The Real Benefits of War:
A Closer Look at the Impact on Innovation by World War II

by

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An essay submitted to the Department of Economics in partial fulfillment of the requirements for the degree of Master of Arts

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Kingston, Ontario, Canada

August 2016

Acknowledgements

First and foremost, I want to thank Professor Jaworski for his help, his guidance, and his feedback. I appreciate everything that you have done for me. Without you, I would have been lost many times and would have had to struggle to get back on the right track.

I also want to thank all the professors who taught me at Queen's University for my Master's in Economics, as well as the professors at Simon Fraser University for my undergraduate degree in Economics. Not only have you opened my eyes to new ideas, but you also made sure the fundamentals were still there. You all played a crucial part in helping me become the person I am today.

I want to thank all my friends in Kingston and back home. I am blessed to have individuals who have encouraged me on throughout the year and supported my ambitions to further my knowledge.

I want to give a special thank you to my significant other, Christina Bell. Your continuous support could never be quantified, and I am forever in your debt. I also want to give a special thank you to my father, Henry Wu, and my grandmother, Bao Zhen Guo. Both of you sacrificed a lot to help me succeed, and I can never repay you for all that you have done for me. I can only say thank you, for everything. Finally, I want to give a special thank you to my late grandfather, Zhen Zhong Wu, who provided the foundation not only for my academics but the kind of person I am today. I know you would have been here to encourage me constantly in my journey and celebrate my success.

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Introduction

World War II was known for its massive destruction and large death count, but it was also recognized for its numerous amounts of new inventions. In the vast devastation that occurred for most countries involved in World War II, one country specifically came out relatively less damaged; the United States. With the exception of Pearl Harbor, there were no attacks on United States' soil. This was due to the geographical distance between the United States and the war fronts in both Europe and the Asian Pacific. Therefore, compared to the European and Asian countries involved in World War II, the United States did not run the risk of capital or technology destruction due to war. Furthermore, historically after World War II, not only did the United States become the most productive economy in the world[1], but they also positioned themselves as world leaders in new technology. Though all these aspects combined makes the United States an interesting case, the impact World War II had on the United States has been conflicting.

Considering the geographical distance between the United States and the war fronts, as well as limitations of the number of soldiers the United States could provide, then it must be the case that to aid the war efforts of the United States, some form of advantage must be induced. However, during the early stages of World War II, Nazi Germany had a technological advantage in military technology, and continued to focus on developing more military-related innovations. Hence, one would expect that the participation of the United States in World War II should stimulate a technological increase in specific sectors (i.e. military related or defense). Though one should expect this outcome, it is uncertain if the

[1] Edward Fulton Denison, *Why Growth Rates Differ* (Washington: Brookings Institution, 1967)

narrative is true, or if it translates to an overall increase in research and development in the United States.

This paper investigates the impact World War II had on innovation in the United States to see if World War II was the main factor in the United States' dominance in technology. Despite the focus on U.S. inventions, the literature still shows two opposing arguments regarding the impact of World War II. One side argues that the newfound focus on research and development throughout the war was a driving factor for not only the United States economy to recover from the Great Depression, but also a driving factor in their dominance in technology[2]. For instance, between 1940 and 1945 the overall United States Government R&D spending increased over 1400 percent (in 1930 dollars). Of the total research expenditure, the Department of Defense research spending decreased from around 35.6 percent to 32.2 percent[3]. Another major factor that complemented the new focus on research and development was the mass production ability of the United States, which gave them access to various resources and "the world's largest domestic market"[4].

The other side argues that despite the increase in inventions observed during World War II, those innovations only have direct military implications and unknown welfare applications. Moreover, the United States' participation in World War II caused more military based initiatives and a greater focus towards the military, thus relocating talent from the private sector[5]. Furthermore, they argue that the postwar era reflected nothing

[2] David C Mowery and Nathan Rosenberg, "The U.S. National Innovation System", in *National Innovation Systems: A Comparative Analysis*, Richard R Nelson ed. by, (New York: Oxford University Printing Press, 2016), 29-75.
[3] Mowery and Rosenberg, "The U.S. National Innovation System".
[4] Richard R. Nelson and Gavin Wright, "The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective", *Journal of Economic Literature* 30, no. 4 (1992): 1931-1964
[5] Alexander J Field, *A Great Leap Forward* (New Haven: Yale University Press, 2011).

more than a “revival of more “normal” patterns of physical capital accumulation (the acquisition of new structures and equipment),” a process that was “disrupted by the financial crisis during the Depression and distorted during” World War II[6].

