8 The US produced 301,572 aircraft between 1940 and 1945. 6,086 were produced in 1940, and 19,433 in 1941. Peak production was in 1944, when the US manufactured 96,318. (Wikipedia, 2017b). The statistic cited by Walton is simply a matter of division. There are 525,600 minutes in a year. 525,600/96,318 = 5.45.
in producing these models can have had much bearing on US productivity levels and growth in the postwar period, because production of almost all ceased prior to or shortly after the end of the war. The war did not effect a dramatic acceleration of the design process. Every military aircraft experiencing significant World War II deployment had been fully designed prior to the war, and, as noted, all but four (the B-29 and the three fighters mentioned above) had been flight tested or were already in active service prior to Pearl Harbor.

What about category 2 experience – gains relevant perhaps not to the manufacture of specific aircraft per se, but to the manufacture of aircraft more generally? It is important to appreciate the unique characteristics of World War II aircraft manufacture. In the postwar period, a very small number of aircraft models approached or exceeded cumulative production runs of 5,000, and most of those that did were small single engine aircraft produced for the general aviation market.: Beechcraft, Cessnas, Pipers, and Aeroncas.

After World War II, only four military aircraft experienced production runs greater than 5,000: the North American F-86 Sabre (9,860; 1947-56), the Republic F-84 Thunderjet (7,524; 1946-53), the McDonnell-Douglas F-4 Phantom II (5,195; 1958-81) and the Lockheed T-33 Shooting Star jet trainer (6,557; 1948-59). More typical was the subsonic heavy bomber, the B-52, originally built between 1954 and 1963, with a cumulative production run of 742. Only one US commercial aircraft, the Boeing 737, has exceeded cumulated output of more than 5,000 in the postwar period. Its production run, which began in 1967, and is now approaching 9,300, has taken place over half a century.

Since the war there has never been and will likely never be another circumstance in which such large numbers of aircraft are produced in such a short time. Compromises did have to be made to enable such high throughput, and they take some shine off the raw data underlying the
learning curves. Because mass producers of aircraft from the automobile industry, particularly Ford at the huge and problem-plagued Willow Run facility, pushed back against the military’s steady stream of change orders, thousands of aircraft rolled off the production line and then flew immediately to one of 19 modification centers. Newly installed equipment was ripped out and replaced, and other changes made, some that customized the aircraft for its intended theatre of operations (Walton, 1956, p. 249), but many because mass manufacture was simply not compatible with the frequency of mid-production change requests desired by the military.\(^9\)

Again, the production achievement was, without qualification, extraordinary. But there is little evidence that World War II experience had persisting beneficial influence in the postwar period either in how aircraft were designed or in how they were built.

The story is similar in the case of ship production. Between 1941 and 1945 eighteen shipyards in the United States built 2,710 Liberty ships. No other ship model before or since has ever approached this record of cumulated output. The production success was helped by process advances replacing rivets with welding. But most of the gains were the result of more mundane learning by doing. This knowledge was of questionable relevance after the war because the US economy has never been and likely never will again be faced with the challenge of producing so many similar ships in such a short period. The mass production of merchant ships between 1942 and 1945 was a unique event. US shipyards, including those owned and operated by the US Navy, also built during or shortly before the war 29 aircraft carriers, 8 battleships, 74 cruisers and light cruisers, 349 destroyers, and over 80,000 landing craft.\(^{10}\) The relevance of this to the

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\(^9\) Ferguson (2005) provides a nuanced treatment of the different approaches to production taken by aircraft manufactures and General Motors as opposed to Ford. Ferguson makes it clear that, contrary to Ford’s optimistic assertions, the manufacture of aircraft bore little relation to that of automobiles.

\(^{10}\) [http://www.taphilo.com/history/WWII/Production-Figures-WWII.shtml](http://www.taphilo.com/history/WWII/Production-Figures-WWII.shtml). By its narrow definition, the US Navy currently has 10 aircraft carriers in active service.
postwar economy, civilian or military, is also questionable. As in the case of aircraft, in the postwar period the US built many fewer but far more expensive combat ships.

Evidence suggests that gains in category 1 were significant, in category 2, moderate, and in category 3 almost entirely absent. Gains in category 3 had the greatest potential for persistence and general applicability. But there is little or no evidence that organizational breakthroughs during the war, which would show up in TFP, help explain success after it. We can get some perspective on this by examining the changing share of “other transportation equipment” (all transport equipment except automobiles) in US manufacturing. In 1941, in spite of Lend Lease, and pre-Pearl Harbor ramping up of military spending, this category comprised 2.2 percent of total manufacturing output. At its peak in 1944 the share had risen to 20.7 percent of a considerably expanded manufacturing sector. By 1948 it had fallen back to 2.7 percent (see also Field, 2011, tables 3.3 and 3.4). Even at the height of the Korean War in 1953, the share rose only to 6.9 percent of manufacturing output, or 2.4 percent of the private nonfarm economy (U.S. Department of Commerce, 1966, Table 1.12, p. 19).

