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WORLD WAR II AND THE GROWTH OF U.S. POTENTIAL OUTPUT

by

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ABSTRACT

Claims that the experience of economic mobilization between 1942 and 1945 laid the supply foundations for output and productivity growth in the United States after the war have formed the basis of the conventional wisdom for decades. This paper argues, in contrast, that the extraordinary mass production of ships, aircraft, and other munitions had little relevance for the postwar period because the wartime output mix and implicit factor prices were unique to that period, never to be repeated. Between 1941 and 1948, total factor productivity within manufacturing declined. Considering together the effects on TFP, the labor force, and the physical capital stock, the impact of World War II on the level and trajectory of US potential output following the war was, on balance, almost certainly negative. (O47, O51, N12)

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Introduction

Whatever the objectives for which it is fought, and whatever their merits, war is in fact an enormous and tragic waste of human and physical resources. Faced with unimaginable carnage and destruction, we may be predisposed to search for silver linings. Economists, historians, and much of the general public, for example, have often been remarkably sanguine about the economic benefits of war, emphasizing its role not only in closing output gaps, but also in accelerating the growth of potential output.

Illustrative examples are easily identified. Three quarters of a century ago, Louis M. Hacker (1940), speaking of the effect of the Napoleonic Wars on England and of that of the Civil War on the United States, opined that "As far as capitalism has been concerned, modern war (while it lasts) has been an unmixed blessing" (p. 250). He waxed particularly enthusiastically about the propulsive impact of the conflict over slavery in the United States: "Under the leadership of the new and vital force released by the Civil War and Reconstruction measures, American industry strode ahead on seven-league boots" (p. 401), and "…railroading, like industrial production, was … transformed in the fires of the Civil War" (p. 227). Although these supply side claims have been vigorously disputed (e.g., Kuznets, 1952, p. 116; Goldin and Lewis, 1975; Lindert and Williamson, 2016), Hacker's sentiments about the longer run positive effects of war continue to resonate, particularly as they apply to the conflict the United States was poised to enter as he published.

William Baumol (1986), for example, based on his reading of Angus Maddison's data, took World War II's contribution to higher productivity growth during and after the war to be established fact: "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" (1986, pp. 1081-82). Vernon Ruttan posed a provocative question in the title of his 2006 book, "Is War Necessary for Economic Growth?" He answered the question affirmatively: "It is difficult to overemphasize the importance of the historical role that military procurement has played in the process of technology development…" (2006, p. 3).[1] Without war, he suggested the R and D spending necessary to develop new general-purpose technologies would simply not be forthcoming. A similar argument, based on a reading of recent historical scholarship, was advanced by Tyler Cowen (2014). The views expressed by these authors reflect a shared optimism about the long run economic benefits of war and military spending.

Robert Gordon (2016) is the most recent instantiation of this enthusiasm. He provides a clear statement of the argument insofar as it applies to the Second World War, and uses macroeconomic data on total factor productivity growth in support of his narrative. Gordon's exuberantly optimistic interpretation of the economic impact of the World War 2, particularly its effect on US aggregate supply, is part of a long tradition that sees silver economic linings in the clouds of war. Evaluating this interpretation is important not only for our understanding of mid-twentieth century U.S. economic history, but also because of its relevance to broader debates about the impact of war and military spending on technological and economic progress.

Long Run Productivity Trends in the US Economy

Studies of long run productivity growth in the United States can be said to have begun with the work of Robert Solow (1957) and John Kendrick (1961). Solow's memorable conclusion (based on Kendrick's then unpublished data) was that a remarkably small fraction of real output growth between 1909 and 1949 could be accounted for by the growth of inputs conventionally

[1] He went on to argue that "military and defense related R&D and procurement has been a major source of technology development across a broad spectrum of industries that account for an important share of U.S. industrial production" (p. 5), emphasizing computers and the internet, but passing lightly over the histories of electricity and the internal combustion engine.

measured. More recent studies with access to longer runs of data agree that the second and third quarters of the twentieth century experienced particularly rapid TFP growth, although there remain important differences about when within those decades the most rapid advance occurred (Abramovitz and David, 2000; Field, 2003, 2011; Gordon, 2016). Field situates it in the 1930s (specifically, measuring between 1929 and 1941), but Gordon now locates it in the 1940s.[2] Whereas Gordon accepted Field's revisionism regarding (at least moderate) productivity advance between 1929 and 1941, he retained (but repackaged 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.[3]

There is little dispute that World War II confirmed the fundamental Keynesian prediction that massive fiscal stimulus combined with expansionary monetary policy could bring a depressed economy to full employment within a very short time. For decades, it has also been argued, as did Baumol, that the war was associated with a permanent boost on the supply side, particularly due to its effect on the growth of total factor productivity (TFP).[4] Gordon developed his version of this view in chapter 16, claiming that its "most novel aspect" was "its assertion that World War II itself was perhaps the most important contributor to the Great Leap." As he warmed to his argument, he abandoned the hedging reflected in his initial inclusion of the word

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[2] Gordon originally settled on One Big Wave as his way of calling attention to the strong TFP growth that characterized the half century between roughly 1920 and 1970. In The Rise and Fall of American Growth he abandoned 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). As justification for his partial appropriation of the phrase, Gordon cited Baumol (the quote referenced above) 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 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. His view, roughly the opposite of what Field argued, epitomized what had for decades been the conventional view of the Depression and the war.

[3] Bakker, Crafts and Woltjer (2017) are of little help in adjudicating these difference, since they don't explore growth across the war years. They argue that the postwar period (1948-73) was the locus of the most rapid TFP growth, a position that Gordon endorsed beginning around 2000 but has now abandoned.

[4] Baumol suggested that "Perhaps the accumulated innovative ideas, unused because of the depression, as well as frustrated savings goals, fueled an outburst of innovation and investment when business conditions permitted."

‘perhaps’: “In fact this chapter will argue that the case is “overwhelming for the “economic miracle” interpretation of World War II along *every conceivable dimension*…” (p. 537, my italics). Gordon claimed that the ‘economic miracle’ propelled total factor productivity to a permanently higher level, and was largely responsible for setting the stage for the golden age (1948-73). This was his explanation: “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).

Gordon’s is the most recent and among the most detailed statements of the “war benefits aggregate supply” argument insofar as it applies to the Second World War. He repeated the oft-cited examples of learning by doing building airframes and Liberty ships, and then argued 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 narrative seems compelling, which is why it has been so widely embraced. But a wide range of evidence is inconsistent with it. In developing a contrasting story, this paper will argue that the war retarded the growth of potential. It did so by destroying human capital and distorting the accumulation of physical capital. Most importantly, it was associated with a slowdown in the growth of total factor productivity.

Sectoral Productivity Data

We begin with a consideration of sectoral productivity data. If the "war benefits aggregate supply" view is correct, we should be most likely to see evidence of spillovers from war mobilization in the manufacturing sector. Table 1 reports growth rates of TFP within the sector over intervals from 1929 through 2015.

Table 1

	Total Factor Productivity Growth in US Manufacturing, 1919-2015 (percent per year)	Source
1919-1929	5.12	Kendrick (1961), table D-1, p. 464.
1929-1941	3.25	See Appendix table A1, text.
1941-1948	-.55	See Appendix table A1, text.
1949-1973	1.49	U.S. Bureau of Labor Statistics (2004), table 2
1973-1995	.68	U.S. Bureau of Labor Statistics (2004), table 2
1995-2005	1.78	www.bls.gov, accessed 4/30/2018
2005-2015	-.16	www.bls.gov, accessed 4/30/2018

Our focus is on the estimation of the growth rates over the period 1941-48 as compared with 1929-41.[5] Kendrick has TFP growth in manufacturing at 5.12 percent year between 1919

[5]1941 is the closest we can come to potential before the effects of full scale war mobilization kick in. Although Lend-Lease and some rearmament had begun, less than 5 percent of cumulative real military spending between 1940 and 1945 inclusive had taken place at the time of Pearl Harbor (Field, 2011, p. 85). By 1948 demobilization was largely complete and the economy, now on a civilian footing, was close to potential, as evidenced by the low 3.8 percent unemployment rate.