To determine the relationship between World War II and the United States' research and development decisions, there first must be a measure of research and development. Since patents are the property rights to new inventions, patents (by their filing date) will be used as a proxy measure for research and development. As well, the focus will be the patents from a specific group of companies that earned the largest portion of government contracts[7,8]. Not only does using these companies act as a proxy reflecting the research and development decisions by the United States government, but these companies also represent the largest firms in their respective sectors. Alternative measures such as the expenditure for research and development are considered, but the merits of using the patent data over using the alternative measures will be discussed in a later section.

The research expands to examine the impact World War II had on the quality of innovation. This stems from the idea that World War II impacted the quality of innovation rather than the number of inventions. It could be that the number of new inventions in the United States may not have changed, but instead, the quality of these inventions increased to swing the technological advantage their way. To measure innovation quality, patent citations are used, for patent citations count the number of future inventions that borrowed

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[6] Field, *A Great Leap Forward*.
[7] Robert Higgs. *Depression, War, and Cold War: Studies in Political Economy*. (New York: Oxford University Press, 2006)
[8] Merton J Peck and Frederic M Scherer. *The Weapons Acquisition Process: An Economic Analysis* (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1962).

ideas off that specific patent[9]. Thus, the greater the quality, the more citations that patent should receive, implying that higher quality patents will have a larger impact on future inventions.

Historical Context

It is well known that World War II started when Germany invaded Poland on September 1st, 1939. It was followed by a declaration of war by Britain (and the British Commonwealth) and France on Germany. Meanwhile, the United States firmly maintained their neutrality, a position that follows the infamous Quarantine Speech by President Franklin D. Roosevelt two years before the start of World War II. Moreover, by the United States Constitution, even if Roosevelt wanted to declare war, he did not have the power to do so, for only the United States Congress has that authority. The only situation that allows the President to engage in battle is if there was an invasion, though it still would not be a declared war unless Congress declares it[10]. Therefore, given the United States' isolationist policies, they were forced to partake in a supportive role to Britain and France during early World War II.

Historically, it was the famous Pearl Harbor incident that led to the United States' participation in World War II. This event was driven by the combined sanctions that the United States government, the British government, and the Dutch government implemented against the Japanese Empire. The sanctions essentially forced Japan to either withdraw their operations in China or forcefully obtain the resources desired by invading

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[9] Zvi Griliches, "Patent Statistics as Economic Indicators: A Survey", *Journal of Economic Literature* 28, no. 4 (1990): 1661-1707.

[10] "Prize Cases 67 U.S. 635 (1862)". *Justia Law*, last modified 2016, accessed June 5, 2016. https://supreme.justia.com/cases/federal/us/67/635/case.html

European territories in Asia[11]. The Japanese Empire did not plan on withdrawing from China[12], instead, they planned on seizing the European territories in Asia to solidify their dominance[13]. In order to do so, they deemed it necessary to eliminate the United States' presence in the Pacific[14]. The combination of the Japanese attack on Pearl Harbor, and the Tripartite Pact, the alliance between Japan, Italy, and Germany, gave the United States a clear platform to join the Allies in the war against the Axis in both the Pacific and Europe. This gives a snapshot of the events leading up to the United States' involvement in World War II.

The United States' participation in World War II and mobilization caused a large change in the domestic U.S. economy. To finance the war, taxes were raised, a rationing system was imposed, and price controls were implemented so that households can obtain at least the minimum amount of necessity goods, such as meats, dairy, canned goods, and oils. In particular, the tax rates in the top tax bracket ranged from 81 percent to 94 percent, while income level subject to that tax rate dropped to $200 000 from $5 000 000. The result of the change in tax policy can be seen in 1944, where almost all employed individuals paid Federal income tax compared to only 10 percent of the employed population in 1940[15]. The rationing system provided a method to divert efforts and goods to the war fronts, while maintaining a minimal amount of goods domestically. As well, the government forced nation-wide savings in the form of war bonds to avoid any future

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[11] David S Painter. "Oil and the American Century" *Journal of American History* 99, no.1, (2012): 24-39
[12] Bradley Lightbody. *The Second World War: Ambitions to Nemesis* (London: Routledge, 2004)
[13] Gerhard L. Weinberg. *A World at Arms: A Global History of World War II (2nd ed.)* (Cambridge: Cambridge University Press, 2005).
[14] James B. Wood. *Japanese Military Strategy in the Pacific War: Was Defeat Inevitable?* (Maryland: Rowman & Littlefield, 2007)
[15] Geoffrey Perett. *Days of Sadness, Years of Triumph* (Wisconsin: The University of Wisconsin Press, 1985)

economic disaster, but these war bonds can also be seen as a way of providing the government with more funds for the war effort. The combination of these policies allowed for an increased focus on the war production. More specifically, between "mid-1940 to mid-1945 munitions makers produced 86 338 tanks; 297 000 airplanes; 17 400 000 rifles, carbines, and sidearms; 315 000 pieces of field artillery and motors; 4 200 000 tons of artillery shells; 41 400 000 000 rounds of small arms ammunitions; 64 500 landing vessels; 6 500 other Navy ships; 5 400 cargo ships and transports; and vast amounts of other munitions"[16]. In other words, the policies implemented during World War II reflected a classic macroeconomics example in production trade-off between guns and butter.