TFP in manufacturing had been growing rapidly between 1929 and 1941 – more rapidly than at any other period with the exception of 1919-1929. Field (2011, table 2.3, p. 54) reported TFP growth in US manufacturing of 5.12 percent per year between 1919 and 1929, 2.76 percent per year between 1929 and 1941, -.35 percent between 1941 and 1948, reviving only to 1.49 percent during the golden age (1948-73). Recalculation of the 1941-48 rate, using slightly different data (reported below) indicate a slightly more negative rate of advance. The decline in manufacturing TFP across the war years is a particularly compelling piece of evidence against Gordon’s views. If he is right, we should expect 1948 manufacturing TFP to have substantially exceeded its level in 1941.
Sectoral Decomposition of PNE TFP Growth, 1941-48

The next section of the paper examines the sectoral contributions to private nonfarm economy TFP growth between 1941 and 1948. The exercise differs from the aggregate calculations described earlier. First there is no attempt at the sectoral level to make cyclical adjustments for the level of TFP in 1941. Second, as in Field (2011), the calculation of sectoral contributions to aggregate TFP growth does not utilize the newer chained index measures of output. Such data are not available at the sectoral level for these time periods. Finally, the approach uses single rather than double deflation. The Bureau of Economic Analysis’s preferred method for calculating sectoral output growth in the GDP by industry section of its website is to deflate the nominal value of gross output, deflate the nominal value of intermediate inputs, and treat the difference between the deflated series as real value added. Whatever the merits of this method, data available prior to 1947 will not support it, so the approach followed, in instances where the calculations go beyond index numbers available in Kendrick (1961), is single deflation of nominal income generated in a particular sector.

We begin by examines productivity growth between 1941 and 1948 in comparison with the depression years (1929-41) for the following sectors: manufacturing, wholesale and retail trade, and railroad transportation. According to Field (2011, table 2.5, p. 59), these three sectors accounted for over 90 percent of total TFP growth in the private nonfarm economy between 1929 and 1941. We then look as well at trucking and warehousing, electric and gas utilities, mining, and construction. Table 8 brings these sectoral estimates together and estimates their respective contributions to aggregate TFP growth.

Productivity Growth in Manufacturing: 1929-41 and 1941-48
As noted, Kendrick has TFP growth in manufacturing at 5.12 percent year between 1919 and 1929, a figure accepted by Abramovitz/David, Field, and Gordon. Although Kendrick provides annual data on output and hours inputted, his capital input series, based on Creamer et al (1960), has a level for 1937 and then again for 1948 but not the intervening years. To calculate a growth rate of total factor productivity to and from 1941, one needs series on output growth, labor input growth, and capital input growth, as well as labor and capital shares that can be used to weight growth rates of the latter two series. In these calculations, capital’s share is assumed to be .3.

The 1966 Department of Commerce publication, The National Income and Product Accounts of the United States, 1929-1965, provides data on nominal income by sector going back to 1929. For manufacturing, nominal income generated in the durables and nondurables subsectors (table 1.12, lines 13 and 24) are converted to real value added using deflators for each subsector (table 8.6, lines 2 and 14; 1958=100.0) and then summed. This yields an estimate of the growth of manufacturing output of 4.43 percent per year between 1929 and 1941, and 1.98 percent per year between 1941 and 1948. Note that in the latter calculation we are measuring from premobilization to the first fully employed post-demobilization year. We are not measuring from 1941 to 1943 or 1944, because the question is not whether the United States succeeded in producing extraordinary flows of military hardware in a short time and experienced productivity gains in doing so (it did), but whether this experience positively influenced productivity levels and rates of growth in the postwar period.

Labor input is calculated in the following fashion. FTEs in the sector are drawn from BEA NIPA Table 6.5a. These numbers are identical to those in Department of Commerce 1966, table 6.4 line 11, except for a small difference for 1948. A difficulty with using FTEs as a proxy for
hours input is that average weekly hours of work change over time. Data in series Ba4580 from Historical Statistics of the United States, Millennial Edition show average weekly hours in manufacturing declining from 44.2 in 1929 to 40.6 in 1941 to 40.2 in 1948. To create a proxy for hours, FTE numbers for 1941 are reduced by multiplying by the ratio of average weekly hours in 1941 to average weekly hours in 1929 (.919). FTE numbers for 1948 are reduced by multiplying by the ratio of average weekly hours in 1948 to average weekly hours in 1929 (.909). Based on these calculations, labor input in manufacturing grew between 1929 and 1941 at 1.22 percent per year, and between 1941 and 1948 at 1.94 percent. These are very close to growth rates based on Kendrick’s manhours series for manufacturing (1.23 and 1.96 percent per year for the two periods respectively). Since we now have estimates of the growth rate of both sectoral output and hours, we can estimate labor productivity growth (their difference) as 3.22 percent per year between 1929 and 1941, and .04 percent per year between 1941 and 1948.

