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War Mobilization and its Impact on Patenting in the United States: 1941-48

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Labor and total factor productivity data indicate that mobilization and demobilization for war between 1941 and 1948 disrupted a strong trajectory of technological advance prevailing during the interwar period, particularly the depression years (1929-41) (Field, 2019a). This paper asks whether patent data can be read as consistent with this narrative. I show that for aviation and shipbuilding, patenting rates were stable compared to the prewar period, but that there were significant declines for chemicals, petroleum, rubber and plastics, instruments, fabricated metals, and other machinery, particularly when comparing 1941-48 with 1932-1940. Similar declines are evident in consumer-oriented sectors where production was eliminated or sharply restricted during the war, including motor vehicles, electrical appliances, and radio and television. Existing explanations for weak wartime patenting focus on "economic conditions" and judicial decisions – particularly compulsory licensing decrees in the late 1930s – along with an intellectual and political environment that allegedly weakened the economic value of patents. The explanation proposed here is that, with a few exceptions, patentable inventive activity declined significantly as a direct consequence of economic mobilization for war.

*I am grateful for comments from participants in seminars at Rutgers University and Santa Clara University

There are many reasons to be cautious in interpreting patent data as indicators of technological innovation. Some patents are more important and valuable than others, so aggregate counts combine apples and oranges. There are alternate ways of protecting intellectual property, including secrecy and the exploitation of first mover advantages. Moving first, even without patent protection, may allow the accumulation of non-codifiable knowhow that gives the firm a production cost advantage viz a viz competitors. The relative attractiveness of these different means of protection may vary over time, across countries, across industries, and according to the type of invention. Process inventions, for example, are easier to protect using secrecy than product inventions, because the latter can be bought, disassembled, and reverse engineered. The intellectual, political, and judicial environment can influence patenting propensities, depending upon whether changes in that environment strengthen or weaken patent rights, or for other reasons.

In spite of these cautions, scholars have continued to look toward patent data for clues as to the course and sectoral location of innovative activity. In a 1990 survey article, after casting some shade on conclusions drawn from TFP calculations ("the use of various, only distantly related, "residual" measures") Zvi Griliches summarized the continuing siren song of patent data:

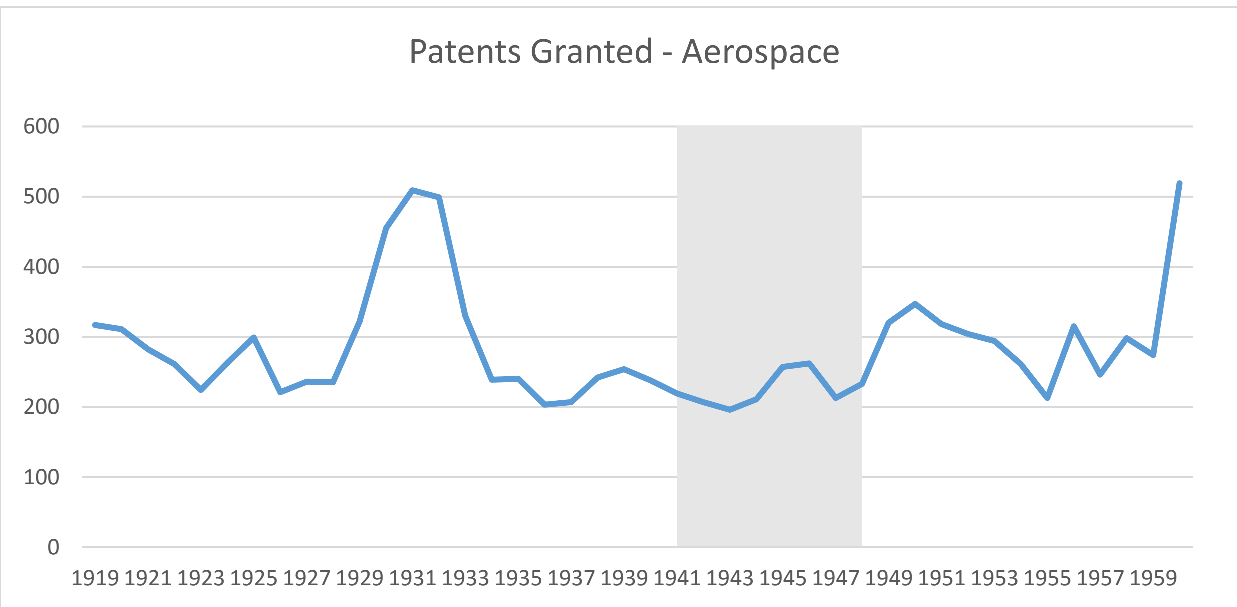
> In this desert of data, patent statistics loom up as a mirage of wonderful plentitude and objectivity. They are available; they are by definition related to inventiveness, and they are based on what appears to be an objective and only slowly changing standard. No wonder that the idea that something interesting might be learned from such data tends to be rediscovered in each generation (1990, p. 1661)

This is clever wordsmithing, on the one hand characterizing a research environment without patent data as a desert (in other words, there's nothing else out there), while on the other, in describing patent data as a mirage, appealing to those who might doubt the ability of such data to reveal much about rates of innovation. Ultimately, of course, one can't have it both ways: either patents can tell us *something interesting* about technological change and productivity, or they can't, a position essentially endorsed by Boldrin and Levine (2013). To his credit, Griliches does ultimately choose, and endorses the former position, arguing that patents are "interesting, in spite of all the difficulties that arise in their use and interpretation." Later in his survey, he makes an even stronger statement: declaring that "… I will argue below that patents are a good index of inventive activity" (1990, p. 1663). And, almost a quarter century later, Petra Moser writes "In the absence of economy-wide data on the quantity of innovations, patent counts have become the standard measure of innovation" (2013, pp. 23-24). Still, the usefulness of patent data as an empirical measure of inventive activity remains controversial, particularly with respect to the explosion of patenting since 1980.

While acknowledging grounds for caution and while retaining some skepticism, this paper proceeds under the working assumption that patent counts may be able to tell us *something interesting* about technological change. It examines data on patents granted in the United States between 1919 and 1960 across a number of important manufacturing industries. It highlights trends and levels during the years 1941-1948, spanning the periods both of economic mobilization for the Second World War and demobilization. Labor and total factor productivity data indicate that mobilization and demobilization for war between 1941 and 1948 disrupted a strong trajectory of technological advance prevailing during the interwar period, particularly the depression years (1929-41) (Field, 2019a). The concern here is whether it is possible to read patent data as consistent with this narrative, in spite of "all the difficulties … in their use and interpretation".

The data in all instances are from Historical Statistics of the United States – Millennial Edition (referred to in the source notes as HSUS). The series referenced classify patents granted according to their sector of origin, which may overlap to a greater or lesser degree with their sector of use. Because these are grant data, they will reflect applications filed some number of months or years earlier. In each figure the years 1941-48 are highlighted using grey shading.

Let's begin with aircraft and engines, which, as has been noted, accounted for a quarter of all spending on ordnance during the conflict. The relevant statistical series is aerospace.