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. The National Income and Product Accounting identities guarantee that nominal income generated by a firm or sector is equivalent to that firm or sector's value added, and thus its contribution to gross product. For manufacturing, nominal income 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) 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 that experience positively influenced rates of productivity growth between 1941 and 1948 and then in subsequent years.

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 U.S. 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 the BEA's 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 framework, 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 (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).[6] Inclusion of a cyclical adjustment for the level of manufacturing TFP in 1941 would increase an estimated growth rate between 1929 and 1941 and further reduce it for 1941-48 (Field, 2010, 2018), although switching to chained index sectoral output growth in manufacturing, were that available, might raise growth rates for both periods.[7]

The data underlying the calculation of TFP growth rates over the intervals 1929-41 and 1941-48 for manufacturing and six other sectors are detailed in Appendix tables A1-7. Table A8 combines these 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 private nonfarm economy (PNE) TFP growth of 1.29 percent per year.

Manufacturing TFP declined between 1941 and 1948 because the government funded expansion of war related plant and equipment had much weaker spillover effects on TFP than did the streets and highways, bridge, tunnel, and hydroelectric dam construction of the 1929-41

[6] The manufacturing output growth rate between 1929 and 1941 used in these calculation (4.43 percent) exceeds that calculatable from Kendrick's table D-II (3.81 percent), which was used in Field (2011). Thus the higher reported TFP growth rate. 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.

[7] The use of chained index estimates for aggregate output increases TFP growth rates for both 1929-41 and 1941-48 because it increases measured growth rates for output. Such measures are not available at the sectoral level for the time periods in question. Thus the 1.29 percent PNE TFP growth between 1941 and 1948 used here is lower than that referenced in the penultimate section of this paper.

period (Field, 2003, 2011). Value added grew between 1941 and 1948, but the rise in manufacturing capital, along with growth in hours, left no space for a positive residual.

Productivity advance in the private nonfarm economy between 1941 and 1948 was, overall, positive. But the main contributors to TFP growth were sectors other than manufacturing, in particular wholesale and retail distribution, railroad transportation, and electric and gas utilities (Appendix table A8). These were sectors, in contrast to manufacturing, that were capital-starved during the war. War did inspire process innovations. But these apparently had more persisting benefits in sectors disadvantaged by war mobilization, not those favored with government funded plant and equipment, and featured in stories about production miracles.

Whether they occurred in favored or unfavored sectors, innovations were often in response to and especially suited to a highly unusual set of input availabilities and implicit factor prices, conditions that 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.

One might argue that 1948 is too soon to see the putative beneficial effects of learning by doing. Within the manufacturing sector TFP did increase after 1948, but much more slowly than during the interwar years, and, in contrast to the prewar period, its rate of advance was generally below the economy wide average.[8] Between 1949 and 1973 TFP growth in the sector was less than half what it was between 1929 and 1941, and less than a third what it had been between 1919 and 1929. The key takeaways are these: the level of manufacturing TFP in the United States was lower in 1948 than it had been in 1941, and grew much more slowly in the postwar years than had been true in the interwar period. Those defending the "war benefits aggregate supply" hypothesis need to claim that without wartime economic mobilization the downward trend in manufacturing productivity growth would have been even more pronounced.

Learning by Doing

Learning by doing is central to the claim that World War II production experience had positive persisting effects on aggregate supply. References almost always begin with the Liberty ships and go on to cite examples of the inverse relationship between cumulated output and unit labor requirements for B-24s, C-47s, or Oerlikon antiaircraft guns.[9] These gains, although they require some qualification, were real. But they did not generalize to the rest of the economy, and did little to boost either civilian or military production capability after it. The manufacture of most of these products 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.

The wartime diversion of resources to military production, moreover, halted direct learning in the production of consumer durables. Then, as now, the most important of these were automobiles. In 1939, the car industry consumed 18 percent of the steel, 80 percent of the

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[8] Exceptions were briefly (and barely) during the 1995-2005 IT boom and, less consequentially, during the doldrums of the dark ages (1973-95).

[9] Roosevelt's "Must List" of January 6, 1942 announced unit production targets for 1942 and 1943 in four categories: Planes, Ships, Anti-Aircraft Guns, and Merchant Ships (Edelstein, 2001, p. 60, citing Smith, 1959, p. 141). Guns and (military) ships were the biggest ticket hardware items in the US war effort (Smith, 1959, p. 7).

rubber, 34 percent of the lead, and 10-14 percent of the copper, tin, and aluminum in the US economy. Output and sales of passenger vehicles rose rapidly in 1940 and 1941, as growing defense spending along with foreign orders primed the pump of an economy finally emerging from a decade of depression. As production levels in the first half of the year began to approach 1929 levels, government economists became concerned that, if war came, rising demands for consumer durables and military hardware could not both be accommodated without exacerbating developing shortages in steel, machine tools, and other key inputs.

Those who believed war inevitable concluded that in order to maximize production of aircraft, tanks, and ships, the United States would need to terminate, or at least dramatically curtail the production of metals-intensive consumer durables, particularly automobiles and white goods (refrigerators, washing machines, and other appliances). Prior to Pearl Harbor industry leaders resisted curtailment, arguing (wrongly) that only a small part of its plant and equipment could be converted to military production. They were joined by officials in the Office of Production Management, who echoed industry fears. After a decade of Depression, their concern was that factories and workers might sit idle during an interval between curtailment and a stream of military orders whose size and timing remained uncertain. The President, government economists, and other New Dealers pushed for speedier reductions in civilian metals-intensive production (Koistinen, 2004, pp. 130-132).

Pursuant to a late summer agreement, modest cutbacks began in August of 1941. The commencement of hostilities in December dramatically accelerated curtailment. Effective January 1, 1942, all sales of as well as the delivery of previously ordered cars, trucks, and parts were prohibited. Effective February 22, 1942, the production of all US passenger vehicles, commercial trucks, and auto parts ceased. Half-finished assemblies, along with many specialized tools and dies, were sent to salvage to be melted down and recycled. Car dealers retained an inventory of 520,000 1942 model 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, resuming 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.[10]

The suggestion that experience gained building B-17s or Sherman tanks generated major beneficial spillovers in civilian production after the war is inconsistent with the sectoral productivity data. Nor is it supported by what we know qualitatively about the evolution of technologies in these sectors progressivity. The 1930s were a fertile period for automotive engineering, during which many modern features, including automatic transmission, power steering, and the V-8 engine were introduced. During the 1950s and 1960s the industry settled into a marketing infused senescence distinguished by planned obsolescence, an emphasis on annual model changes, and steadily deteriorating quality, which ultimately left it at the mercy of foreign competitors (Zeitlin, 1995, p. 75).[11]

The story was not noticeably different in the appliance sector. Refrigerator and appliance production, including washing machines, cookstoves, metal office furniture, and vacuum cleaners 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 1942 and August 1945.

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[10] The situation with respect to truck technology is somewhat more nuanced. Between 1942 and 1945 the US produced for the military close to 2.4 million light, medium, light-heavy, and heavy-heavy trucks (Smith, 1959, p. 9).

[11] "In the United States…wartime aircraft production appears to have had little impact on domestic manufacturing practice outside of the industry itself" (Zeitlin, 1995, p. 75). Even the latter can be questioned.

The war was undoubtedly associated with advances in 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 the atomic bomb. Nuclear power, of course, did have civilian applications, but its benefits in the postwar economy were mixed, and, given the prewar state of scientific and technical knowledge, it likely would have arrived with or without the war. It took Enrico Fermi and his colleagues at the University of Chicago less than a year following Pearl Harbor to produce the world's first controlled nuclear chain reaction.

Based on the English experience, Davis and Stammers suggest that advances in gas turbine technology may have been an area where the war genuinely advanced a useful postwar technology (1975, p. 515). But since we cannot be entirely sure of the counterfactual, even here, the conclusion is uncertain: jet engines might well have arrived as quickly in the absence of the conflict. Aircraft design was advancing rapidly during the 1930s, with a high rate of obsolescence and technical progress. By 1938 US commercial aviation already transported more than a million passengers a year, a carriage that had increased more than twenty-fold over the prior decade (Holley, 1964, pp. 11-12).