To estimate TFP growth, we also need to know how fast capital input was growing. The BEA’s Fixed Asset Table 2.2 provides chain type quantity indexes for the net stock of private fixed assets, enabling calculation of the growth of the real stock of industrial equipment (line 11) and manufacturing structures (line 48). These growth rates are then combined, weighting them by the average shares of equipment and structures in the manufacturing capital stock, based on values from Fixed Asset table 2.1, Current Cost Net stock of Private Fixed Assets. This yields manufacturing capital growing across the depression years at 1.11 percent per year and 3.90 percent per year between 1941 and 1948.

Putting these three series together in the standard growth accounting equation, and weighting capital growth by .3 and labor input growth by .7, we have manufacturing TFP growth of 3.25 percent per year between 1929 and 1941, and -.55 percent per year between 1941 and 1948.
1948 (table 1). These numbers differ slightly from the 2.76 per year between 1929 and 1941 and -.35 percent per year reported by Field (2011).\(^\text{11}\) Neither set of estimates is consistent with the Gordon narrative. Table 8 combines sectoral TFP growth rate estimates with data on sectoral shares in the private nonfarm economy, permitting calculation of percentage point contributions to aggregate TFP growth. Between 1941 and 1948, the manufacturing sector contributed -.21 percentage points per year to PNE TFP growth.

**Wholesale and Retail Trade**

We adopt a similar approach for wholesale and retail trade. Nominal income generated in the sector is from Department of Commerce 1966, table 1.12. These flows are deflated by the personal consumption expenditure (PCE) deflator (Department of Commerce, 1966, table 8.1, p. 158). This shows real output growing in the sector at 3.2 percent per year between 1929 and 1941, and 5 percent per year between 1941 and 1948. For labor input, FTEs for both wholesale and retail trade are drawn from BEA NIPA Table 6.5A. It is not possible to adjust the 1941 FTEs for changes in the average hours per week, but retail FTEs for 1948 are adjusted downward because of the decline from 42.8 to 40.2 hours reported in HSUS Series Ba4580. We have labor input growing at 1.5 percent per year between 1929 and 1941, and 2.7 percent per year between 1941 and 1948. Together with the output growth numbers, we can estimate labor productivity growth at 1.64 percent between 1929 and 1941 and 2.23 percent between 1941 and 1948.

Capital input is estimated from BEA Fixed Asset Table 2.2, lines 44 (multi-merchandise shopping structures) and 46 (warehouses). Growth rates for the two series are combined,

\(^{11}\) The higher TFP growth rate between 1929 and 1941 compared with Field (2011) is principally driven by the measure of output growth in the calculations described above (4.43 percent), which exceeds that calculatable from Kendrick’s table D-II (3.81 percent), which was used in Field (2011). For 1941-48, the 1.98 percent per year output growth calculated here is slightly less than a rate based on Kendrick’s output index, which grows at 2.20 percent per year over that period.
weighted according to the average value of these two components at the beginning and end of each period (BEA Fixed Asset Table 2.1). We have capital growing at -0.8 percent between 1929 and 1941, and -0.9 percent between 1941 and 1948. Bringing all three series together, and assuming a capital share of 0.3, we have TFP growing at 2.27 percent per year between 1929 and 1941, and 3.26 percent per year between 1941 and 1948 (table 2).

Because of its relatively large size and robust rate of TFP advance, the sector contributed 0.71 percentage points to PNE TFP growth between 1941 and 1948 – the largest contribution of any sector. In contrast to manufacturing, labor input in trade declined through 1942 and 1943 before beginning to recover, although FTE levels in both subsectors were still lower in 1945 than they had been in 1941. In contrast to manufacturing, of course, capital input declined. The fact that productivity growth between 1941 and 1948 was much higher in trade than in manufacturing suggests that sectoral productivity advance across the war years may have had more to do with learning by doing \textit{without} than with learning by doing.

For railroads, a sector which, in contrast with 1917-18, performed very well during the war, productivity growth remained about as high between 1941 and 1948 (or 1950) as it was during the 1929-41 period. The huge loads carried during the war represented a swan song for American railroads, at least with respect to passenger traffic, which began dwindling in the 1950s until all that remained were a few subsidized routes run by Amtrak. But productivity growth in freight transportation after the war remained respectable (Field, 2011, pp. 112-115). Faced with exceptionally strong demand and tight labor availabilities, the sector was able to extend the trajectory of advance displayed between 1929 and 1941 (2.56 percent per year between 1941 and 1948 vs 2.94 percent in the earlier period). The Depression years had seen a shift toward diesel electric motors and progress toward unlimited freight interchange, and
systematic rationalization in which hours, locomotives, and rolling stock all declined by a quarter or a third, while output changed hardly at all. Here the data is drawn from Kendrick; in contrast to the two previous sectors, Kendrick has annual data in levels throughout the relevant time intervals. The sector contributed .11 percentage points per year to PNE TFP advance.

Trucking and warehousing (table 4) takes output and employment from Kendrick, and capital from BEA FAT table 2.2, line 19: trucks, busses, and light trailers. Data limitations in Kendrick require measuring to and from 1942 rather than 1941, and the use of employment numbers for labor input. They show TFP growth retreating from the torrid advance between 1929 and 1941 of 12.61 percent per year to a still very strong 3.36 percent per year between 1942 and 1948. The sector contributed .04 percentage points per year to PNE TFP growth between 1941 and 1948.