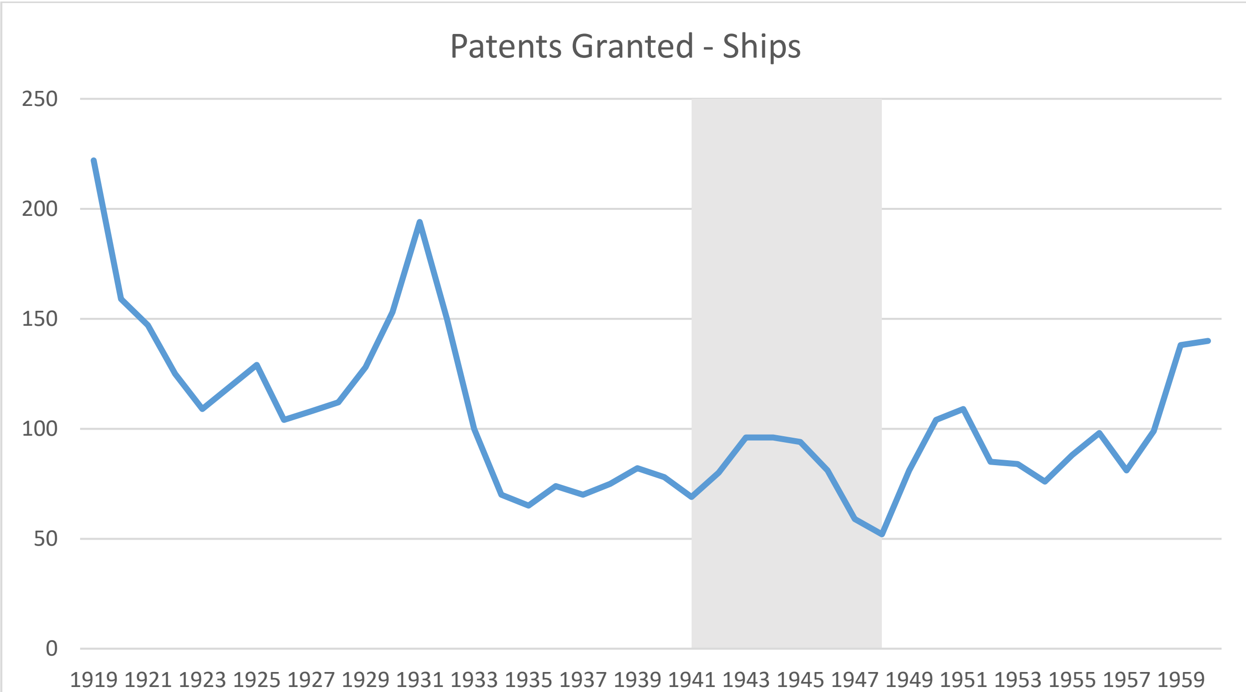
Source: HSUS, series Cg51.

The series shows a huge peak in aviation patenting during the years 1930, 1931, 1932, and 1933, followed by a return to levels between 200 and 300 between 1934 and the end of demobilization in 1948. Suppose we take the peak as indicative of a surge in technological advance in aviation, which is consistent with other evidence. I do not mean to suggest, here or elsewhere, that severe recession is necessarily a good means of stimulating innovative activity. There may be instances in particular industries where there is a positive influence, but these are likely to be the exception rather than the rule (see Field, 2011, ch. 12). A more likely explanation is simply that aviation was a technological paradigm ripe for exploitation, and that these advances probably would have occurred irrespective of the stage of the business cycle. The extraordinary patenting in this sector during the worst years of the Depression is therefore likely coincidental. It should be kept in mind as well that because of the lag between application and grants some (but not all) of this surge can be attributed to applications filed in the late 1920s.

The war period is not associated with a noticeable downturn in patenting. Levels during war and demobilization were roughly identical with those in the six years preceding, averaging 232 between 1934 and 1940, and 225 between 1941 and 1948. These numbers suggest that the war did not disrupt a healthy prewar rate of advance in this sector. This finding is consistent with the Davies and Stammers claim (1975, p. 515), that wartime advances, particularly in the area of jet propulsion, may have been one of the few areas yielding a significant positive supply side legacy for the postwar period, on the civilian as well as military side.

It should be noted, however, that although the war does not appear to have disrupted the pace of patenting in this sector, neither did it lead to a noticeable surge, which might be considered surprising given the enormous resources allocated to airframe and aircraft engine production between 1941 and 1945 (roughly one out of every four dollars spent on the war)..

Although the numbers are considerably lower, the data on patenting in ships traces out a similar pattern:



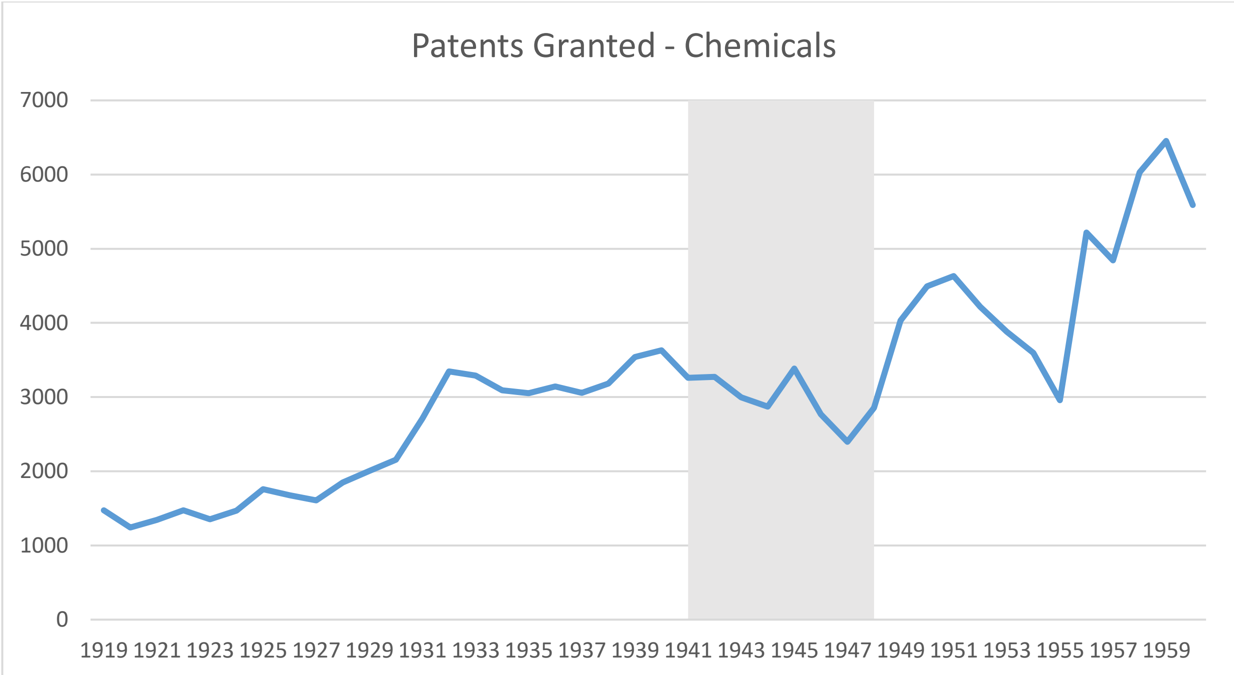
Source: HSUS, series Cg53.

The series shows a spike coming off of the end of World War I, and another spike (as in aircraft) during the years 1930-32. Average levels comparing 1934-1940 with 1941-48 are virtually identical (73), although there is a noticeable uptick in 1943, 1944, and 1945, with a falling off thereafter. Again, we can say that the wartime mobilization that led to the huge naval construction program, in part to remedy the damage from Pearl Harbor, along with the mass production of Liberty Ships, Victory Ships, and tankers, does not appear to have disrupted a prewar rate of technological advance, at least insofar as this is reflected in patenting data. In contrast with aviation, however, this likely left a minimal postwar supply side legacy, both because the economy never again undertook a naval construction program of this magnitude, and never mass-produced merchant ships again. And, in contrast with the aircraft jet engine developments, new naval propulsion systems were simply not as revolutionary in the postwar period.

As has been noted, we cannot say whether the advances in jet propulsion occurred because of or in spite of the war. The postwar supply legacy is not plausibly connected to learning by doing producing World War II aircraft, since no US aircraft in the Second World War used jet propulsion. Indeed, the larger military contractors preferred to focus their development efforts on refinements to piston technology. Advances in jet propulsion seem to have come more frequently from smaller companies.

The data for both aviation and ships, however, are significant because they show that the major declines in patenting in other sectors that will be documented below cannot simply be attributed to a shortage of patent lawyers or a breakdown of the operations of the U.S. patent office during the war and immediately after, or some other ad hoc explanation. Within sectors that identified patentable inventions or innovations, individuals or companies went ahead and obtained legal protection for their intellectual property, in spite of wartime exigencies.