The B-29, one of the few combat aircraft that had not yet flown at the time the US entered the war, and the single most expensive weapons system in the Second World War (more than $3 billion as compared with $2 billion for the Manhattan project), was entirely pressurized, boasted a state of the art fire control system, and advanced monocoque technique – the external skin of the plane contributed to its structural integrity. But that design concept went back decades—and the last generation of bombers with propellers likely would have had it with or without the war. As was the case for every other aircraft discussed below, the design work on the B-29 was completed prior to Pearl Harbor, with the first orders placed in May of 1941.

With the exception of approximately 14,000 gliders, all of the 276,000 military aircraft produced between 1942 and 1945 were piston driven. A 1971 Smithsonian Institution study (Fayette, 1971) documents that almost all of the technical improvements in such engines predated 1940 (see especially figure 71, p. 84). That is in part because development work shifted to jet engines, but it also demonstrates that the production of hundreds of thousands of aircraft engines under wartime conditions did not automatically lead to major improvements in their performance or reliability.

The evidence for learning by doing as a contributor to declining production cost at the product level is solid, and on the surface would seem an obvious explanation for an alleged boost to TFP. Such a boost, as we have seen, is not evident in the manufacturing productivity data. In order to understand why, we must identify where the technological progress is claimed to have been most concentrated, and consider why it might not have benefitted 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 these observations. Alchian also took the effects of learning by doing as well established, and explored how reliable were statistically estimated learning parameters in airframe production in predicting the decline in labor requirements per pound of aircraft as a function of cumulated output.

The productivity gains experienced in the manufacture of military goods – not just airframes but also Liberty Ships, Oerlikon antiaircraft guns, and other ordnance, were important for the war effort. Let's begin with aircraft production, which absorbed a quarter of all wartime spending on munitions ($45 billion) (Koistinen, 2004, p. 38). Learning by doing might have generated three types of advance that could have contributed to a residual measuring 'technological' progress in manufacturing between 1941 and 1948 and on into the postwar period: 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 within a very short time frame, and 3) gains that might have applied to manufacturing more generally.

It is uncontroversial that gains in category 1 were large. The United States produced approximately 276,000 aircraft between 1942 and 1945, and 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). Twenty-one World War II aircraft in the United States meet 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 B-25 (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).[12] These bomber production runs exceeded by two orders of magnitude those common in the postwar period.[13]

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 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.

[12] The only heavy bomber that had not flown prior to Pearl Harbor, was the B-29, 3,970 of which were built. This was the aircraft that delivered atomic bombs to Hiroshima and Nagasaki, as well as the Abel airblast at Bikini atoll in July of 1946. Production of B-29s ceased in 1946.

[13] The B-52, produced between 1952 and 1962: 742; the B-1A and B, produced between 1973 and 1974 and then again between 1983 and 1988: 104; the B-2, produced between 1987 and 2000: 21. Here are comparable numbers for postwar military transport aircraft, along with years of production in parentheses: Lockheed C-141 Starlifter: 285 (1963-1968). Lockheed C-5 Galaxy: 131 (1968-73; 1985-1989); Boeing C-17 Globemaster III: 279 (1991-2015).

The Douglas C-47, the military transport version of the DC-3, remained in production until 1952, but the rate of production slowed greatly after the war. Total production was 16,079, including 607 civilian versions (DC-3s 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.[14]

Constructing so many aircraft in such a short period was an extraordinary achievement. During 1944, the United States completed an airplane on average once every five and a half minutes (Walton, 1956, p. 540).[15] But 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. None of the experience acquired in producing these models can have had much direct 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.

What about category 2 – gains relevant perhaps not to the manufacture of specific aircraft per se, but to the manufacture of aircraft more generally? This was, after all, an industry in which the United States became a world leader after the war, with consequences that transformed

[14] See Smith (1959, p. 27) for statistics on Army aircraft production in close agreement with the comparable numbers from Wikipedia.
[15] 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.

regional economies, particularly in the West. It is important in this regard to appreciate the unusual and indeed unique characteristics of World War II aircraft manufacture. The country – indeed the world – never again produced such vast quantities in a similarly compressed time frame. In the postwar period, a very small number of aircraft models have approached or exceeded cumulative production runs of 5,000, and most of those that did were small single engine piston driven aircraft produced for the general aviation market: Beechcraft, Cessnas, Pipers, and Aeroncas. We have already noted that there was very little improvement in the performance or reliability of piston driven aircraft engines during the war.

Following 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). The subsonic heavy bomber, the B-52, originally built between 1954 and 1963, had a cumulative production run of 742. Only one US commercial aircraft has exceeded cumulated output of more than 5,000 in the postwar period. Production of the Boeing 737 began in 1967 and on March 13, 2018, surpassed 10,000. That cumulative output, however, has taken place over half a century, not two or three years.

Some compromises, moreover, had to be made to enable the extraordinary wartime rate of throughput. 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 and eventually refused to accommodate more of them. A consequence was that thousands of aircraft rolled off the production line and were then flown immediately to one of 19 modification centers run by the Army Air Force. 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 change requests desired by the military.[16]

The story is similar in the case of ship production. Between 1941 and 1945 eighteen shipyards in the United States produced 2,710 Liberty ships. No other ship model before or since has ever approached this record of cumulated output (the ship was based on an 1879 British design). The gains in labor productivity were partly enabled by replacing rivets with welds; the remainder has traditionally been attributed to more mundane learning by doing. As in the case of aircraft, we must somewhat qualify our enthusiasm about production successes. Thompson (2001) suggests that much of the measured labor productivity improvement over time was attributable to quality deterioration and capital deepening, rather than advance in TFP. The quality deterioration was evident in the more than 100 Liberty ships that sank within ten years of launch due to hull or deck fractures resulting from poor welds. Even if we acknowledge significant learning by doing in producing these vessels, such knowledge was of questionable relevance after the war because the US economy has never been and likely never will be faced again with the challenge of producing so many similar ships in such a short period.

US shipyards, including those owned and operated by the US Navy, also produced a prodigious number of naval vessels between 1941 and 1945 inclusive: 31 aircraft carriers, 6 battleships, 42 battle, heavy, and light cruisers, 302 destroyers, 191 submarines, and 78,242 landing craft (U.S. Department of Commerce, 1947, table 247, p. 222). The relevance of this to

[16] Ferguson (2005) provides a nuanced treatment of the different approaches to production taken by aircraft manufactures and General Motors as opposed to Ford. He makes it clear that, contrary to Ford's optimistic assertions, the manufacture of aircraft bore little relation to that of automobiles. Thus the flow rate of output is somewhat overstated, since many of these planes had to be partially deconstructed and retrofitted before they could be used.

the 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 vessels.[17]

We can conclude that the 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 scant 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 spite of Lend Lease, foreign aircraft orders, and pre-Pearl Harbor increases in military spending, the category comprised just 2.2 percent of total manufacturing output in 1941. At its peak in 1944 that 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).

It is more useful to view the 1942-45 achievements as reflecting the application of techniques learned building automobiles and refrigerators in the interwar period to the mass production within a very compressed period of aircraft and other military goods designed, in most cases, before the war. The supply side foundations for the postwar period were already largely in place in 1941, and were in part what made economic mobilization for war so successful.

[17] The U.S. Navy currently (2018) operates 10 aircraft carriers.

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. In addition, the country experienced a large increase in physical capital associated with military command structures, forts, and bases. The utility of this capital after the war is an important question, both in cases where the capital might contribute to postwar non-military production, and where it could only be used for military purposes. In the latter case, if a large accumulated stock of military ships, tanks, aircraft, hardware and structures produced or constructed during the war made it possible subsequently to devote a smaller share of US production capability to the manufacture or construction of such goods, that stock could, after the war, have allowed for greater accumulation of government infrastructure complementary to private production, or production and acquisition by the private sector of physical capital useful in civilian production.