The analyses of the electric and gas industries (table 5) are also based on Kendrick. Both sectors had experienced strong growth in TFP between 1929 and 1941, and growth continued at a slightly higher rate between 1941 and 1948: 5.87 percent for electric, and 5.45 percent for gas. In the absence of a better way to do this, these growth rates are weighted by data on the number of employed persons in the respective subsectors in 1929 (Kendrick, 1961, table H-X). Even though the sector is roughly half the size of railroads, the high rate of TFP advance means that utilities contributed .13 percentage points to PNE TFP growth, as compared with railroads’ .11 percentage points.

Mining is covered in table 6, with output and hours from Kendrick, and capital from the BEA’s Fixed Asset Table 2.2. TFP fell to .64 percent per year between 1941 and 1948 as compared with 2.09 percent per year between 1929-41. Because of its relatively small share and modest TFP, the sector’s contribution to PNE TFP growth is a negligible .02 percentage point.
Finally, construction (table 7). The Depression years had been a dismal period for construction, with TFP declining at .91 percent per year. Measuring between 1941 and 1948 the situation got worse, with TFP falling at 2.71 percent per year, contributing -.15 percentage points to the overall PNE TFP growth rate.

The remainder of the private nonfarm economy (sectors not covered in tables 1-7) is split between finance, insurance and real estate (10.1 percent), transportation services other than railroads and trucking (1.9 percent) and other services not elsewhere classified (10.7 percent), for a total of roughly 23 percent of the PNE. Based on Kendrick’s data, PNE TFP growth between 1941 and 1948 was 1.29 percent per year.\(^{12}\) The sectors discussed in tables 1-7 contribute on net .69 percentage points, implying .60 percent points in the residual sector, which in turn implies a 2.65 percent annual TFP growth in the residual services category (see table 8).

Between 1941 and 1948 the biggest percentage point contributors to PNE TFP growth were wholesale and retail trade, followed by the residual service category, electric and gas utilities, and railroads, with much smaller contributions from trucking, telephone and telegraph, and mining. TFP growth was negative in manufacturing, and strongly negative in construction. A cocktail of very strong demand, tight labor availabilities, and capital growth that was crowded out seems to have been a more powerful stimulus to TFP growth over the course of mobilization and demobilization than the disruptive and temporary imposition of a new product mix combined with massive government infusions of equipment and structures and priority access to materials and labor within wartime manufacturing.

\(^{12}\) Note that because I have not attempted cyclical adjustments for the sectoral estimates, I am including a cyclical adjustment for the aggregate growth rate here. Also, in contrast to the discussion in the first part of the paper, output growth is not based on chained index measures.
The Legacy of Wartime Capital Accumulation

The war resulted in an enormous accumulation of physical capital in the form of military hardware, producer durables such as machine tools and dies, and industrial structures, such as the massive Willow Run facility built near Detroit. Much of this was of limited utility after the war. With the exception of B-29 bombers produced towards the end of the war, most of the aircraft produced were, at its conclusion, deemed obsolete and declared surplus. Tens of thousands were flown to ‘boneyards’ in Arizona – air bases such as Kingman and Davis Montham. Engines were removed for steel scrap and the airframes guillotined, fed immediately into onsite smelters where the metal reemerged as aluminum ingots. Many aircraft operating overseas were never repatriated. Abandoned in their theatre of operation, it was simply not worth the cost in fuel and manpower to fly them back to the states so they could be scrapped. Similar fates befell Liberty ships (scrapped and recycled for the steel), tanks, and other military equipment.13 These goods had been produced to fulfill an extraordinary need. With the war ended, so did that need.

It was not just aircraft and freighters. What do the following naval vessels have in common, along with several captured German and Japanese ships?

**Aircraft carriers:** USS Saratoga, USS Independence  
**Battleships:** USS Arkansas, USS Nevada, USS New York, USS Pennsylvania  
**Cruisers:** USS Pensacola, USS Salt Lake  
**Destroyers:** USS Lamson, Anderson, Conyngham, Mugford, Ralph Talbott, Mayrant, Trippe, Rhind, Stack, Wilson, Hughes, Muston, and Wainwright  
**Submarines:** USS Apogon, Pilotfish, Skipjack, Searaven, Tuna, Skate, Dentuda, Parche  
**Attack Transports:** (20)  
**Landing Ship Tanks (LSTs):** (6)  
**Landing Craft Tanks (LCT):** 15  
**Miscellaneous naval vessels** (21)

13 Weyerhauser maintained a small fleet of Liberty ships after the war, but they made more of a contribution to the postwar Greek and Italian merchant marines than they did to that of the US. Aristotle Onassis got his start by acquiring several surplus ships. Most of the remainder were mothballed by the U.S. Navy and ultimately scrapped.
They were destroyed or made so severely radioactive that all but nine (which were decontaminated and sold for scrap) had to be scuttled as the result of two atomic blasts (Operations Crossroads), an airblast on July 1, 1946 (Abel) and an underwater detonation on July 26, 1946 (Baker). The tests had been designed to demonstrate that naval vessels could survive nuclear blasts, thus countering claims that such ships were obsolete in the atomic age. The test results indicated the opposite. At the time there were complaints that tons of steel that could otherwise have been recycled went to the bottom of the ocean.