Another policy created as a result of World War II was the Selective Training and Service Act of 1940. This Act conscripted males aged between 18 to 45 and required males between 18 to 65 to register, where only certain males, such as farmers and professors, were able to avoid the draft. The draft resulted in an increase of 10.87 million in the armed forces between 1940 and 1944[17]. Despite not drafting all the males, it caused a shortage in the number of available male workers. The shortage caused by conscription forced the labor market to hire any remaining available male workers and be open to new hiring practices to fill the demand. This in turn can be reflected in the reduction of unemployment, which fell "from 14.6 percent to 1.2 percent", or by 7.45 million, between 1940 and 1944[18]. To replace conscripted male workers, one change came from child-labor laws, which adapted to allow the employment of teenagers. The more renowned practice was the introduction of women into the labor force to replace conscripted males. Additionally,

[16] Robert Higgs. "Wartime Prosperity? A Reassessment of the U.S. Economy in the 1940s" *Journal of Economic History* vol.52, no.1 (1992)
[17] Higgs. "Wartime Prosperity? A Reassessment of the U.S. Economy in the 1940s".
[18] Higgs. "Wartime Prosperity? A Reassessment of the U.S. Economy in the 1940s".

children were convinced to volunteer on farms, or at the local gardens on roofs or empty parking lots[19]. As well, they were encouraged to help out around the house[20], since most households essentially became single parent households due to conscription sending the fathers to the war fronts.

Not only was the United States focused on providing the war fronts with sufficient troops, equipment, and machinery, but they also focused on developing better inventions to aid in their war efforts. This is because, Germany had a military technological advantage compared to the United States, Britain, and the rest of the Allies. For instance, Germany was able to use their U-boat submarines to disrupt shipments from the Allies across the Atlantic. They were also able to send cryptic messages that could be only deciphered by an Enigma machine, another piece of German technology. Moreover, Germany continued focusing on improving their military technology, developing both the V1 (cruise missile) and V2 (rocket-powered ballistic missile). This puts pressure on the United States and other Allied nations to improve their military technology. If not, it could be the case that the Axis would maintain a military technology advantage and also increase the chances of the Allied nations falling.

The pressure for the United States to focus on research and development in military technology was reflected in the increase in spending by the United States government. Between 1940 and 1945, "research expenditure of the Department of Defense rose from $29.6 million to $423.6 million (in 1930 dollars)"[21]. Since the United States were only

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[19] Stuart A Kallen, *The War at Home* (San Diego: Lucent Books, 2000).

[20] "World War II On the Home Front: Civic Responsibility", *Smithsonian in Your Classroom*, 2007, accessed July 23, 2016, http://www.smithsonianeducation.org/educators/lesson_plans/civic_responsibility/smithsonian_siyc_fall07.pdf.

[21] Mowery and Rosenberg, "The U.S. National Innovation System"

looking to contract out to large corporations during this period, corporations such as General Motors Corp. (hereafter GM), Ford Motors Co. (hereafter Ford), Chrysler Corp., Aluminum Company of America (hereafter ALCOA), Curtiss-Wright Corp., U.S. Steel Corp, Bethlehem Steel Corp., and United Aircraft Corp. were listed as top ten corporations that earned government contracts in 1940[22]. While GM, Curtiss-Wright Corp., Ford, Consolidated Vultee Aircraft Corp. (hereafter Convair), United Aircraft Corp., Douglas Aircraft Co. (hereafter Douglas), Inc., Bethlehem Steel Corp., Chrysler Corp., General Electric Co., and Lockheed Aircraft Corp. (hereafter Lockheed) were the top ten companies of the largest defense contractors throughout World War II[23]. Therefore, not only were these companies combined earning the largest portions of government contracts, but were also large entities in their respective industries.

Ford, GM, and Chrysler were the largest three U.S. automotive corporations during that period. Ford, alone, produced 390 000 tanks and trucks, 27 000 engines, 270 000 Jeeps, over 8 000 B-24 Liberators, and hundreds of thousands of parts, gun mounts, and machine tools for the war effort[24]. Ford was not the only company producing tanks and vehicles, both GM and Chrysler Corp were producing vast quantities, and all three corporations supplied not only the United States but other Allied nations as well. However, of the three corporations, Ford and GM faced controversial stances for both companies had factories in Germany. Furthermore, both corporations earned the Order of the German Eagle in 1938, which is an award given to diplomats foreign to Nazi Germany. These three

[22] Higgs. *Depression, War, and Cold War: Studies in Political Economy*
[23] Peck and Scherer. *The Weapons Acquisition Process: An Economic Analysis*.
[24] A.J. Baime. *The Arsenal of Democracy* (Boston: Houghton Mifflin Harcourt, 2014)

automotive companies were large entities in the automotive market, especially Ford and GM, given their international presence before World War II.