With the temporary exception of B-29 bombers, most of the aircraft produced during the war were, at its conclusion, deemed surplus: obsolete and/or unneeded. 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. Towards the end of the war some aircraft were flown directly from the factory gate to Arizona for disassembly and recycling. 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 United States so they could be scrapped. Similar fates befell Liberty ships (scrapped and recycled for the steel), tanks, and other military equipment.[18] These goods had been produced to fulfill an extraordinary need. With the war ended, so did most of that need.

It was not just aircraft and freighters. A veritable flotilla of ships, including two aircraft carriers, four battleships, thirteen destroyers, five submarines, and multitudinous other naval vessels were destroyed or made so severely radioactive in the South Pacific that almost all had to be scuttled. This was the result of two atomic blasts (Operations Crossroads), an airblast on July 1, 1946 (Abel) and an underwater detonation on July 26, 1946 (Baker). Several vessels sank immediately at Bikini as the result of the explosions. Most of the rest were towed to Kwajalein (about 400 kms) for tests, and then scuttled. A few were brought to Pearl Harbor or West Coast US harbors before being used for target practice and then sunk. Two submarines and four smaller ships were successfully decontaminated and sold for scrap. The tests had been designed to demonstrate that naval vessels could survive nuclear bombs, thus countering claims that such ships were obsolete in the atomic age. The tests demonstrated the opposite, and the third planned shot was cancelled. At the time some members of Congress complained that tons of steel that could otherwise have been recycled went to the bottom of the ocean (Weisgall, 1994, pp. 77-78; 317-322).

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 or conventional ordnance, the knowledge that was acquired in building these durables also dissipated. Creative destruction is a feature of production knowledge as

[18] Weyerhauser maintained a small fleet of Liberty ships after the war, but surplus Liberty ships 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. Most of the remainder were mothballed and ultimately scrapped.

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 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. 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.[19] The US did use multipurpose machine tools, which could more easily be repurposed, but principally in the shops producing machine tools.

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, and ultimately to a peak of $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

[19] Again, see Ferguson (2005, p. 166) for a nuanced discussion of variation among manufacturers in these practices.

postwar market. A few tanks were converted to tractors or bulldozers.   Overall, recycling and disposal posed huge logistical challenges.

What, more generally of the billions of dollars of government funded equipment and structures built to produce all the military hardware? To the degree we insist on adjusting upward the growth of the capital stock relevant to private sector production (Gordon, 1969), higher capital growth rates will further reduce the already negative rates of measured TFP advance within manufacturing between 1941 and 1948. For US manufacturing, table 1 shows that labor productivity growth between 1941 and 1948 was negligible (.04 percent per year), mirroring the reduction in the growth of value added per worker across the Civil War years (Lindert and Williamson, 2016, p. 150).

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. 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 GOCO contractors, ALCOA had not been given an option to buy the new government plants it operated, and after the war it faced a new competitor in the form of the Reynolds Aluminum Corporation.

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 or no longer needed 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 explanation is that there was often only a single bidder. 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 given the new realities of military technology. 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.

The conflict also left the country with a vastly expanded network of military structures, a physical plant substantially in excess of the country's needs in the postwar period. The

Pentagon, completed in 1943 at a cost of $78 million, was the small tip of a very large iceberg. As of June 30, 1945, the Army had spent within the United States $7.2 billion on command (non-industrial) plant. This total compares with $8 billion for industrial facilities, of which $7 billion was for government plants and $1 billion for equipment in privately owned plant. Along the way, the Army acquired ownership of additional acreage in the country exceeding the combined area of the six New England states (Smith, 1959, pp. 441, 444, 447). Once built, new forts and bases created political coalitions in favor of their retention. It took decades, including the establishment of multiple Base Realignment and Closure Commissions, for the country to make a dent in that surplus.

Influences on Potential Output

Are there other ways whereby the Second World War might have had a large and persisting positive impact on potential output in the United States? It might have done so by sweeping away retardative institutional obstacles through a permanent change in the philosophy or instrumentalities of government. It might have done so by destroying infrastructure, plant or equipment, allowing it to be replaced or rebuilt along more efficient lines. These two varieties of 'prairie fire' explanation, common in the literature, suggest that in spite of, indeed, because of its destructive power, war burns away historical underbrush, clearing paths for modern, more dynamic growth.[20]

The Second World War did leave significant institutional, normative, and economic legacies for the United States. It solidified a compression of wages that endured for three

[20] These ideas draw strength from an older and highly evocative tradition that saw war as rejuvenative. Theodore Roosevelt was a notable exponent of this view. The 'benefits' of destroyed infrastructure as well as reconfigured institutions are often referenced as partially explaining rapid growth in Germany and Japan in the thirty years after the Second World War. Voightländer and Voth (2013) draw links between war, human capital losses, higher land-labor ratios, and the ability to sustain increases in per capita output in early modern Europe.

decades. Experience with high tax rates and the introduction of withholding gave the federal government expanded fiscal capacity. Controls on wages led inadvertently to the U.S. 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, but see also Jaworski, 2017). The war was not, however, associated with a political revolution or fundamental changes in the instrumentalities of government. Nor, aside from the destruction on the island of Oahu and possibly the wear and tear on plant and equipment resulting from running double and triple shifts (Higgs, 2004, pp. 504, 515-16) did the war damage infrastructure within the United States and its territories.

The argument must therefore turn on something other than "prairie fire" reasoning: longer run effects on total factor productivity growth and/or the growth of hours and physical capital services. In other words, it must turn on more straightforward growth accounting explanations.[21] The prairie fire analogy may be relevant for other countries in other historical instances, but not, by and large, for the United States in World War II. Because the impact on potential hours is so clearly negative (more on this below), and because the effect on capital services, although more complex, is likely mildly retardative, any argument that the war accelerated the advance of potential output must rely on a strong persisting boost to TFP.

The fundamental growth accounting equation tells us that growth of output can be decomposed into contributions from the growth of total factor productivity, the growth of hours, and the growth of capital. As has been noted, TFP in manufacturing declined between 1941 and 1948, and it is in that sector that we would most have expected to see longer run consequences of

[21] 'Prairie fire' effects might of course, ultimately be reflected in any of the components of a growth accounting exercise.

the wartime production experience. TFP in manufacturing did eventually increase in the postwar period, but at a much slower rate than had been true during the interwar period. The BLS historical multifactor productivity tables for manufacturing (2004) show TFP in the sector growing at 1.49 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 (1949-73) it was persistently below it. If we look ahead all the way to the first decades of the twenty first century (table 1), we see an unmistakable downward trend in manufacturing TFP growth, undisrupted by the war, and interrupted only briefly by the decade long IT boom beginning in 1995. Advance dropped to two thirds of a percent per year during the dark ages between 1973 and 1995 before reviving during the IT boom, but then becoming mildly negative between 2005 and 2015.

The immediate postwar impact of the war on potential hours was also clearly negative. 405,399 mostly prime age males never returned. Most would have been alive in the absence of the war. There were another 607,000 casualties. To this one must add the wartime induced spike in injury and fatality rates in U.S. manufacturing and railroads, potentiated by the rise in hours in both sectors, as well as the 8,651 deaths in the U.S. Merchant Marine resulting from sunk cargo ships.[22] The 50 percent wartime rise in female labor force participation (Schweitzer, 1980, p. 90) largely dissipated during the immediate postwar period.

The counterfactual with respect to capital is more complex. The country emerged in 1948, inter alia, with a vastly expanded aluminum production industry and a reduction in its industrial

[22] Kendrick (1961, Table D2, p. 466, Table G3, p. 545; Carter et al, 2006, Series Ba4742, Ba4678, Ba4679.

concentration, a synthetic rubber capability that had been developed basically from scratch, and the Big Inch and Little Inch pipelines, bringing crude oil and refined petroleum products from East Texas to the East Coast.[23] But both public and private capital accumulation in areas not militarily prioritized had been repressed. Wartime priorities 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 Fixed Asset Tables, tables 7.1 and 7.2). 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).