As thousands of tons of obsolete or no longer needed military equipment lay parched on the Arizona desert, as hundreds of rusting Liberty and naval war ships prepared for scrappage, or targets for atomic bombs, the knowledge that was acquired in building these durables also dissipated. Creative destruction is a feature of production knowledge as much as it is of products, and was particularly severe under the extraordinary conditions of World War II production and its aftermath.

What of the enormous production of machine tools paid for by the government? Machine tool output increased two orders of magnitude during the war. Annual production during the Depression was approximately 7,000 per year, generated by roughly 200 specialized firms. In 1940, 110,000 were produced, and in 1941, 185,000. At the peak of production in August of 1942, machine tools were being generated at an annual rate of 365,000, although by 1944, more than a year before the war ended, production had already fallen back to less than half the peak rate (Walton, 1956, p. 229; see also Ristuccia and Tooze, 2013, table 1).

There was indeed a huge investment in plant and equipment by the government (some of the GOPO capital whose consequences Gordon began his career examining). But the mass production techniques that made volume production of tanks and aircraft possible in the United
States relied overwhelmingly on single purpose machine tools, and the majority of these tools and related jigs and frames were scrapped with reconversion. The US did use multipurpose machine tools, which could more easily be repurposed, but principally in the shops producing machine tools.

The Scrappage Problem

Already beginning in 1944, the country confronted serious surplus and scrappage issues. By early 1945 disposal agencies had surplus inventories of roughly $2 billion dollars – equivalent to the entire cost of the Manhattan Project. By V-J day that had risen to $4 billion. Surplus inventories peaked at $14.4 billion in mid-1946 (Cook, 1948, pp. 10-11). Most military hardware, with the exception of jeeps and trucks, was not dual use. Automobile manufacturers, in any event, lobbied against repatriation of such vehicles, concerned they would spoil the postwar market. A few tanks were converted to tractors or bulldozers. Overall, recycling and disposal posed huge logistical challenges.

What, more generally of the $16B of government funded equipment and structures built to produce all the military hardware? Gordon (1969) suggested that government statisticians had not adequately reckoned the value of this capital in considering the contributors to postwar production. To the degree we insist on adjusting upward the growth of the capital stock relevant to private sector production, higher capital growth rates will further reduce the already declining rates of measured TFP advance between 1941 and 1948. Moreover, if our measures of the growth of private sector capital are truly biased downward, we would still expect to see strong effects in the growth of labor productivity (because of higher true rates capital deepening). For

14 Again, see Ferguson (2005, p. 166) for a nuanced discussion of variation among manufacturers in these practices.
US manufacturing, table 1 shows that labor productivity growth between 1941 and 1948 was effectively nil (.04 percent per year).

A large fraction of the government investment in plant and equipment was of little value in the postwar period. That is why so much of it was scrapped, or sold for pennies on the dollar in the postwar period. A competing narrative suggests these were giveaways, sweetheart deals for large military contractors. Gordon (1969, p. 224), for example, suggests that private firms might have chosen the five year amortization of capital improvements offered to them by the government because they were concerned postwar demand would render their capacity excess. His discussion does not adequately address the likelihood that manufacturers correctly anticipated that their new equipment and structures would be only imperfectly suited, or in some cases not suited at all to the postwar production mix. A careful reading of the literature suggests that the prices at which industrial plant was disposed of were generally reasonable. Disposal took place amid strong political currents favoring antimonopoly and the encouragement of small business. The aluminum industry, in particular, was restructured on a more competitive basis than had been the case prewar, an outcome anticipated from the start: unlike other GOPO contractors, ALCOA had not been given an option to buy the new government plants it operated.

The problem of scrappage extended not just to the tools of war but also to the tools and parts that made them. Often the cost of scrappage was greater than the quantity of recoverable materials. But inaction was not an option, because unless the now obsolete parts and equipment, machine tools and dies, and finished tools of war were cleared out and disposed of, they would clog production facilities and adversely impact the revival of civilian production. Scrappage was already a serious challenge prior to VJ day. Change orders for tanks or bombers could instantly obsolete assembled parts, tools, jigs and frames, as well as completed (but now obsolete) units.
Mass production techniques pioneered in the 1920s and 1930s and used to build military
equipment in the 1940s relied on single purpose jigs, frames, and machine tools. These were of
no more use after the war than most of the military equipment they had helped produce, or the
jigs, frames and machine tools used to produce cars that had been ripped out and recycled in
1942.

Why were government plants sold for only a fraction of their construction cost? Part of
the problem is that there was often only a single bidder for them. But another reality is that they
were often not ideally suited to the needs of postwar production. Plants had been constructed to
manufacture a product mix some of which would never return. Some were not built to last
more than a few years. They were dispersed around the country to protect them from bombing, a
questionable precaution in an age of intercontinental ballistic missiles. A prime example was the
Geneva steel mill built in Vineyard, Utah, a heavily polluting white elephant operated by US
Steel during the war and bought by the company in 1946 for what critics said was a fraction of
its worth (after being sold in 1987 it ceased operations in 2002). Even within an aircraft
production facility, the locations of individual structures were uneconomically dispersed, to
make the facility less vulnerable to air attack. Government built industrial facilities after the war
did have value, but it was on average a fraction of their cost of construction.