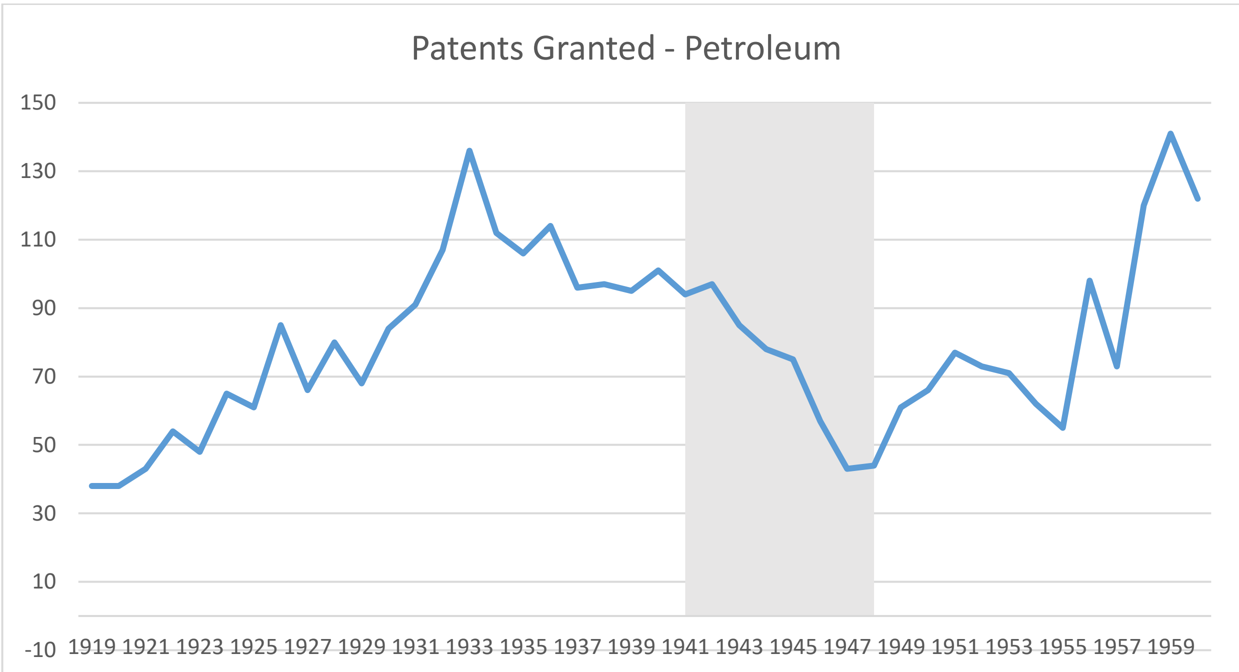
Once we move away from planes and ships, the impact of the war on patenting rates begins to look consistently and sharply negative.   Let's consider chemicals.



Source: HSUS, series Cg48.

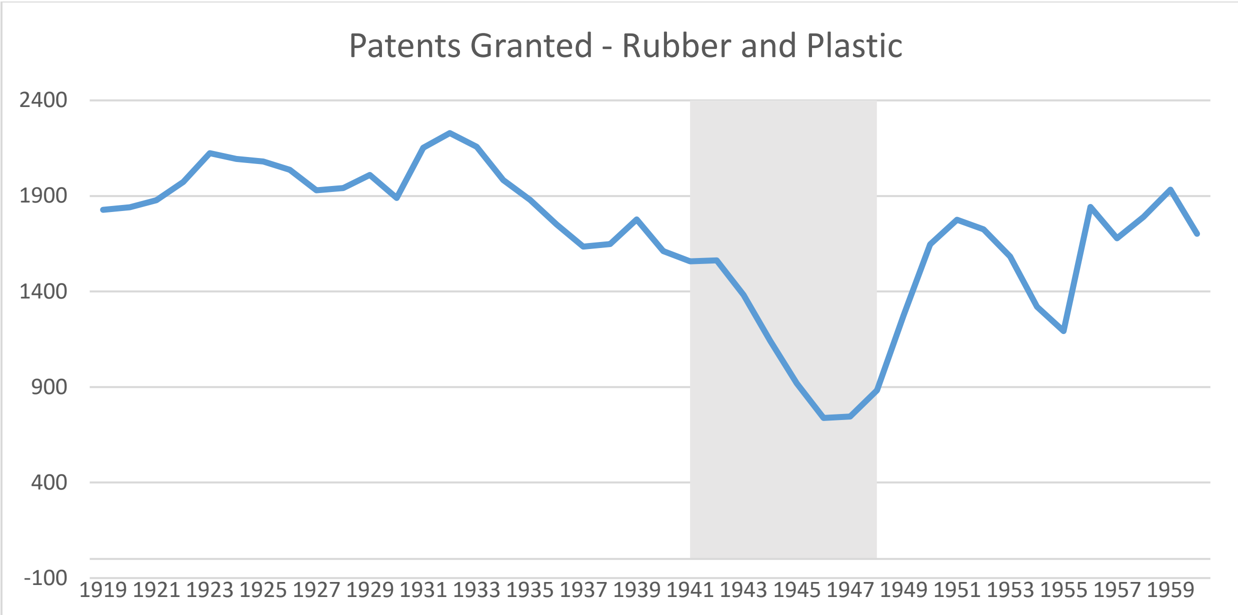
Chemicals was an especially innovative sector during the Depression years, with huge increases in R and D spending and personnel, bolstered by emigrés from Nazi Germany. Chemicals are also an industry where patents are considered the most effective means of protecting intellectual property (Moser, 2014). Patents granted increased by 2/3 between 1929 and 1932, and then remained at high levels through 1941. There is a noticeable downward trend during mobilization and demobilization. Patents granted averaged 3,260 per year between 1932 and 1940 inclusive, and 2,976 between 1941 and 1948.

Similarly in petroleum. Patents granted doubled between 1929 and 1933. Some of those gains are given back during the later years of the Depression, although levels remain considerably above those experienced in the 1920s. Between 1941 and 1948, however, patenting levels plunged. Patents granted averaged 107 per year between 1932 and 1940 inclusive, and 72 between 1941 and 1948.



Source: HSUS, series Cg50.

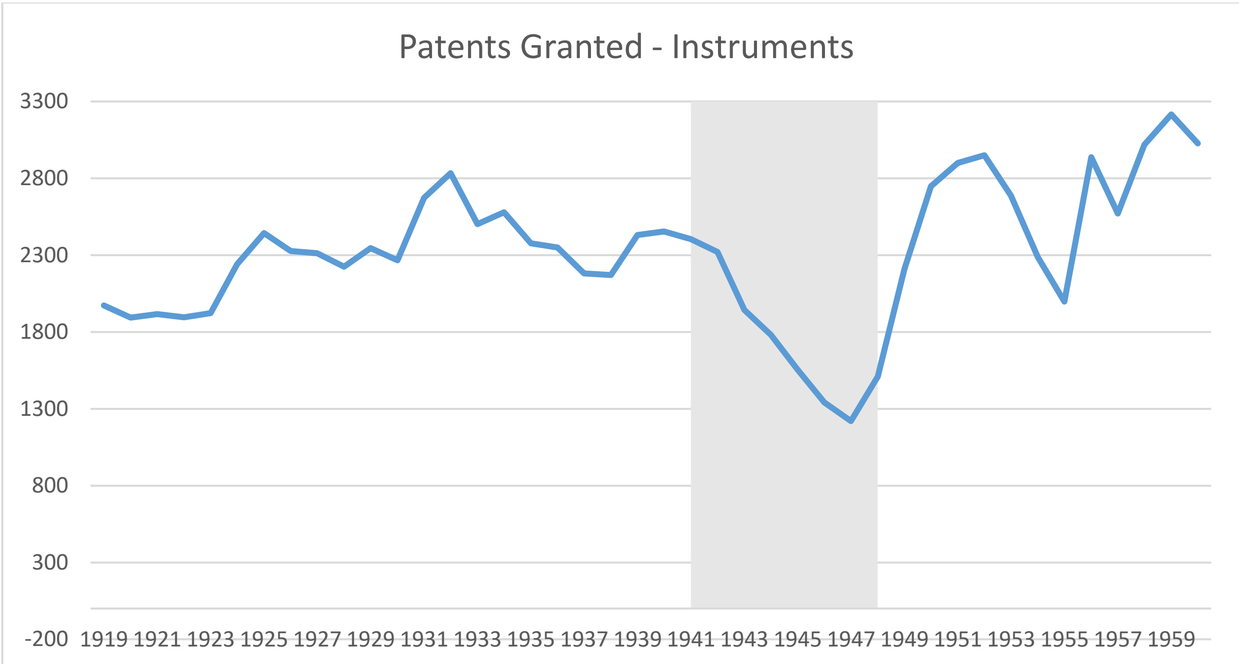
Rubber and plastics had high patenting rates in the 1920s, which persisted through the Depression, although there was a modest drop off after the high levels in 1930, 1931 and 1932.