Abramovitz and David wrote that "the war … imposed restrictions on civilian investment, caused a serious reduction in private capital accumulation and retarded normal productivity growth" (2000, p. 547). The above data support this view, although Gordon stated that because of his 'new' interpretation, it was "called into question".[24]

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[23] Between 1939 and 1943, capacity in the aluminum industry increased seven-fold, from 325 million pounds per year to 2.3 billion pounds per year. This contributed critically to U.S. dominance in military and commercial aviation after the war. The new synthetic rubber industry was created in response to the cut off during the war of access to natural rubber supplies in the Far East. Output increased from 28 million tons in 1942 to 922 million tons in 1945 (Koistinen, 2004, pp. 138, 149). The Big Inch and Little Inch pipelines transported fuel without exposing it to the risk of submarine predation along the Gulf and Atlantic coasts.

[24] While endorsing for the most part Abramovitz/David's conclusions about the war, Field took issue with their broader narrative of the twentieth century as reflecting a dependence on knowledge-based growth that differed

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 understatement 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. On the other hand, investments by the Defense Plant Corporation had added significantly to manufacturing capacity in war prioritized sectors.

The Macro Evidence on Total Factor Productivity

The aggregate TFP growth rates presented in chapter 16 of Gordon (2016) are the principal, indeed the only quantitative empirical support for his interpretation of the beneficial supply side effects of the war. His figure 16-5 appropriately highlights the generally strong TFP growth between 1920 and 1970, as compared with the decades prior to and following these years. But this beautifully symmetric bar graph, with TFP growth rates peaking in the decade of the 1940s and falling off monotonically in the decades immediately preceding and following, is deeply 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,[25] apparently echoing Baumol's interpretation of the

fundamentally from what had been true in the nineteenth. Abramovitz/David generalized from the high TFP growth of the first half of the twentieth century, a generalization which the data from the second half did not support. TFP growth in the last third of the twentieth century was in fact lower than it had been during the comparable period in the nineteenth.

[25] Gordon presented his estimates in bar graph, not tabular form, so these numbers are approximate. The Rise and Fall of American Growth brought to a popular audience as well as many economists an interpretation of the broad contours of US economic growth since 1870. Gordon considered the evolution of productivity, consumption, and more generally the U.S. standard of living from the end of the Civil War to the present day. Although the research was determinedly historical – sixteen of eighteen chapters focused principally on the past -- it was the pessimistic forecast for the future developed in previous working papers and summarized in chapters 17 and 18 that generated the lion's share of critical discussion and commentary. The debate featured dueling TED talks from Gordon on the one hand and Eric Brynjolfsson and Andrew McAfee on the other (both from 2013), as well as optimist rebuttals to Gordon from his colleague Joel Mokyr (2016), Deirdre McCloskey (2016), and others.

Maddison data. Here is the problem. Kendrick (1961), Abramovitz and David (2000), Field (2003, 2011) and Gordon all operate within an NBER tradition emphasizing the necessity, to the extent possible, of estimating trends in macroeconomic series by measuring between peaks. There are strong cyclical effects on productivity, particularly TFP, which is why it is so important to measure growth rates between years when the economy is at or close to potential. Figure 16-5 reports decadal growth rates of TFP across intervals bracketed by census years. There is no reason to expect census years to coincide with business cycle peaks, and in most instances they don't.

1940 was considerably below potential: Lebergott unemployment was close to 15 percent. 1941 is the closest we can get to full employment prior to the economic distortions 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. As for the pre-Depression peak, 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.

The use of 1940 as a benchmark is the most problematic. 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, as compared with calculations that measure to and from 1941. As a consequence, decadal rates of TFP growth between census years are unlikely to be good proxies for peak to peak measures across the 1930s (1929-41) or across the war years (1941-48).

As noted, Gordon has TFP growth between 1940 and 1950 at about 3.4 percent per year (figure 16-5). Real output calculated using chained index methods grew at 5.6 percent per year over that interval (Bureau of Economic Analysis, NIPA Table 1.1.6). That leaves 2.2 percent per year for the combined contribution to growth of increases in labor and capital input. But we do not want to measure from trough to peak, and we were well below potential in 1940. Real output growth between 1941 and 1948, again from the BEA, was 4.3 percent per year. The growth rate is lower principally because 1941 is closer to potential than 1940, part of the reason 1941's measured TFP level is higher than for 1940. If Gordon's 1940-50 TFP growth rate of 3.4 percent mirrored its growth between 1941 and 1948, only .9 percent per year would be left for the combined contribution to growth of increases in capital and labor input. But (weighted) input growth was in fact almost twice that (1.67 percent per year). Under these assumptions the highest rate at which TFP could have been growing was 2.63 percent annually.[26]

Consider now productivity growth across the Depression years. The difference between the peak to peak (1929-41) measure and the between-census dates measure of real output growth is less dramatic than for the 1940s, because both 1930 and 1940 were below potential. Still, measuring between 1930 and 1940 real output grew at 2.70 percent annually, whereas between 1929 and 1941, it advanced at 2.87 percent per year. Between 1929 and 1941 inputs conventionally measured increased hardly at all (.07 percent per year),[27] meaning TFP between 1929 and 1941 grew at 2.80 percent per year. Gordon has TFP growth between 1930 and 1940

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[26] Kendrick (1961, Table A-XXII) shows private domestic economy labor input growing at 1.71 percent per year between 1941 and 1948.[26] The BEA's Fixed Asset Table 1.2, line 3 shows private sector fixed assets growing at 1.58 percent per year over the same period. Weighting labor input growth by .7 and capital input growth by .3, we have growth of inputs conventionally measured at about 1.67 percent per year.[26] TFP could not have been growing at 3.4 percent per year between 1941 and 1948 because 3.4 (TFP growth) + 1.67 (input growth) > 4.3 (output growth).

[27] Private sector quality adjusted labor input was basically unchanged, increase 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, Fixed Asset Table 1.2, line 3). Weighting capital growth by .3 and labor growth by .7 we have inputs conventionally measured increasing hardly at all (.07 percent a year).

at 1.8 percent per year. A considerable part of the difference has to do with Gordon's bespoke capital service adjustments, about which more below.

Both the 2.63 percent estimate of TFP growth between 1941 and 1948 and the 2.80 estimate for 1929 and 1941 are before a cyclical adjustment for 1941. 1941 is the closest we can get to full employment before full scale war mobilization, but it still evidenced close to 10 percent unemployment. A cyclical adjustment will raise the TFP estimated growth rate for 1929-41 and lower it for 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 rate of economy-wide TFP, above and beyond trend (Field's law). A cyclical adjustment based on this regularity adds close to half a percentage point to the 1929-41 growth rate of TFP, and subtracts even more from the 1941-48 rate.

Based on Field's law, we can estimate 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 approximately .5 log percentage points to a TFP growth rate calculated over the period 1929 – 1941 (2.8 +.49 = 3.29). At the same time, using the adjusted 1941 level and calculating growth to 1948, we have TFP growth across the war years of 1.80 percent.[28] Gordon's table 16.5 suggests TFP growth in the 1930s half that during the 1940s: 1.8 vs 3.4 percent per year. My calculations suggest that the relevant peak to peak TFP growth rates across the 1930s and across the war years were roughly the reverse.

I use changes in Lebergott rather than Darby unemployment on the right hand side of the regressions and in the cyclical adjustment calculations because the Lebergott numbers offer a

[28] Adding 6 percent to the 1941 TFP level reduces the 1941-48 growth rate by .83 log percentage points.

better proxy for the output gap in the private nonfarm economy. The dependent variable in the regressions is the change in the natural log of TFP in the private nonfarm economy (Field, 2010). The difference between the two unemployment series is the inclusion by Darby of federally funded workfare (emergency workers) during the depression as employed (see Lebergott, 1964, Darby, 1976). There is little reason to believe that the hiring of CCC or PWA or WPA workers would have affected measured TFP in the private nonfarm economy because the hiring of unemployed workers into government provided relief jobs would have had little influence on the ratio of capital to labor in the private sector, the principal factor driving the procyclicality. For this reason the Lebergott numbers are the preferred series in making a cyclical adjustment to the level of 1941 TFP in the private sector.