Conclusion

The use of the word ‘miracle’ to describe US war mobilization took shape in 1942, in an
address by Eugene Wilson, CEO of United Aircraft. Picking up on this theme, the Ford Motor
Company ran advertisements describing its production efforts as “the greatest miracle of mass
production the world has ever seen.” In his January 1943 SOTU address, Roosevelt used similar
words, referring to the “miracle of production” (Wilson, 2016, p. 106) The spread of this
language was in part the result of efforts led by the US Chamber of Commerce to insure that private business got all or most of the credit for winning the war, even though production was very much a joint government – industry effort.

Symptomatic of this was insistence that the names of all military aircraft begin with the name of the prime contractor, even if the aircraft had been largely designed and tested by government personnel, and even if the manufacture was in plants and with equipment entirely owned by the US government (the practice was never successfully extended to naval vessels, tanks or other land vehicles). Contrary to the situation today, the US Navy built roughly half its warships in its own government owned and operated shipyards, and the US Army controlled arsenals where weapons design, testing and some production of weaponry, particularly artillery and small arms, took place. Production took place largely within plants wholly owned by the US government, which by the end of the war comprised between 15 and 25 percent of US manufacturing capacity (Wilson, 2016, p. 258). Tens of thousands of US government employees, both military and nonmilitary, negotiated contracts, audited books, inspected output, and in some cases, with the backing of armed soldiers, took over production facilities where labor or other problems threatened the war effort.

The ‘economic miracle’ narrative emerged against the backdrop of a continuing contest over how to characterize and credit the production achievements. Business leaders were so focused on this that they began expressing unease about references to ‘miracles’, believing it did not fully credit the contribution of the production experience gained in “150 years of free enterprise” prior to the war, as put by the president of the National Association of Manufacturers.

15 A number of aircraft models were produced by more than one contractor.
in a speech in December of 1943 (Wilson, 2016, p. 106). Private sector leaders systematically omitted reference to or denigrated the contributions of government personnel. While their repeated insistence that achievements were in spite of the bureaucratic hamstringing of government officials was questionable, the business leaders’ claim that success depended on prior production experience and their eventual push back against appeals to the supernatural should be credited.

The fundamental growth accounting equation tells us that the growth of output can be decomposed into contributions from the growth of hours, the growth of capital, and the growth of total factor productivity. As we have seen, TFP growth in manufacturing was negative between 1941 and 1948, and that is the sector in which we would most have expected to see longer term consequences of the wartime production experience. TFP in manufacturing did of course grow in the postwar period, but there is little evidence that the war catalyzed an acceleration in the rate. To the contrary. The BLS historical multifactor productivity tables for manufacturing (2004) show TFP in the sector growing at 1.5 percent per year between 1949 and 1973 – less than half the growth rate during the 1930s (1929-41), and less than a third what it was during the 1920s (1919-29). In the interwar period the growth of manufacturing TFP was consistently above the average for the private nonfarm economy. In the golden age (1948-73) it was persistently below it. Indeed, if we look at the century from 1919 onward, we see a generally downward trend in manufacturing TFP growth, undisrupted by the war.16

The immediate postwar impact of the war on potential hours was clearly negative. 607,000 service people suffered wounds, and 405,399 mostly prime age males never returned. Most

16 The IT boom between 1995 and 2004 appears as a temporary upward blip; progress during that ten year period was narrowly concentrated within the old SIC 35 and 36.
would have been alive in the absence of the war. The 50 percent rise in female labor force participation (Schweitzer, 1980, p. 90) largely dissipated during the immediate postwar period. The possible influence of the war on the baby boom would take us too far into the realms of speculation; in any event such influences, if they existed, had little connection to learning by doing in military production.

The counterfactual with respect to capital is more complicated, even with respect to the immediate postwar period. The country emerged in 1948, inter alia, with a vastly expanded aluminum production industry and a reduction in its industrial concentration, a synthetic rubber capability that had been developed basically from scratch, the Big Inch and Little Inch pipelines from Texas to the East Coast built in response to U-boat threats to coastal transport, and an infrastructure that allowed US firms to dominate civilian and military aircraft production in the postwar period. But both public and private capital accumulation in areas not militarily prioritized was stunted, and this negative effect must also be considered, particularly given the likelihood that the economy was finally emerging from the shadow of the Great Depression in 1941.17

The US production experience in the second world war starved the economy of government investment in streets and highways, bridges and tunnels, water and sewage systems, hydro power and other infrastructure that had played such an important role in the growth of productivity and potential across the depression years. These categories of government capital complementary to private capital grew at a combined rate of .15 percent per year between 1941 and 1948, as opposed to 4.17 percent per year between 1929 and 1941 (BEA FAT, tables 7.1 and 17 This was not simply due, as many have suggested, to Lend Lease and the stimulus from military rearmament. Of total real military spending between 1939 and 1945, less than one twentieth had taken place by the time of Pearl Harbor (Field, 2011, table 3.1, p. 85).
Portions of the private economy not deemed critical to the war effort also subsisted on a thin gruel of new physical capital. Trade, transportation, and manufacturing not directly related to the war are cases in point. Private nonfarm housing starts, which had finally recovered to 533,200 in 1941, close to the 1925 peak (572,000), plunged to 114,600 in 1944, barely above the 1933 trough of 76,000 (National Bureau of Economic Research accessed via FRED, 2017).