Source: HSUS, series Cg64

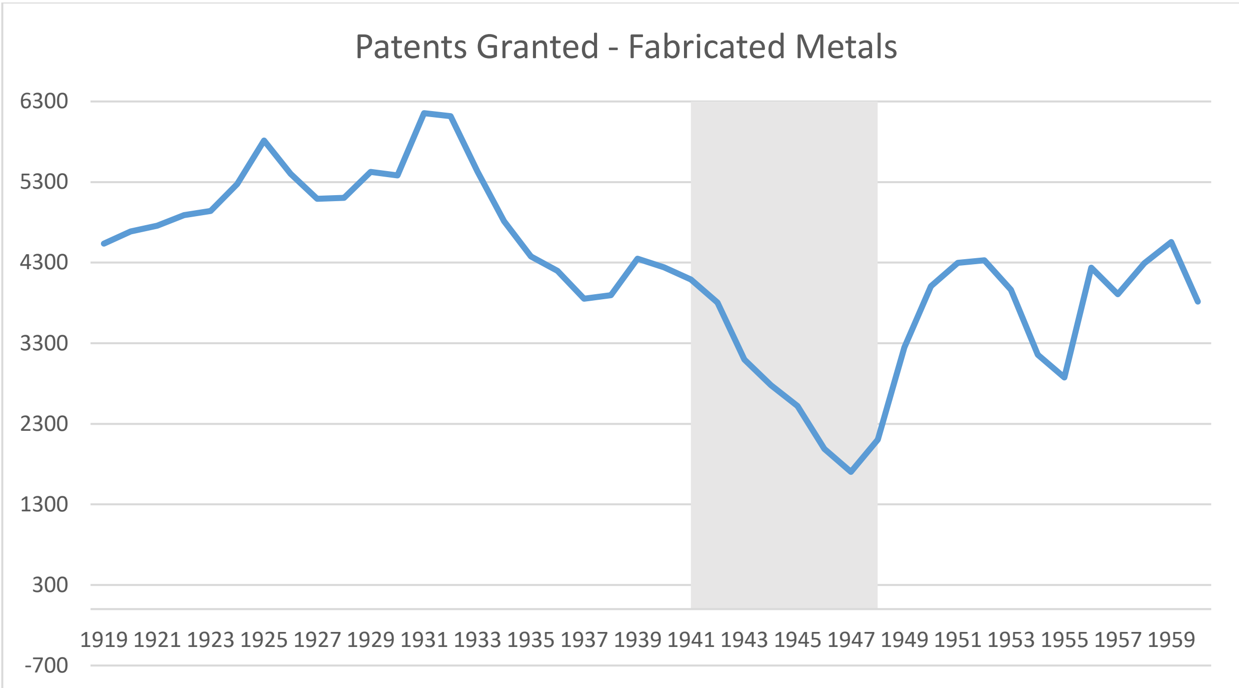
But, as was the case in chemicals and petroleum, there is a sharp drop off between 1941 and 1948. Patents granted averaged 1,852 per year between 1932 and 1940 inclusive, and 1,116 between 1941 and 1948. This is consistent with an interpretation of the U.S. synthetic rubber program as one involving the development and exploitation of scientific and technological knowledge already in place at the time of Pearl Harbor (Field, 2019b).

Instruments shows a relatively stable rate of patenting between 1925 and 941, with a similar sharp drop between 1941 and 1948. Patents granted averaged 2,431 per year between 1932 and 1940 inclusive, and 1,759 between 1941 and 1948.

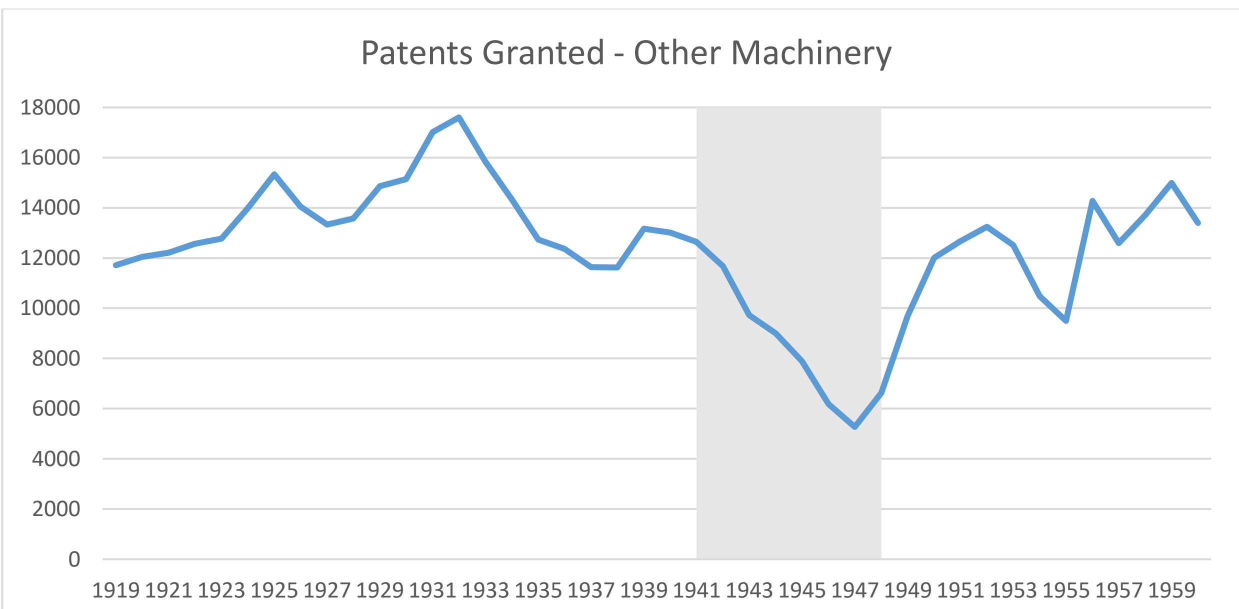


Source: HSUS, series Cg58.

Fabricated metals tells a similar story, with rates plummeting between 1941 and 1948. Patents granted averaged 4,586 per year between 1932 and 1940 inclusive, and 2,761 between 1941 and 1948.



Source: HSUS, series Cg57.



Source: HSUS, series Cg61.