Curtiss-Wright Corp., United Aircraft Corp., Convair, Douglas, and Lockheed were to the aerospace industry what GM, Ford, and Chrysler were to the automotive industry. Curtiss-Wright Corp, Convair, Douglas, United Aircraft Corp., and Lockheed ranked second, fourth, fifth sixth, and tenth respectively in wartime production contracts[25]. As well, ALCOA, U.S. Steel Corp., and Bethlehem Steel Corp. were also the largest parties in the metal industry in the United States during World War II. Bethlehem Steel Corp ranked seventh in wartime production contracts, while U.S. Steel Corp ranked seventeenth[26]. ALCOA on the other hand, was battling an illegal monopolization charge against the United States Justice Department since 1938[27] , reflecting their significant position in the aluminum industry. Production-wise, Curtiss-Wright Corp. produced over 146 000 electric propellers, 142 000 engines, and 29 000 airplanes[28], while, ALCOA increased the number of plants by twenty to meet their wartime demands[29].

The historical information provided shows insight to the situation in the United States during World War II. One important implication from the narrative is that there was clear incentive for the United States to improve military technology. This was due to the battles fought in the Pacific and Europe at the same time, a limited number of troops they were able to provide, and their technological disadvantage to the Germans in military

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[25] Peck and Scherer. *The Weapons Acquisition Process: An Economic Analysis*.
[26] Peck and Scherer. *The Weapons Acquisition Process: An Economic Analysis*.
[27] "Alcoa in The USA: The Alcoa Story", *Alcoa.Com*, last modified 2016, accessed August 10, 2016, https://www.alcoa.com/usa/en/alcoa_usa/history.asp.
[28] "Company History", *Curtiss-Wright Corporation*, last modified 2016, accessed June 21, 2016, http://www.curtisswright.com/company/history/
[29] "Alcoa in The USA: The Alcoa Story", *Alcoa.Com*

technology. In particular, there was the finite number of soldiers the United States could provide without crippling their economy and mass production abilities, and these troops were split between the battles against the Japanese in the Pacific, as well as the battles against the other Axis members in Europe. The incentive would spill over to firms who have military connections, for not only would it benefit the firm's ability to distance themselves from the competition in their field, but it allows them to sell their new military inventions to all Allied nations. The focus on military technology may potentially have spillover effects on technology with applications that could better welfare, such as penicillin.

Another important narrative from the historical information are the welfare sacrifices made during World War II. Despite the low unemployment rates, the increased taxes and the forced savings would reduce the household income. Even if the household income did not decrease, the forced rationing in the United States would only provide the minimum amount for a family's survival during World War II. Meanwhile, conscription changed family dynamics such that many families essentially became temporary single parent households. These temporary single parent households also ran the risk of becoming permanent single parent households. Therefore, it is important to remember the sacrifices made during World War II. It is possible that the findings could justify the sacrifices or provide more evidence on the detrimental impact of World War II.

Data

Patents are used as a proxy measure of research and development because a "patent for an invention is the grant of a property right to the inventor, issued by the United States Patent and Trademark Office"[30]. Therefore, the date when a patent is filed would represent a closer estimate of when the invention was created compared to the priority date, the grant date, or the publication date. Data on the annual aggregate number of patents is obtained from the United States Patent and Trademarks Office (hereafter USPTO). The annual patent data is broken down into utility patent applications, design patent applications, plant patent applications, utility patents, design patents, plant patents, and patent grants to foreign residents. Only utility and design patent applications will be considered, since applications are a closer estimation to when new inventions were created, while plant-based patents are not included for they are "granted to anyone who invents or discovers and asexually reproduces any distinct and new variety of plant" [31] and only represent 1 percent of the total number of utility applications.

One way to define the firms who obtained the largest proportion of U.S. government contracts is to use the list of "leading corporate operators Government-owned, contractor-operated (GOCO) facilities)" [32] provided by Higgs. The list includes large corporations such as GM, ALCOA, Curtiss-Wright Corp., U.S. Steel Corp., Ford, Bethlehem Steel Corp., Chrysler Corp., United Aircraft Corp., General Electric Co. (hereafter GE), and Henry J. Kaiser Co. (hereafter Kaiser). Not only did those companies

[30] "General Information Concerning Patents", *United States Patent and Trademark Office*, last modified 2016, accessed May 15, 2016, http://www.uspto.gov/patents-getting-started/general-information-concerning-patents.