Adjustments to Labor and Capital Input

Over his career Gordon has made various adjustments to labor and capital input that changed 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 adjustments and the then newfound enthusiasm for 1950-64.

In The Rise and Fall of American Growth, Gordon shifted back to locating his great leap in the second quarter of the century, but continued to propose several capital service flow adjustments. These include adding government capital,[29] 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. The adjusted series allocates a higher fraction of a higher log point increase between 1928 and 1950 to the 1928-41 period, and a lower fraction to 1941-50. This will reduce estimates of TFP increases for the entire economy in the former period by more than it does in the latter period. But it is not enough to overturn the conclusion that such growth was higher across the Depression years than it was across the war years.

Replacing Gordon's "official BEA capital" with his adjusted capital (which includes all three of the above adjustments) adds 20.9 log points to 1941 capital levels as compared with 1928 (Gordon, 2016, table A-2, line 5, p. 666). This implies an upward adjustment of 1.6 percent per year (20.9/13) in the continuously compounded growth rate of capital between 1928 and 1941. Assuming a capital share of .3, this adjustment would chop .48 percentage points off my estimate of 3.29 percent per year between 1929 and 1941, bringing it down to 2.81.

The adjustments also raise capital growth rates for the period 1941 to 1950, but by much less. Official BEA capital increases 18 log points, whereas the adjusted series goes up 21.2 points, a 3.2 log point difference, which, dividing by 9, would add .36 percentage points per year to the continuously compounded growth rate of capital between 1941 and 1950. Again using .3 for capital's share, and assuming Gordon's revised capital growth rate between 1941 and 1950 would look similar to that between 1941 and 1948, this would reduce my estimate of TFP growth between 1941 and 1948 by .11 percentage points, bringing it down from 1.80 to 1.69 percent per

[29] Gordon includes not just government capital clearly complementary to private sector capital (e.g. streets, highways, bridges, tunnels, and sewers) but also military structures (but not equipment). Each of these adjustments raises conceptual and other issues that deserve more extended discussion.

year, as compared with 2.81 across the Depression years (1929-41). Whatever their merits, these adjustments are unlikely to reverse the conclusion that economy-wide TFP growth was substantially higher across the 1929-41 period than it was between 1941-48 or 1941-50.

Differences in the way productivity growth is calculated across different periods, particularly the intervals selected, can 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 misleads insofar as it suggests a very high trend growth rate of TFP across the war years. Mobilization 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.

Conclusion

The 'economic miracle' narrative, which Gordon whole-heartedly embraced, emerged against the backdrop of a continuing contest over how to organize, characterize and credit the production successes. 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,[30] 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 design, testing and some production of weaponry, particularly artillery and small arms, took place. Outside of the Navy Yards and Army Arsenals, 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.

Business leaders were so focused on who should get credit for the production achievements that they eventually 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 in a speech in December of 1943 (Wilson, 2016, p. 106). While the repeated insistence by private sector leaders that achievements were in spite of the bureaucratic hamstringing of government officials was self-serving, their claim that success depended on

[30] A number of aircraft models were produced by more than one contractor.

prior production experience and their eventual push back against appeals to the supernatural can be endorsed.

In 1948, the United States stood astride the world, both militarily and economically. Japan, having endured two atomic bombings as well as the earlier firebombing of Tokyo, lay prostrate. Germany and much of Europe was in ruins. The Soviet Union had suffered 20 million war-related deaths. England had sold off much of its remaining overseas economic empire to pay for military spending. The United States appeared relatively unscathed, and it was easy to connect the country's success in producing hundreds of thousands of aircraft and other military hardware with the level of its potential output after the war and the large productivity gap between the US and the rest of the world then evident. But the connection is a mirage. The economy's postwar capabilities are almost entirely attributable to conditions already in place in 1941. As far as the long run advance of aggregate supply is concerned, the military conflict was a detour, as had been the case for the Civil War and, it appears, the Revolutionary War and its aftermath (Lindert and Williamson, 2016, ch. 4).

Although the war did leave the economy with assets that benefited postwar production capability, it distorted physical capital accumulation, crowding out investment in sectors of the economy not critical for the military effort. 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 the Appendix documents, 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. A longer-term impact on TFP of learning by doing in wartime production is doubtful, because the output mix as well as factor prices differed after the war, and there were few spillovers from this learning to the production of other products.

The conventional wisdom about the supply side effects of the war is premised on an interpretation of aggregate productivity data buttressed by learning by doing narratives. The use of census date intervals to calculate TFP growth in the 1930s and 1940s creates a misleading picture of peak to peal trend growth rates during the interwar period because of the strong procyclicality of TFP measures and the fact that a sizable output gap persisted in 1940. Sectoral productivity data show that TFP growth within manufacturing was negative over the latter interval, the biggest percentage point contribution to TFP growth between 1941 and 1948 actually coming from wholesale and retail distribution, a sector starved of resources during the conflict. TFP growth in manufacturing during the golden age (1948-73) was positive but much lower than during the interwar period, and below the economy wide average, whereas between 1919 and 1941 it was above it.

When subject to critical analysis, the learning by doing narratives, which seem so compelling on their face, collapse as an explanation for an alleged boost to postwar TFP advance, which in any event is not evident in the productivity data. The paper looks in depth at the case of aircraft (the largest category of spending on munitions during the conflict) as well as the Liberty Ships. The learning that took place during the war was largely irrelevant afterwards, because the output mix was different and we never again mass produced such large quantities of aircraft or ships in such a limited time frame. Creative responses to shortages of critical raw materials such as steel were irrelevant after the war when more “normal” peacetime factor prices returned.

For economists and economic historians who work on the United States, the war frequently remains a cipher, a series of years to be omitted from time series regressions or otherwise passed over. But it continues to play an important role in the macro narrative of the twentieth century – both in closing the output gap remaining in 1941, and in (allegedly) laying the groundwork on the supply side for postwar advance. For the United States, as for other combatants, the Second World War was in fact an enormous and tragic waste of human and physical resources.[31] Economically disruptive, it greatly distorted 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 accomplished in the production of military hardware was indeed exceptional. But the impact on the growth of U.S. potential output of this unique and never to be repeated experience was almost certainly retardative.

[31] Other countries suffered more, both in absolute terms and relative to their size. The argument here is with the optimistic view of the war's impact on U.S. aggregate supply.

REFERENCES

Abramovitz, Moses and Paul A. David. 2000. "American Macroeconomic Growth in the Era of Knowledge Based Progress: The Long Run Perspective," in S.E. Engerman and R. Gallman (2000), pp. 1-92.

Alchian, Armen. 1963. "Reliability of Progress Curves in Airframe Production." Econometrica 30 (October): 679-693.

Arrow, Kenneth. 1962. "The Economic Implications of Learning by Doing." Review of Economic Studies 29 (June): 155-173.

Bakker, Gerben, Nicholas Crafts, and Pieter Woltjer. 2017. "The Sources of Growth in a Technologically Progressive Economy, 1899-1941." CAGE Working Paper No. 341, University of Warwick.

Baumol, William J. 1986. "Productivity Growth, Convergence, and Welfare: What the Long-run Data Show." American Economic Review 76 (December): 1072-1085.

Brynjolfsson, Eric and Andrew McAfee. 2013. "The Key to Growth? Race with the Machines." TED talk. Available at https://www.ted.com/talks/erik_brynjolfsson_the_key_to_growth_race_em_with_em_the_machines.

Carter, Susan B., Scott Gartner, Michael Haines, Alan Olmstead, Richard Sutch and Gavin Wright. 2006. Historical Statistics of the United States, Millennial Edition. Cambridge: Cambridge University Press.

Cook, James Allan. 1948. The Marketing of Surplus War Property. Washington, D.C. Public Affairs Press.

Cowen, Tyler. 2014. "The Lack of Major Wars May be Hurting Economic Growth." The New York Times (June 14). Available at https://www.nytimes.com/2014/06/14/upshot/the-lack-of-major-wars-may-be-hurting-economic-growth.html.