Higgs (2010) adds an additional twist to this argument by emphasizing the wear and tear on the capital stock caused by double and triple shifts, and the understate of depreciation allowances caused by the repressed inflation during the war. Once price controls were removed and inflation accelerated between 1945 and 1950, those allowances were inadequate to repair the ravages of intensive wartime utilization. Although the war effort did leave the economy with some assets that benefited postwar production capability, it distorted physical capital accumulation, crowding out investment in sectors of the economy not prioritized by the military.

The US suffered more than a million military casualties. On the home front, the increase in the female labor force between 1940 and 1944 proved to be a flash in the wartime pan. As we have seen, between 1941 and 1948 total factor productivity deteriorated in manufacturing and construction, and in the aggregate grew more slowly than had been true between 1929 and 1941. The longer term impact on TFP of learning by doing in wartime production was minimal, because the output mix as well as factor prices were different after the war, and there were few spillovers from this learning to the production of other products. TFP growth in manufacturing between 1949 and 1973 was substantially lower than it had been in the 1920s and 1930s.

The war was an enormous and often tragic waste of human and physical resources. It was economically disruptive, greatly distorting the economy for a period of several years, as sectors critical to the war effort expanded several fold and then as rapidly shrunk. Gordon argued that
“the case is overwhelming for the economic miracle interpretation of World War II along every conceivable dimension…” What the United States achieved in the production of military hardware was indeed extraordinary. But its impact on the growth of U.S. potential output was almost assuredly negative.
REFERENCES


### Table 1

Manufacturing Productivity Growth: 1929-41; 1941-48

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**Sources:**
- Bureau of Economic Analysis, Fixed Asset Table 4.2, line 9
- Department of Commerce, 1966, tables 1.12, 8.6
- Historical Statistics of the United States, series Ba4580
- See text for full description.
Table 2
Productivity Growth in Wholesale and Retail Trade

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Growth rates

<table>
<thead>
<tr>
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<td>1929-41</td>
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Sources: US Department of Commerce, 1966
BEA NIPA Table 6.5A; FAT tables 2.1 and 2.1
HSUS series BA
4580
See text for full discussion.
<table>
<thead>
<tr>
<th></th>
<th>Output</th>
<th>Hours</th>
<th>Capital</th>
<th>Labor Prod</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td>100</td>
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Table 4
Productivity Growth in Trucking and Warehousing

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<tr>
<th></th>
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<th>Employment</th>
<th>Capital</th>
<th>Labor Prod</th>
<th>TFP</th>
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<td>Levels</td>
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<td></td>
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<td></td>
<td></td>
</tr>
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<td>1942</td>
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<td>6.484</td>
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<td>1948</td>
<td>123.9</td>
<td>107.2</td>
<td>11.918</td>
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<td>1950</td>
<td>174.2</td>
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<td>Growth rates</td>
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<td>1942-50</td>
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<td>0.0601</td>
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</table>

Sources: Output and Employment from Kendrick, 1961, table G-VIII, p. 553. Capital from BEA FAT 2.2, line 19, trucks, busses, and light trailers. See also Field 2011, table 2.6, p. 51. Note that labor input is employment, not FTEs or hours.
Table 5  
Productivity Growth in Electric and Gas Utilities

<table>
<thead>
<tr>
<th></th>
<th>Electric</th>
<th></th>
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<th>Manhours</th>
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<th></th>
<th></th>
</tr>
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<tbody>
<tr>
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<td>Output</td>
<td>Hours</td>
<td>Capital</td>
<td>LP</td>
<td>TFP</td>
<td>Gas Share</td>
<td>Electric</td>
</tr>
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<td>Levels</td>
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<td>100</td>
<td>100</td>
<td>100</td>
<td>0.6523</td>
<td>756</td>
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<tr>
<td></td>
<td>1941</td>
<td>186.5</td>
<td>82.5</td>
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<td>194.7</td>
<td>0.3477</td>
<td>231</td>
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<tr>
<td></td>
<td>1948</td>
<td>314.8</td>
<td>95.7</td>
<td>116.3</td>
<td>293.7</td>
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<td>172</td>
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</table>

Rates of Growth

|          | 1929-41  | 0.0519   | -0.0160  | 0.0063   | 0.0680   | 0.0555   | 0.0510   | -0.0073  | 0.0082   | 0.0483   | 0.0415   | 0.0964   | 0.0592   | 0.0220   | 0.0373   | 0.0545   | 0.0572   |
| 1941-48  | 0.0748   | 0.0212   | 0.0108   | 0.0536   | 0.0587   | 0.0419   | 0.0320   | 0.0220   | 0.0373   | 0.0545   |          |          |          |          |          |          |