[31] "General Information Concerning Patents", *United States Patent and Trademark Office*

[32] Higgs, *Depression, War, and Cold War: Studies in Political Economy*.

combine to make up 32.5 percent of all GOCO plants as of June 30th, 1940[33], but they also represent a significant portion of their respective industries. Thus, the behaviour of these enterprises, towards research and development, act as a representation of the impact World War II had on both the United States and particular U.S. industries.

Alternatively, since the major focus for the United States was improving technology with direct military implications, the list of "The Top 100 Largest Defense Contractors" in World War II[34] are also considered. From this list, this study focuses on the top ten companies which include: GM, Curtiss-Wright Corp., Ford, Convair, United Aircraft Corp., Douglas, Inc., Bethlehem Steel Corp., Chrysler Corp., GE, and Lockheed. From the list, it is evident that there are more corporations with direct military relationships despite some overlap with Higgs' list. For instance, in this list of ten companies, half of them are aircraft companies compared to two aircraft companies on the list by Higgs'. Like Higgs' list, since the government only deals with large corporations, it follows the same argument for why these companies can act as a proxy to represent the United States and specific industries. Therefore, the list of top defense contractors represents a more detailed inspection on how the war impacted industries that had direct military relations.

Given that the data is compiled based off two lists of companies provided by different sources, it is clear they do not represent random samples. This poses the issue that the results obtained from these datasets would not necessarily be representative of corporations in the United States, as well as the possibility of biased results. Since in each list only the top ten corporations are taken, it also implies that results may not necessarily be representative of the list. Despite these drawbacks, due to the fact that the United State

[33] Higgs, *Depression, War, and Cold War: Studies in Political Economy*.
[34] Peck and Scherer. *The Weapons Acquisition Process: An Economic Analysis*.

government only dealt with large corporations, the results are still representative of the United States government. In particular, the largest companies earned the largest portion of the government contracts. For instance, according to Higgs' list, the top ten companies earned 32.5 percent of all GOCO contract values, where GM alone accounts for 7.1 percent[35]. This implies that these corporations were not given equal contract values, and that the companies earning a larger portion of the contracts would further represent the investments made by the United States government. Therefore, these lists reflect the decisions by the United States government in terms of how the corporations who get the most funding behave. As mentioned earlier, since the United States only dealt with large corporations, it then can be seen that these companies are the largest companies in their respective industries. Thus, despite the possible bias, these lists of companies still provide a representation of what is occurring in the United States.

The time frame of focus is between 1935 to 1955, approximately four years before the war, and roughly ten years after. As a result, the time frame does not only include World War II, but the end of the Great Depression, and a portion of the post-war period. Furthermore, it will also capture the period where the United States participated in World War II (i.e. December 7th, 1940) since they did not join at the beginning of the war. Thus, given the time frame of this study, it is possible to see whether or not World War II had a significant impact on the research and development decisions of the United States or of the specific industries of interest. Alternatively, it is possible to investigate if another period, such as the post-war period, is the driving factor in influencing research and development decisions. Furthermore, because patents during the time have held "intellectual property

[35] Higgs, *Depression, War, and Cold War: Studies in Political Economy*.

rights…for a term of 17 years”[36], it can be tested how pre-World War II inventions impacted post-war inventions.