Creamer, Daniel, Sergei Dobrovolsky, and Israel Borenstein. 1960. Capital in Manufacturing and Mining: Its Formation and Financing. Princeton: Princeton University Press.

Darby, Michael R. 1976. "Three-And-A-Half Million U.S. Employees Have Been Mislaid: Or, An Explanation of Unemployment, 1934-1941." Journal of Political Economy 84 (February): 1-16.

Davies, D., & Stammers, J. 1975. "The Effect of World War II on Industrial Science." Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences, 342(1631): 505-518. Retrieved from http://www.jstor.org/stable/78750.

Edelstein, Michael. 2001. "The Size of the U.S. Armed Forces During World War II." Research in Economic History 20: 47-97.

Engerman, Stanley L. and Robert E. Gallman. 2000. The Cambridge Economic History of the United States, Volume III, The Twentieth Century. Cambridge: Cambridge University Press.

Ferguson, Robert G. 2005. "One Thousand Planes a Day: Ford, Grumman, General Motors and the Arsenal of Democracy." History and Technology 21 (June): 149-175.

Field, Alexander J. 2003. "The Most Technologically Progressive Decade of the Century," American Economic Review 93 (September): 1399-1414.

Field, Alexander J. 2010. "The Procyclical Behavior of Total Factor Productivity in the United States, 1890-2004." Journal of Economic History 70 (June): 326-50.

Field, Alexander J. 2011. A Great Leap Forward: 1930s Depression and U.S, Economic Growth. New Haven: Yale University Press.

Field, Alexander J. 2018. "Manufacturing Productivity" in Oxford Handbook of American Economic History, eds. Louis P. Cain, Price Fishback, and Paul Rhode. Oxford: Oxford University Press, forthcoming.

Goldin, Claudia and Frank Lewis. 1975. "The Economic Cost of the American Civil War: Estimates and Implications." Journal of Economic History 35 (June): 299-326.

Gordon, Robert J. 1969. "$45 Billion of U.S. Private Investment has been Mislaid." American Economic Review 59 (June): 221-38.

Gordon, Robert J. 2013. "The Death of Innovation, the End of Growth." TED talk. Available at https://www.ted.com/talks/robert_gordon_the_death_of_innovation_the_end_of_growth.

Gordon, Robert J. 2016. The Rise and Fall of American Growth: the U.S. Standard of Living Since the Civil War. Princeton: Princeton University Press.

Hacker, Louis M.. 1940. The Triumph of American Capitalism: The Development of Forces in American History to the End of the Nineteenth Century. New York: Columbia University Press.

Higgs, Robert. 2004. "Wartime Socialization of Investment: A Reassessment of US Capital Formation in the 1940s." The Journal of Economic History 64 (June): 500-520.

Higgs, Robert. 2010. "Private Capital Consumption: Another Downside of the Wartime "Miracle of Production." , available at https://fee.org/articles/private-capital-consumption-another-downside-of-the-wartime-miracle-of-production/?utm_medium=popular_widget accessed February 6, 2017.

Holley, Brinton Jr. 1964. Buying Aircraft: Material Procurement for the Army Air Force. Washington, D.C.: Office of the Chief of Military History, Department of the Army.

Jaworksi, Taylor. 2017. "World War II and the Industrialization of the American South." Journal of Economic History 77 (December): 1048-1082.

Koistinen, Paul A. C. 2004. Arsenal of World War II: The Political Economy of American Warfare, 1940-1945. Lawrence, KS: University Press of Kansas.

Kuznets, Simon. 1952. "National Income Estimates for the United States Prior to 1870." Journal of Economic History 12 (Spring): 115-130.

Lerbergott, Stanley. 1964. Manpower in Economic Growth: The American Record Since 1800. New York: McGraw Hill.

Lindert, Peter H. and Jeffrey G. Williamson. 2016. Unequal Gains: American Growth and Inequality Since 1700. Princeton: Princeton University Press.

McCloskey, Deirdre. 2016. "Relax, Economic Pessimists, the Sky Will Not Fall." Available at http://www.prospectmagazine.co.uk/magazine/relax-economic-pessimists-robert-gordon-lawrence-summers-economic-growth-not-over.

Mokyr, Joel. 2016. "Technology and Economic Growth." Available at https://www.project-syndicate.org/commentary/technology-and-economic-growth-by-joel-mokyr-2016-11.

National Bureau of Economic Research, Number of New Private Nonfarm Housing Units Started, One-Family for United States [A0201AUSA176NNBR], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/A0201AUSA176NNBR, February 11, 2017.

Ristuccia, Christiano Andrea and Adam Tooze. 2013. "Machine Tools and Mass Production in the Armaments Boom: Germany and the United States, 1929-44." Economic History Review 66: 953-974.

Rockoff, Hugh. 2012. America's Economic Way of War. Cambridge: Cambridge University Press.

Ruttan, Vernon. 2006. Is War Necessary for Economic Growth? Military Procurement and Economic Development. Oxford: Oxford University Press.

Schweitzer, Mary. 1980. "World War II and Female Labor Force Participation Rates." Journal of Economic History 40 (March): 89-95.

Smith, R. Elberton. 1959. The Army and Economic Mobilization. Washington: Government Printing Office.

Taylor, C. Fayette. 1971. Aircraft Propulsion: A Review of the Evolution of Aircraft Piston Engines. Washington: Smithsonian Institution Press.

Thompson, Peter. 2001. "How Much Did the Liberty Shipbuilders Learn? New Evidence for an Old Case Study." Journal of Political Economy 109 (February): 103-137.

United States Department of Commerce. 1947. Statistical Abstract of the United States. Washington: Government Printing Office.

United States Department of Commerce, Office of Business Economics. 1966. The National Income and Product Accounts of the United States, 1929-65. Washington: Government Printing Office.

United States Bureau of Economic Analysis, National Income and Product Account tables, and Fixed Asset Tables, both available at http://www.bea.gov. Accessed January 23, 2016.

United States Bureau of Labor Statistics. 2004. "Multifactor Productivity in U.S. Manufacturing and in 20 Manufacturing Industries." Dated February 10.

Voightländer, Nico and Hans-Joachim Voth. 2013. "Gifts of Mars: Warfare and Europe's Early Rise to Riches." Journal of Economic Perspectives 27 (Fall): 165-186.

Walton, Francis. 1956. The Miracle of World War II: How American Industry Made Victory Possible. New York: Macmillan.

Weisgall, Jonathan. 1994. Operation Crossroads: The Atomic Tests at Bikini Atoll. Annapolis: Naval Institute Press.

Wikipedia. 2017a. s.v. "List of Most-Produced Aircraft." Available at https://en.wikipedia.org/wiki/List_of_most-produced_aircraft ; accessed January 18, 2017.

Wikipedia, 2017b. s.v. "World War II Aircraft Production." Available at https://en.wikipedia.org/wiki/World_War_II_aircraft_production; accessed January 18, 2017.

Wilson, Mark R. 2016. Destructive Creation: American Business and the Winning of World War II. Philadelphia: University of Pennsylvania Press.

Wright, Gavin. 2017. "World War II, the Cold War, and the Knowledge Economies of the Pacific Coast." Working paper, Stanford University.

Zeitlin, Jonathan. 1995. "Flexibility and Mass Production at War: Aircraft Manufacture in Britain, the United States and Germany, 1939-1945." Technology and Culture 36 (January): 46-79.

APPENDIX

This appendix provides the data underlying the conclusion that TFP in manufacturing between 1941 and 1948 declined, estimates TFP growth in other sectors during this same period, and examines sectoral contributions to private nonfarm economy TFP growth between 1941 and 1948. The exercise differs from the discussion of trends in aggregate TFP discussed in the main body of the paper. 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 examining 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 A8 brings these sectoral estimates together and estimates their respective contributions to aggregate TFP growth. The calculations reflected in table A1 are described in the main text.

We adopt a similar approach for other sectors, beginning with wholesale and retail trade (table A2). 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, 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 -.8 percent between 1929 and 1941, and -.9 percent between 1941 and 1948. Bringing all three series together, and assuming a capital share of .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 .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. And in contrast to manufacturing, 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 without than with learning by doing.