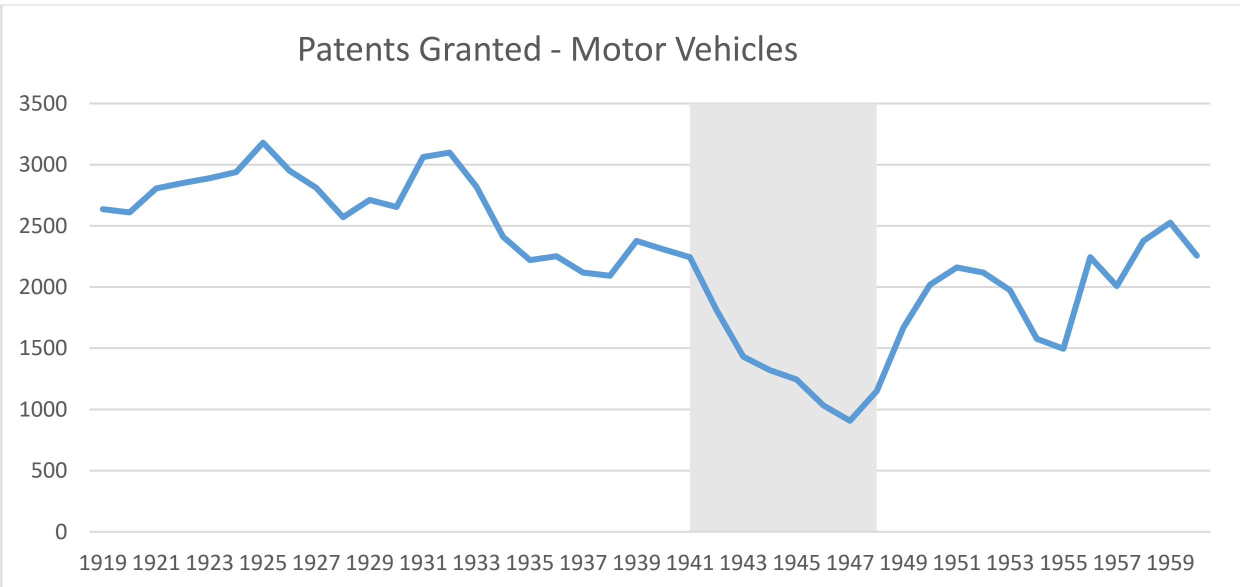
One of the largest patenting categories included in the data is other machinery, which excludes office machinery as well as computers. This displays the same patterns we have now seen in so many other sectors. Patents granted averaged 13,590 per year between 1932 and 1940 inclusive, and 8,629 between 1941 and 1948.

Both of the latter are large categories, and the data in the series are highly coincident, reflecting the overall time series of patenting within manufacturing. Since so much of the war effort involved the fabrication of metal into the tools of war, and the fabrication of metal into the tools for making those tools, one might be surprised to find so little evidence here in support of a favorable postwar supply side legacy. One can point to the increases after 1948. But these merely returned patenting rates to pre-conflict depression era levels.

In all of these sectors, a believer in the conventional wisdom might have anticipated the experience of war mobilization to have had a favorable impact on patenting rates. With the exception of aircraft and ships, we see instead sharp declines.

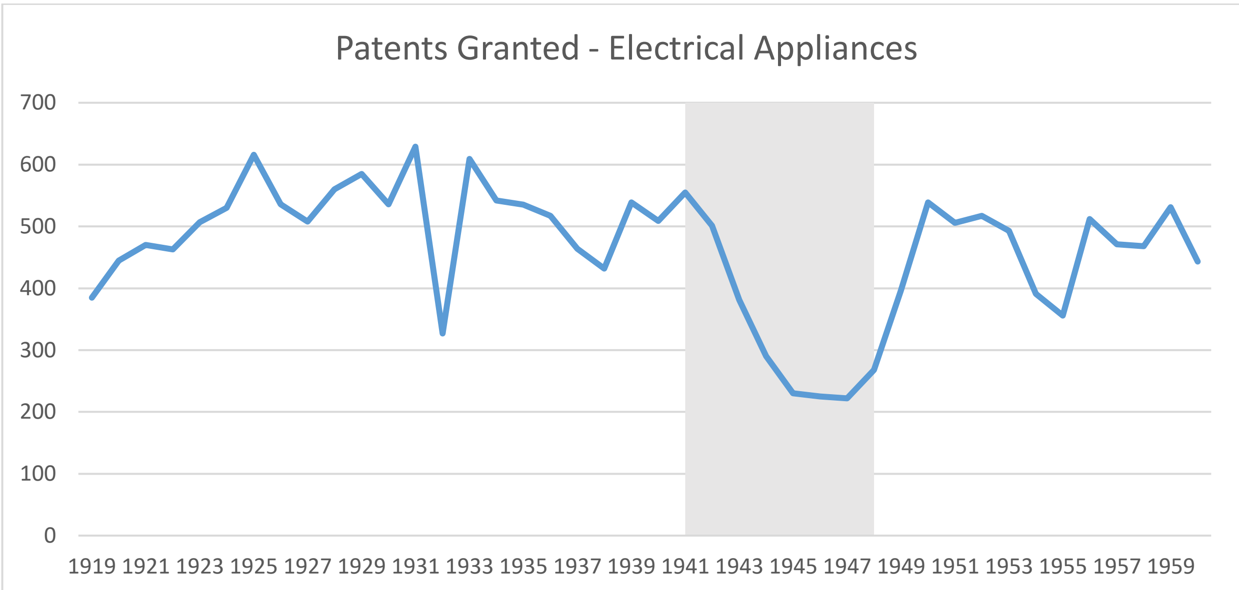
We turn now to sectors where the declines to be demonstrated will perhaps not be as surprising, even to those endorsing the conventional wisdom. These are (largely) consumer-oriented sectors where both research and development and production shut down from the first half of 1942 through the fourth quarter of 1945.

Let us begin with motor vehicles. The data show relatively high rates throughout the interwar period, consistent with the Raff and Trajtenberg (1996) narrative, which views the product and industry as relatively mature by 1941. There is a precipitous decline in patenting between 1941 and 1948. Patents granted averaged 2,411 per year between 1932 and 1940 inclusive, and 1,393 between 1941 and 1948. An obvious explanation for this is the cessation of research and development spending as well as production, which could have produced innovations as the result of learning by doing. Automobile production ceased in February of 1942. 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. Passenger vehicles produced for the 1946 and 1947 model years were little changed from those manufactured during the 1941 and abortive 1942 model years.



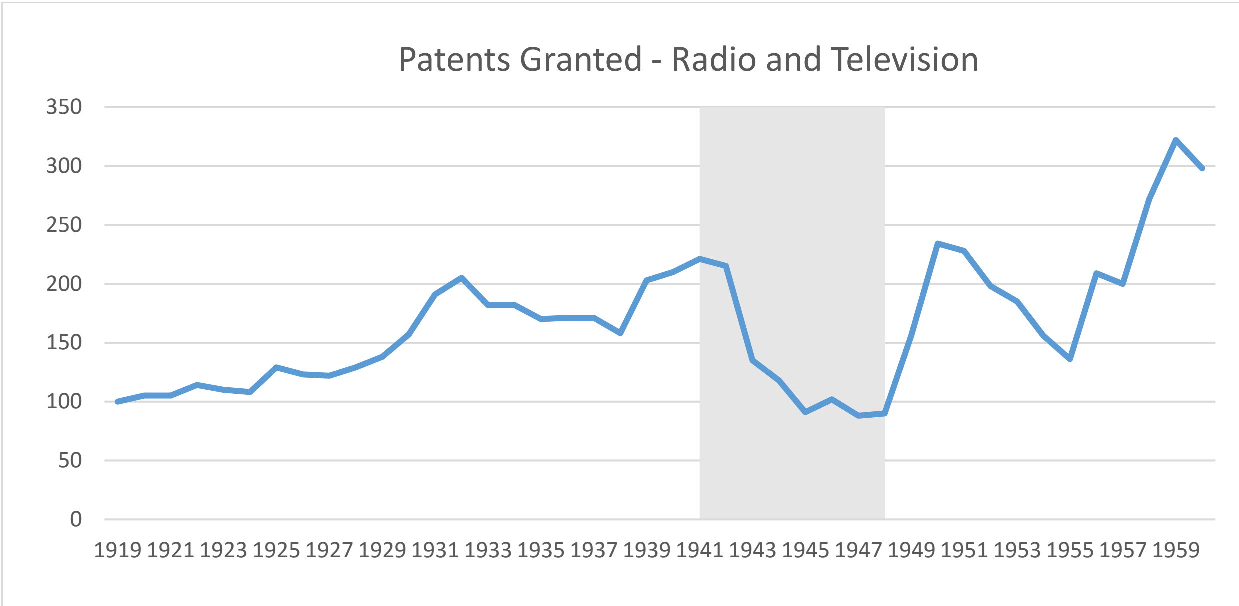
Source: HSUS, series Cg52.