Raw Data Collection Process

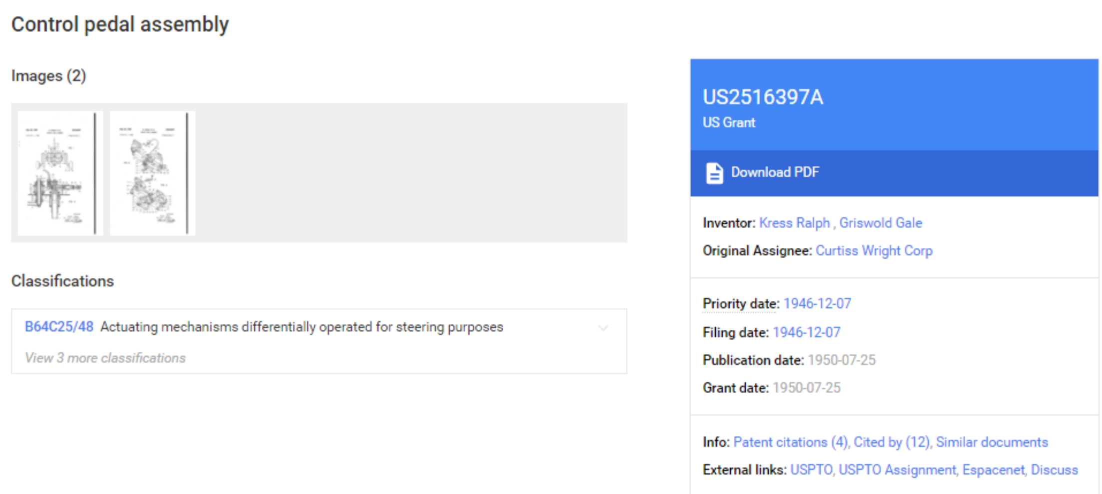
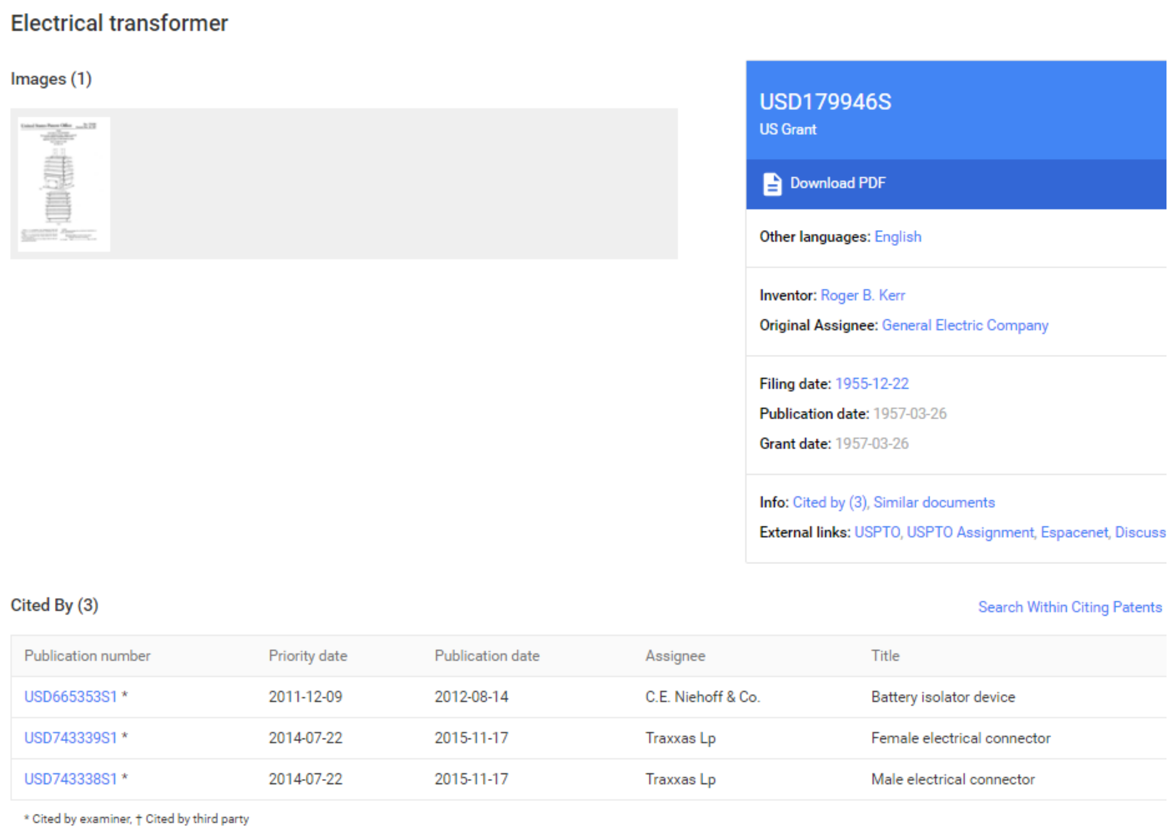


Figure 1: Example of a Google Patent Page (Patent: US2516397A)[37]
Note: Using the Control Pedal Assembly patent page from Google Patents to illustrate the information provided on for utility patents that can be scraped following the process explained in the Raw Data Collection Process section
Source: Image is a screen shot from Google Patents (https://patents.google.com/patent/US2516397A)

Aggregate annual patent data is retrieved from the USPTO, while patent counts for individual companies are obtained through Google Patents. Patent count data is collected for each company between 1935 and 1955, and the individual patent ID is obtained through Google Patents. For example, US2516397A is a patent ID for a patent assigned to the Curtiss-Wright Corp and is the patent for the ‘Control Pedal Assembly’[38]. Using the patent ID, information regarding the patent filing date, priority date, publication date, grant date, the inventor(s), the assignee(s), the number of claims, the number of citations by the patent,

[36] Tom Nicholas, "The Role of Independent Invention in U.S. Technological Development, 1880–1930", *Journal of Economic History* 70, no. 01 (2010)
[37] Google Patents. “Control Pedal Assembly” https://patents.google.com/patent/US2516397A (May 15, 2016)
[38] Google Patents. “Control Pedal Assembly”

the number of citations the patent received, and the number of patents in the same patent families is obtained from the Google Patent (Figure 1). Also, there is a difference in the information provided in a design patent compared with utility patents. More specifically, design patents do not contain a priority date (Figure 2). Despite this, it is not an issue since the date of importance is the filing date, because the filing date represented when the patent was filed and acts as an estimate for the creation of the new invention/innovation.