Table 6
Productivity Growth in Mining

<table>
<thead>
<tr>
<th></th>
<th>Output</th>
<th>Hours</th>
<th>Capital</th>
<th>LP</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>100</td>
<td>27.435</td>
<td>-</td>
<td>0.0052</td>
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<tr>
<td>1941</td>
<td>106.5</td>
<td>77</td>
<td>26.989</td>
<td>0.0321</td>
<td>0.0209</td>
</tr>
<tr>
<td>1948</td>
<td>133.3</td>
<td>88.9</td>
<td>35.147</td>
<td>0.0205</td>
<td>0.0064</td>
</tr>
</tbody>
</table>

Rates of Growth

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1929-41</td>
<td>0.0052</td>
<td>-0.0218</td>
<td>-0.0014</td>
<td>0.0270</td>
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<tr>
<td>1941-48</td>
<td>0.0321</td>
<td>0.0205</td>
<td>0.0377</td>
<td>0.0115</td>
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</table>

Sources:
Output and Hours: Kendrick, 1961, table C-2, p. 397.
Capital: BEA FAT table 2.2, line 30, mining and oilfield equipment.
Table 7
Productivity Growth in Construction

<table>
<thead>
<tr>
<th>Nominal income Deflator</th>
<th>Real Output</th>
<th>FTEs</th>
<th>Capital</th>
<th>LP</th>
<th>TFP</th>
</tr>
</thead>
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<tr>
<td>Levels</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>1929</td>
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<td>4219</td>
<td>38.6</td>
<td>109.3</td>
<td>1774</td>
<td>8.553</td>
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<td>1948</td>
<td>10612</td>
<td>76.7</td>
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<td>2278</td>
<td>19.699</td>
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Rates of Growth

<table>
<thead>
<tr>
<th></th>
<th>1929-41</th>
<th>1941-48</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0058</td>
<td>0.0149</td>
<td>0.0086</td>
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<tr>
<td>0.0337</td>
<td>0.0357</td>
<td>0.1192</td>
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</table>

Sources:
Capital: BEA FAT table 2.2, line 29, Construction Machinery
Table 8
Sectoral Contributions to TFP Growth within the U.S. Private Nonfarm Economy, 1941-48

<table>
<thead>
<tr>
<th>Sector</th>
<th>1941 Nominal Income (billion $)</th>
<th>1941 PNE Share</th>
<th>1948 Nominal Income (billion $)</th>
<th>1948 PNE Share</th>
<th>1941-48 Sector Percentage Point Contrib. to PNE TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Industries</td>
<td>104.2</td>
<td></td>
<td>224.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less Agriculture, Forestry, Fisheries and Government</td>
<td>85.3</td>
<td></td>
<td>182.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>33.2</td>
<td>0.389</td>
<td>67.6</td>
<td>0.371</td>
<td>-0.0055</td>
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<tr>
<td>Wholesale and Retail Trade</td>
<td>17.4</td>
<td>0.204</td>
<td>41.7</td>
<td>0.229</td>
<td>0.0326</td>
</tr>
<tr>
<td>Railroads</td>
<td>3.8</td>
<td>0.044</td>
<td>7.1</td>
<td>0.039</td>
<td>0.0256</td>
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<tr>
<td>Trucking and Warehousing</td>
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<td>0.012</td>
<td>2.3</td>
<td>0.013</td>
<td>0.0336</td>
</tr>
<tr>
<td>Telephone and Telegraph</td>
<td>1.1</td>
<td>0.013</td>
<td>2.8</td>
<td>0.015</td>
<td>0.0181</td>
</tr>
<tr>
<td>Electric and Gas Utilities</td>
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<td>Mining</td>
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<td>0.030</td>
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<td>Construction</td>
<td>4.2</td>
<td>0.049</td>
<td>10.6</td>
<td>0.058</td>
<td>-0.0271</td>
</tr>
<tr>
<td>TOTAL of Above</td>
<td>65.2</td>
<td>0.764</td>
<td>141.2</td>
<td>0.775</td>
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</tr>
<tr>
<td>Residual Services</td>
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<td></td>
</tr>
<tr>
<td>FIRE</td>
<td>9.3</td>
<td>0.109</td>
<td>18.4</td>
<td>0.101</td>
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<tr>
<td>Other transport services</td>
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<td>0.018</td>
<td>3.5</td>
<td>0.019</td>
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<tr>
<td>Services n.e.c.</td>
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<tr>
<td>TOTAL Residual Services</td>
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<td>0.230</td>
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<td>TOTAL PNE</td>
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<td>0.995</td>
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</table>

Sources:
- Sector share = average of 1948 and 1941 nominal income in sector divided by income in all sectors less government and agriculture, forestry, and fisheries
- Sectoral TFP Growth: see tables 1-7
- PNE TFP Growth: Kendrick, 1961, table A-XXIII.