Electrical appliances show a relatively stable rate of patenting from 1924 through 1941, followed by a precipitous drop between 1941 and 1948. Patents granted averaged 2,394 per year between 1924 and 1940 inclusive, and 1,759 between 1941 and 1948. The explanation here is similar to that for cars: production and research on consumer electrical appliances ceased for most of the duration of the war.



Source: HSUS, series Cg42.

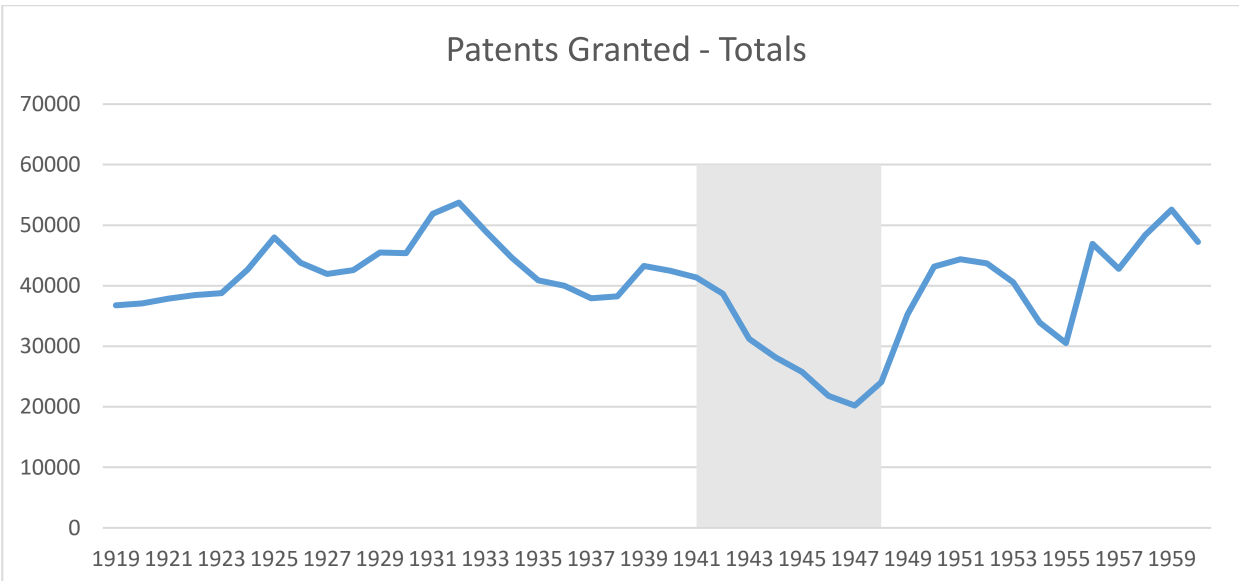
Finally, radio and television displays a rising trend over the interwar period, followed by a very sharp drop between 1941 and 1948. Patents granted averaged 184 per year between 1932 and 1940 inclusive, and 133 between 1941 and 1948. In May of 1941, nine months prior to the cessation of automobile production, General Electric shut down all R and D on civilian radio and television in order to focus on military orders (Klein, 2013, p. 105).



Source: HSUS, series Cg69.

Griliches asked, "'What can one use patent statistics for?' Can one use them to interpret longer term trends? If so, did inventiveness really decline in the 1930s and early 1940s, as indicated by such statistics…" (1990, p. 1662). Unfortunately, he made no real effort to answer either of these questions, which would require one to consider the depression years and the war years separately. Scherer at least tried, arguing that "The sharp decline in patenting during the depressed 1930's can be attributed to unfavorable economic conditions, while the slump during World War II is explained by the historical tendency for patenting to decline during wartime" (1959, p. 130). Aside from the weakness of the explanation for the 1940s, both Griliches and Scherer write as if it were commonly understood that there was a precipitous drop in patenting during the depression. But that stylized fact is questionable.

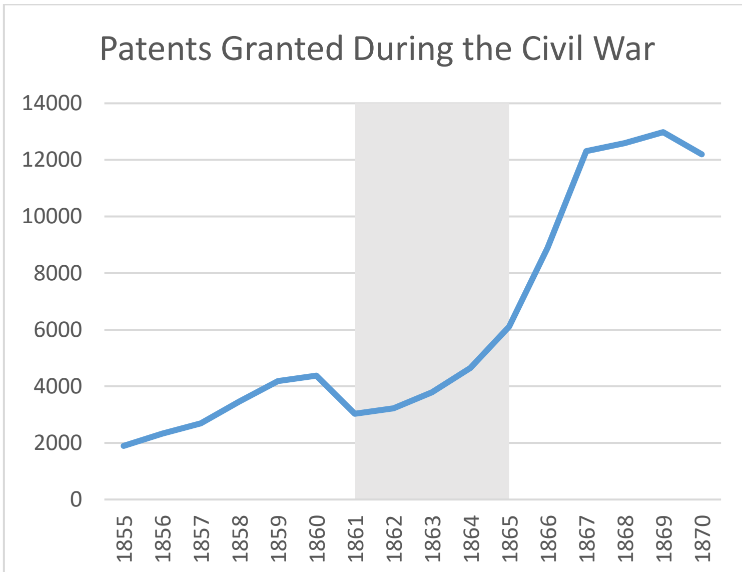
It is true that there is a decline in patent applications comparing the 1920s with the Depression years, particularly after 1930 (HSUS, Series Cg27). If we consider data for patents *granted*, however, there is not in fact a decline during the Depression years. The average number of patents granted annually between 1919 and 1929 was 41,224. Between 1930 and 1941 inclusive it was 44,077. Between 1942 and 1948 inclusive, however, it was 27,132. So there is not a decline during the Depression years, but there is a decline during the war years, whether we look at applications or grants. The actual economic history is treated casually here.



Source: HSUS, series Cg27.

Patenting dropped during the war. Scherer's explanation of the decline is that it is attributable to "the historical tendency for patenting to decline during wartime". That is hardly an explanation! It was moreover not true during the Civil War (see HSUS, series Cg27 and Cg30). The average number of patents granted between 1855 and 1860 inclusive was 3,156. Between 1861 and 1865 inclusive it was 4,162. It is true that patents awarded dropped by about a quarter during the first two years of the war, but then recovered sharply, with numbers in both

1864 and 1865 higher than any previously recorded. The decline during the first two years of the war, can be partially attributed to the withdrawal of inventors resident in the Confederate States from participation in the US patent office, or refusal to grant patents to those where were so resident (the Confederate Patent Office issued 266 patents between 1862 and 1865). The war years are highlighted in grey.



Source: HSUS, series Cg27.

For a detailed discussion of changes in the types of patenting during the conflict, in particular a redirection of inventive activity toward military technologies and inventions that remediated the damage of war, such as better prostheses, see Khan (2016). The overall rise in patenting during the nineteenth century conflict might make one somewhat more sympathetic to the Beard-Hacker thesis about the economic impact of the Civil War. But it also brings us back to the lack of an adequate explanation for the drop during the Second World War. Scholars are certainly aware of the data, as the quote from Scherer indicates. Repeating the stylized fact, and echoing Scherer, Griliches wrote that "It is also clear that economic conditions impinge on the rate of which patents are applied for. Applications were lower during the Great Depression and also during World War II…" (p. 1663). As we've seen, patents granted were *not* noticeably lower during the Great Depression, and in fact rose. As for the Second World War, what were the 'economic conditions' during the period of economic mobilization that reduced applications? Employment was superfull, the output gap was positive rather than negative, strong profits were the rule – certainly all of this differed markedly from what was true during the Depression years.