Electrical transformer

Images (1)

USD179946S
US Grant

Download PDF

Other languages: English

Inventor: Roger B. Kerr
Original Assignee: General Electric Company

Filing date: 1955-12-22
Publication date: 1957-03-26
Grant date: 1957-03-26

Info: Cited by (3), Similar documents
External links: USPTO, USPTO Assignment, Espacenet, Discuss

Cited By (3)

Search Within Citing Patents

Publication number	Priority date	Publication date	Assignee	Title
USD665353S1 *	2011-12-09	2012-08-14	C.E. Niehoff & Co.	Battery isolator device
USD743339S1 *	2014-07-22	2015-11-17	Traxxas Lp	Female electrical connector
USD743338S1 *	2014-07-22	2015-11-17	Traxxas Lp	Male electrical connector

* Cited by examiner, † Cited by third party

Figure 2: Example of a Design Patent from Google Patents (Patent: USD179946S)[39]
Note: Using the Electrical Transformer patent page from Google Patents to illustrate the available information provided for design patents, while also showing the difference between the information for utility patents and design patents.
Source: Image is a screen shot obtained from Google Patents (https://patents.google.com/patent/USD179946S)

[39] "Electrical Transformer", *Google Patents*, last modified 2016, accessed July 15, 2016, https://patents.google.com/patent/USD179946S.

The pattern in the web pages of the patents lies in the last section of the URL after the last common slash. More specifically, that part of the URL is just the patent ID, and given this pattern, it is possible to scrape the patent information from the web page. Hence, it possible to gather all of the information needed to create the data set by web-scraping. The web-scraping process is done through the program R, and specific packages (‘xml2’ and ‘rvest’). The process first starts with gathering all the patent IDs, from the specified lists of companies, between January 1st, 1935 to December 31st, 1955, which can be done with another web-scraping function. Although, in this case, it was done manually by using the Google Patent search engine. An issue with Google Patent results is that it only displays the first 300 results. Therefore, the date in the search parameter must correct such that the results are less than 300. Once the patent IDs are collected, the URL for each patent can be obtained by combining the “https://patents.google.com/patent/” and the patent ID, thus allowing the URL to be read via the ‘read_html’ function of the ‘xml2’ package. On each page, there is a similar underlying code that contains all the information divided up into nodes, where each pathway to the information needed can be seen by inspecting the page such as Figure 1 and Figure 2. The information for the nodes can be extracted and then put on a table that can be appended, which is necessary since the function that does all of this can only handle a certain amount of web-scraping without crashing the program.

Though the manual method of obtaining the patent IDs may be questioned due to the possibility of human error, it should be noted that Google Patent’s results are sometimes inconsistent, and as a result, using a web-scraping function may produce different results when scraping the patent IDs for each company. As well, for each corporation, the total number of patents differ, and consequently it becomes difficult to have a constant span of dates such that the Google Patent results only display no more than 300 results at a time. Lastly, for some corporations, the Google Patent results page shows duplicates, thus the manual method, though more time consuming, provides a relatively more accurate result, especially since for each corporation, the information is gone through at least twice.

Data Manipulation

Given the raw data obtained through the web-scraping process, the date is aggregated into annual values for each company. This process first starts with recoding the corporation names such that the first assignee slot contains the corporation of interest and is spelled the same way for that given corporation. Then the year variable is extracted from the filing date, and dummy variables are created for each year to act as a count variable. From this, the data is aggregated by corporation and the sum of the dummy variables report the total number of patents for each corporation for the specified year. Next, the total number of patent citations, citations, and non-patent citations are aggregated, by filing year and corporation, and appended into the data set. Also, data from the USPTO regarding the total number of patents, filed historically[40], can be included, as well as data regarding the total contract value obtained by the companies of interest during World War II[41].