For railroads (table A3), a sector which, in contrast with 1917-18, performed 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 A4) 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 rather than hours 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 A5) 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 A6, with output and hours from Kendrick, and capital from the BEA's Fixed Asset Table 2.2. TFP growth 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 advance, the sector's contribution to PNE TFP growth is a negligible .02 percentage point.

Finally, construction (table A7). 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.[32] The sectors discussed in tables A1-7 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 A8).

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 and allocations of materials and labor within wartime manufacturing.

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[32] Note that because I have not attempted cyclical adjustments for the sectoral estimates, I am also not including a cyclical adjustment for the aggregate growth rate here.

Table A1

Manufacturing Productivity Growth: 1929-41; 1941-48

		Nominal Output	Nominal Durables	Deflator -1958=100 Durables	Nondur	Real Output	FTEs	Adjusted FTEs	Manu Capital	Labor Prod.	TFP
Levels	1929	21945	11303	56.4	54.5	39567	10428	10428	10.136		
	1941	33211	20317	50.4	47.7	67343	13137	12067	11.576		
	1948	67571	35448	86.4	88.5	77349	15276	13824	15.209		
Growth Rates											
	1929-41					0.0443		0.0122	0.0111	0.0322	**0.0325**
	1941-48					0.0198		0.0194	0.0390	0.0004	**-0.0055**

Sources: Nominal Output: Department of Commerce, 1966, table 1.12

Deflators (1958=100): Department of Commerce, 1966, table 8.6

FTEs: Bureau of Economic Analysis: NIPA Table 6.5

FTEs adjustment: HSUS, series Ba4580

Capital: Bureau of Economic Analysis, Fixed Asset Table 4.2, line 9

See text for full description.

Table A2
Productivity Growth in Wholesale and Retail Trade

	Nom. Income	PCE Deflator	Real Output	FTEs WT	FTEs RT	FTEs RT Adjust.	Hours Proxy	Multimerch. Shop.	Warehse	Capital Comb.	Labor Prod.	TFP
Levels												
1929	13511	55.3	244.32	1631	4215	4215	5846	13.95	16.499			
1941	17411	48.7	357.52	1952	5075	5075	7027	13.318	14.946			
1948	41674	82.3	506.37	2428	6477	6084	8512	12.822	14.053			
Growth rates												
1929-41			0.0317				0.0153	-0.0039	-0.0082	-0.0057	0.0164	**0.0227**
1941-48			0.0497				0.0274	-0.0054	-0.0088	-0.0068	0.0223	**0.0326**

Sources: US Department of Commerce, 1966
BEA NIPA Table 6.5A; Fixed Asset Tables 2.1 and 2.2
HSUS series BA 4580
See text for full discussion.

Table
A3
Productivity Growth in US Railroads

	Output	Hours	Capital	Labor Prod	TFP
Levels					
1929	100	100	100		100
1941	105.5	68.6	94.5		141.8
1948	141.8	79.4	93.9		169.6
1950	128.6	63.5	95.6		184.8
Growth rates					
1929-41	0.0045	-0.0314	-0.0047	0.0359	**0.0291**
1941-48	0.0422	0.0209	-0.0009	0.0214	**0.0256**
1941-50	0.0220	-0.0086	0.0013	0.0306	**0.0294**

Source: Kendrick, 1961, table G-3, p. 545.

Table A4

Productivity Growth in Trucking and Warehousing

	Output	Employment	Capital	Labor Prod	TFP
Levels					
1929	10.4	56.9	6.258		
1942	74.5	89.7	6.484		
1948	123.9	107.2	11.918		
1950	174.2	129.7	14.054		
Growth rates					
1929-42	0.1515	0.0350	0.0027	0.1164	**0.1261**
1942-48	0.0848	0.0297	0.1015	0.0551	**0.0336**
1942-50	0.1062	0.0461	0.0967	0.0601	**0.0449**

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 A5
Productivity Growth in Electric and Gas Utilities

Electric

	Output	Hours	Capital	LP	TFP
Levels					
1929	100	100	100		100
1941	186.5	82.5	107.8		194.7
1948	314.8	95.7	116.3		293.7
Rates of Growth					
1929-41	0.0519	-0.0160	0.0063	0.0680	**0.0555**
1941-48	0.0748	0.0212	0.0108	0.0536	**0.0587**

Natural Gas

	Output	Hours	Capital	LP	TFP
Levels					
1929	100	100	100		100
1941	163.6	91.6	110.3		164.6
1948	321.3	138.6	128.7		241
Rates of Growth					
1929-41	0.0410	-0.0073	0.0082	0.0483	**0.0415**
1941-48	0.0964	0.0592	0.0220	0.0373	**0.0545**

	Manhours 1929
Electric	756
Natural Gas	231
Manufactured Gas	172

Electric share	0.6523
Gas Share	0.3477

1941-48 Weighted Average TFP Growth:
0.0572

Sources: Kendrick, 1961, table H-VIII, H-IX, H-X, pp. 592-98.

Table A6

Productivity Growth in Mining

	Output	Hours	Capital	LP	TFP
Levels					
1929	100	100	27.435		
1941	106.5	77	26.989		
1948	133.3	88.9	35.147		
Rates of Growth					
1929-41	0.0052	-0.0218	-0.0014	0.0270	**0.0209**
1941-48	0.0321	0.0205	0.0377	0.0115	**0.0064**

Sources:

Output and Hours: Kendrick, 1961, table C-2, p. 397.

Capital: BEA FAT table 2.2, line 30, mining and oilfield equipment.

Table A7
Productivity Growth in Construction

	Nominal income	Deflator	Real Output	FTEs	Capital	LP	TFP
Levels							
1929	3835	37.6	102.0	1484	7.711		
1941	4219	38.6	109.3	1774	8.553		
1948	10612	76.7	138.4	2278	19.699		
Rates of Growth							
1929-41			0.0058	0.0149	0.0086	-0.0091	**-0.0072**
1941-48			0.0337	0.0357	0.1192	-0.0020	**-0.0271**

Sources:
Nominal Income: US Department of Commerce, 1966, table 1.12
Deflator for Total Structures: US Department of Commerce, 1966, table 8.7, p. 165
FTEs: US Department of Commerce, 1966, table 6.4.
Capital: BEA FAT table 2.2, line 29, Construction Machinery

Table A8

Sectoral Contributions to TFP Growth within the U.S. Private Nonfarm Economy, 1941-48

	1941 Nominal Income (billion $)	1941 PNE Share Nominal Income	1948 Nominal Income (billion $)	1948 PNE Share Nominal Income	1941-48 Sector TFP Growth	1941-48 Percentage Point Contrib. to PNE TFP
All Industries	104.2		224.2			
Less Agriculture, Forestry, Fisheries and Government	85.3		182.8			
Manufacturing	33.2	0.389	67.6	0.371	-0.0055	-0.0021
Wholesale and Retail Trade	17.4	0.204	41.7	0.229	0.0326	0.0071
Railroads	3.8	0.044	7.1	0.039	0.0256	0.0011
Trucking and Warehousing	1.0	0.012	2.3	0.013	0.0336	0.0004
Telephone and Telegraph	1.1	0.013	2.8	0.015	0.0181	0.0003
Electric and Gas Utilities	2.1	0.024	3.7	0.020	0.0572	0.0013
Mining	2.4	0.028	5.4	0.030	0.0064	0.0002
Construction	4.2	0.049	10.6	0.058	-0.0271	-0.0015
TOTAL of Above	65.2	0.764	141.2	0.775		0.0069
Residual Services						
FIRE	9.3	0.109	18.4	0.101		
Other transport services	1.5	0.018	3.5	0.019		
Services n.e.c.	8.9	0.104	19.5	0.107		
TOTAL Residual Services	19.6	0.230	41.4	0.227	0.0265	0.0060
TOTAL PNE		0.995		1.002		0.0129

Sources: Share of private nonfarm economy: US Department of Commerce, 1966, table 1.12

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 A1-7. PNE TFP Growth: Kendrick, 1961, table A-XXIII.