Scherer's 1959 book was influenced by the intellectual, political, and judicial conflict between those emphasizing the dynamic role played by the patent system in both encouraging invention and making public information about advances, and the static (and undesirable) effects associated with grants of legally enforceable temporary monopolies. The book reflected a view that compulsory licensing decrees, an intellectual environment increasingly hostile towards patents because of their abuse and monopolistic features, and the anti-corporate sentiments encouraged by the Temporary National Economic Committee (TNEC) hearings all served to reduce the economic value of patents and discourage patenting. But the TNEC operated only from June 1938 through April of 1941, and Roosevelt's rhetorical attacks on "economic royalists" faded quickly in the light of the looming conflict with Germany and Japan. In 1977 Scherer questioned whether compulsory licensing adversely affects patenting. Moreover, if a judicial and intellectual attack on the sanctity and value of patent protection was as effective as some patent lawyers and academic clearly felt, we would not expect rates to have rebounded after the war, as they clearly did.

The patents literature suggests that after these Second New Deal attacks on patent rights, an era of "strong" protection for patent rights reemerged only in the early 1980s, with the creation in 1982 of a centralized appellate court, the Court of Appeals for the Federal Circuit (Hall and Ziedonis, 2001, p. 101). There is strong circumstantial evidence that strengthening patent rights did succeed in increasing patenting, but little or no evidence of demonstrably positive effects on innovation or productivity. Boldrin and Levine concluded that … "it is fair to say that the sector-level, national, and cross-national evidence fail to provide any clear empirical link from patents to innovation or to productivity" (Boldrin and Levine, 2013, p. 7.).

So we come back to this: While scholars have noted the downward trend in both applications and grants during the Second World War, they have not provided a satisfactory explanation. It is possible of course that "economic conditions" or some other type of shock associated with wartime reduced the propensity to patent for a given level of innovation. But it is also possible that the explanation is simpler: with a few exceptions, patentable inventive activity declined as a direct consequence of economic mobilization for war.

The war shifted the balance in R and D heavily towards development, a change in balance that persisted after the war in comparison with what had been true during the depression years. In the private sector, expenditures on basic research are typically quite moderate, because of ex ante uncertainty about whether these explorations will lead to patentable and commercially exploitable inventions. Only after some of this uncertainty is resolved will corporations commit large amounts of money to development. At that stage, R and D workers may not be able fully to describe the final product or processes, but they are reasonably confident there is a path forward that will eventually lead to success: "…the risks of complete technical failure have been minimized. Although the technical problems which remain are often difficult, capable scientists and engineers know that they can be solved." (Scherer, 1959, pp. 33- 35). Scherer offered the history of the invention and development of nylon and time pattern of expenditures at Dupont on this synthetic fiber as an illustration (1959, pp. 29-31). The same language can characterize the US synthetic rubber program (Field, 2019b). Scherer noted in his summary of the R and D process that initial productivity levels in new products are usually abysmal: "As a rule, the first innovated items are produced under conditions of inefficiency which are eliminated only slowly" (1959, pp. 35-36). This helps explain why an economy forced with massive changes in its output mix is likely to experience declining productivity levels.

The Second World War involved huge expenditures on development of processes that built on existing foundations of basic research. This was true even in the case of the Manhattan project: "Most of the essential basic discoveries, conceived at relatively low cost in university laboratories and private foundations, were in hand when the Manhattan atomic bomb project commenced during World War II" (1959, p. 35). Again, with the possible exception of jet propulsion, the overwhelming urgency of pushing forward the mass production of military goods placed a lower premium on basic research. choing this perspective, in the introduction to its five volume report submitted in 1952, the Presidents' Materials Policy Commission[1] included this aside:

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[1] In January of 1951 President Truman appointed the commission, which was headed by William S. Paley, chairman of CBS, and included among its five members the Harvard economist Edward S, Mason.

> Men far wiser than this Commission in the affairs of science warn us that, particularly since 1940, we have been far more industrious in putting our scientific facts to work than in increasing the store of fundamental knowledge, and that we need to take vigorous steps to bring the effort we devote to the search for more knowledge into better balance with the manpower and treasure we apply to making use of what we already know…(1952, p. 16).

Daniel Gross makes a similar observation: "Aggregate patenting declined by nearly 50% by the height of the war in 1943, as resources were diverted away from invention and into war and military production (2019, p. 12). Gross's paper is about a patent secrecy program that covered areas considered critical to national security. Initially these orders were predominantly for innovations in the chemical industry; later in the war for advances in communications and electronics. The effect of the patent secrecy program on the quantitative analysis in this paper is, however, likely to be small, Whereas monthly patent applications fell from a peak of over 4000 in April of 1940 to a trough of just over 2000 in August of 1943, close to the peak of industrial mobilization for war, the monthly number of patent applications with a secrecy order never exceeded 200 (Gross, Figure 1).

What about the Civil War? If we stipulate that the conflict appears to have had at best small negative effects on the advance of technology and overall some net positive effects, we are compelled to ask why this experience is so different from that of the Second World War. The explanation likely comes down to these contrasts. Most of the weaponry (rifles, artillery pieces and ammunition) produced during the Civil War was manufactured in government owned armories, and the military technology of the time had nothing comparable to the tanks, aircraft, and other motorized vehicles of World War II. Large increases in the production of wool blankets and uniforms (but not cotton goods), boots and saddles, canvas tents, and horse drawn carts took place in the North, but this did not represent a radical shift towards the temporary mass production of goods in which the manufacturing sector had little experience. The output mix did not involve products noticeably different from those produced in the years immediately preceding, although the quantities demanded of certain products certainly went up substantially. As Stanley Engerman observed, "It is crucial to note that the industries most frequently cited as affected by the Civil War do not fit into the category of war-related industries as that terms is customarily used. Rather, they are consumer goods industries…" (1966, p. 181).

There was nothing comparable to the Defense Plant Corporation's funding of billions of dollars of new facilities, many of which, it was understood, would be of questionable value after the conflict. The manufacturing sector did not undergo the huge expansion followed by shrinkage experienced between 1941 and 1948. During the Civil War there was nothing comparable to the wholesale conversion of a mature automobile industry producing millions of vehicles annually in very large assembly and parts fabrication facilities to the production of military goods in which it had little or no experience. In sum, the contrasts between "old" and "new" goods were much less stark than was true between 1941 and 1948.

Both Scherer and Schmookler look at patent applications, which do decline more than grants during the 1930s, and attribute this to a changed judicial environment and a greater frequency of compulsory licensing orders. But if those changes were associated with a drop in frivolous applications or those with a lower probability of being granted, while at the same time the number of patent grants increased, what is the explanation? Do we conclude that the increases during the Depression are due to greater leniency on the part of patent examiners? This makes no sense if the argument is that the government interest in protecting intellectual property waned during the Depression. One can acknowledge that the lags between application and granting of a patent complicate the interpretation of these data, while still maintaining that the data on patents actually granted is the more meaningful measure of new patentable processes or products likely to have economic value.

It should be remembered, of course, that patentable product or process breakthroughs are only part of the knowledge accumulation that may be reflected in productivity advance. For example, much of the informal knowledge among managers and production workers that allowed costs per unit to drop systematically with cumulated output might not be codified or codifiable. But this was of course true before economic mobilization as well.

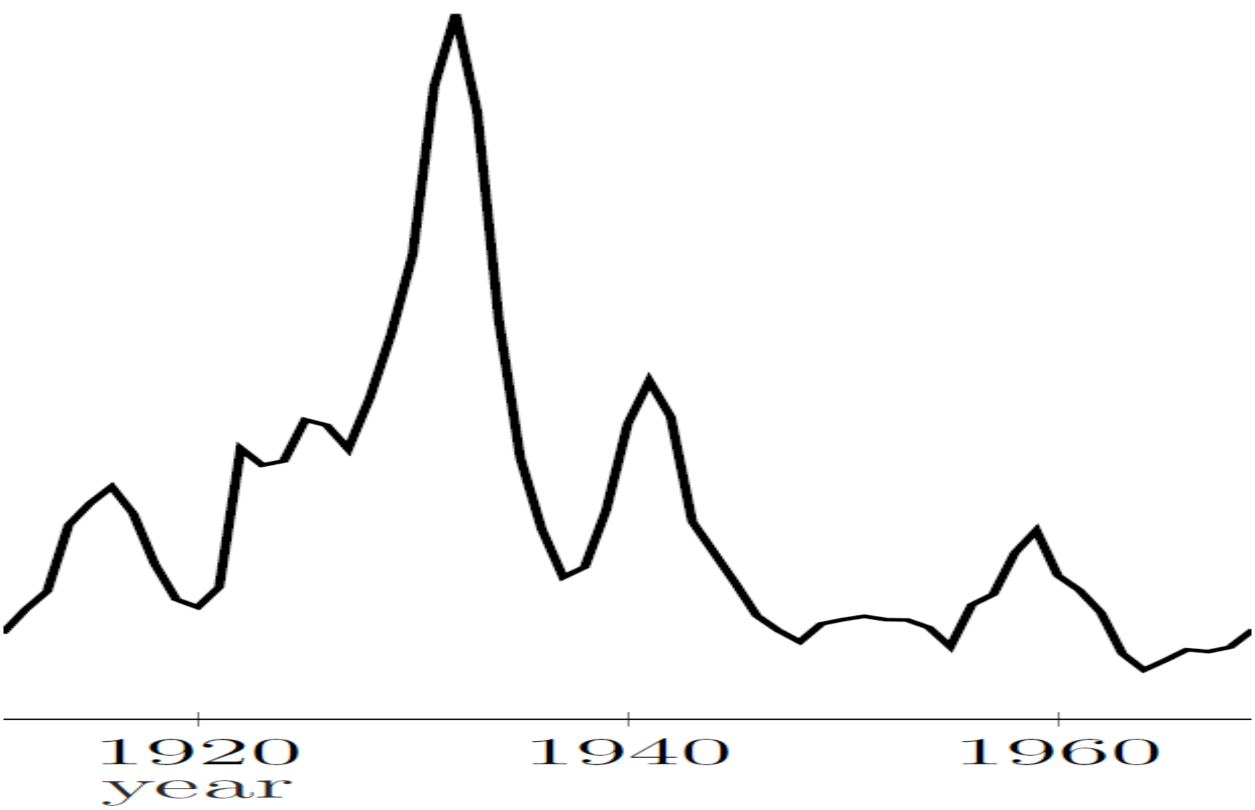
The overall picture here is one in which increases in military spending associated with a radical shift in the manufacturing output mix adversely affected patenting. If this is not consistent with the Civil War experience, it is consistent with an effect identified by Griliches in a regression explaining the log of U.S. domestic patent applications between 1953 and 1987 (Griliches, 1989, p. 310). The rate of growth of the national defense component of real GDP and its lagged value both had large, robust, and statistically significant *negative* effects on patent applications. A 10 percent increase in real defense spending was associated with a 5 percent decline in domestic patent applications.

Finally, a number of recent empirical papers have attempted to separate out more important from less important patents, leading to refined time series that deal more effectively with the heterogeneity in the scientific and commercial value of different patents. The most ambitious of these is a working paper by Kelley, Papanikolaou, Seru, and Taddy (2018; henceforth KPST). These authors use textual analysis to measure the similarity of different patent pairs, and using these similarity measures identify what they consider to the most important (breakthrough) patents. Breakthrough patents are those which are distinct (dissimilar) to prior patents, and thus novel, but similar to subsequent patents, and thus influential (impactful). Their research required digitizing close to the entire corpus of U.S. patent grants from 1840 to 2010, and then quantifying the similarity of texts in each pair of patents. They started by calculating, for each patent, how frequently each word appeared in the text. To put more weight on terms that were less common in prior patent grants, they multiplied this frequency by the backward inverse document frequency, the log of the ratio of the total number of patents granted prior to the one in question to those in that set which contained the term in question. Thus, for each patent, words with high scores were those mentioned frequently in the patent in question but infrequently in the universe of prior patent grants.

For each patent they created a vector containing the scores for each word. They then measured the similarity of every pair of patents in their study, recalculating the vector for the more recent patent using the backward inverse document frequency for the older of the two. The two vectors were multiplied together and their cosine similarity calculated and used as a measure of similarity. Cosine similarity is easy to understand for two dimensions but becomes almost impossible to visualize for higher dimensionality vectors such as these; one can think of it as something like a correlation coefficient for two vectors. This exercise produced a 9 million by 9 million matrix (30 terrabytes of data). To reduce the computational burden, they threw out pairs with less than 5 percent similarity.

The authors then selected "breakthrough patents" which were both novel at the time they were granted and influential afterwards. To measure the novelty of a patent grant they calculated the inverse of the sum of the similarity scores of that patent with all patents granted in the previous five years (backward similarity). They then calculated forward similarly by aggregating the similarity scores for all patents granted in the next T calendar years. Patent significance (quality) was then defined simply as the ratio of the forward similarity score for the patent to its backward similarity: Significant patents are those which have high forward similarity and low backward similarity.

Time Pattern of Breakthrough Patents, According to KPST (2018)



Source: KPST, 2019, Figure 7, panel A).

Breakthrough patents are those with quality scores in the top 5 percent of the distribution of all patents. KPST's long time series of per capita breakthrough patents shows peaks in the 1930s, and collapse during the period of war mobilization, consistent with the message of this paper, and cis consistent as well with the view that the Civil War, unlike World War II, was not a period of retrogression (figure 7, panel A, excerpted above).

Conclusion

Near the conclusion of his 1990 survey article, Griliches reaffirmed the importance of patent data: "In spite of all the difficulties, patents statistics remain a unique resource for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and the potential industrial, organizational, and technological detail" (p. 1702). As noted, he posed questions about patenting rates in the Depression years and then World War II, but then made no attempt at all to answer them. Boldrin and Levine, in contrast, state without qualification that the number of patents awarded has no connection with measured productivity (2013, p. 3). There is a bit of an escape hatch in their argument, however, which is largely based on data after 1980, which shows an explosion of patenting following the strengthening of patentee rights described earlier that is questionably associated with upticks in productivity. Boldrin and Levine's biggest objection is to systems that provide strong protection for patentees. It still may be the case that patenting rates are more highly correlated with and reflective of innovation and productivity growth during period in which there were weaker protections, and greater propensities for court ordered compulsory licensing decrees, precisely the judicial environment that appears to have emerged during the 1930s, and then persisted for roughly half a century.

This paper asks whether patent data can be read in a manner that supports the impression of overall technological stasis evident in labor and total factor productivity data (Field, 2019). The counts do appear to have *some* connection to measured productivity growth rates, correlating, roughly, with high TFP growth between 1929 and 1941 and weak (negative in manufacturing) TFP growth between 1941 and 1948. And the trends within particular sectors are generally consistent with what we know of the evolution of these industries during the war. There is no reason here or elsewhere that we should be prepared to take patent data as dispositive with respect to rates of innovation. But when examined in the light of other types of evidence or data they may provide additional support for (or cause us to question) a narrative emerging from analysis of these sources.

We have known since at least Griliches and Scherer that World War II saw a decrease in the frequency of overall patenting. As noted earlier Griliches offers no explanation, and Scherer's is not much better: "the historical tendency for patenting to decline during wartime." World War II is widely understood in the United States as a period in which the exigencies of military conflict created a premium on development rather than research. For World War II, the effects of disruption in raw material supplies, particularly rubber from the Far East and oil and oil products from the Gulf Coast to the Eastern seaboard, combined with radical changes in the output mix along with extraordinary time pressure to meet production targets, are likely to explain explain both sharp declines in labor and total factor productivity and lower patenting rates.

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