[40] "U.S. Patent Activity, CY 1790 To Present", *USPTO*, last modified 2016, accessed July 16, 2016, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm.
[41] Matthew Rose, Harrison F Houghton and John Malcolm Blair. *Economic Concentration and World War II.* (Washington [D.C.]: U.S. G.P.O., 1946)

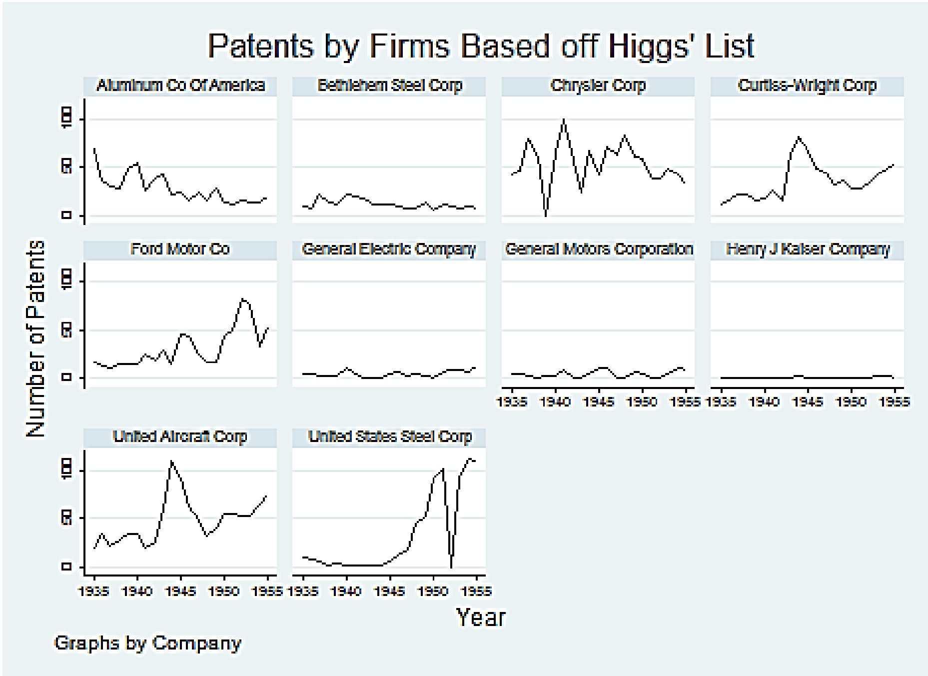


Figure 3: Number of Patents Filed by Firms based off Higgs' List

Note: Figure 3 shows the number of total annual patents filed by each of the top 10 companies from Higgs' list of companies earning the largest portions of GOCO contracts.

Source: Data used for this graph was obtained as depicted by the Raw Data Collection Process and then aggregated by year

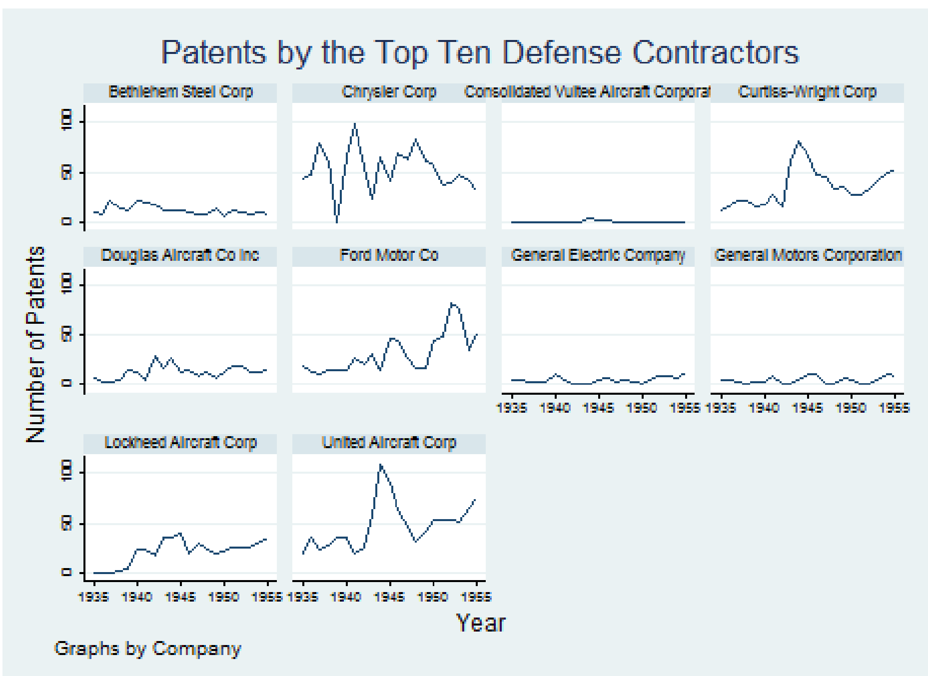


Figure 4: Number of Patents Filed by the Top 10 Defense Contractors (1940-1944)

Note: Figure 4 shows the number of total annual patents filed by each of the top 10 companies with the largest defense contracts between 1940 and 1944

Source: Data used for this graph was obtained as depicted by the Raw Data Collection Process and then aggregated by year

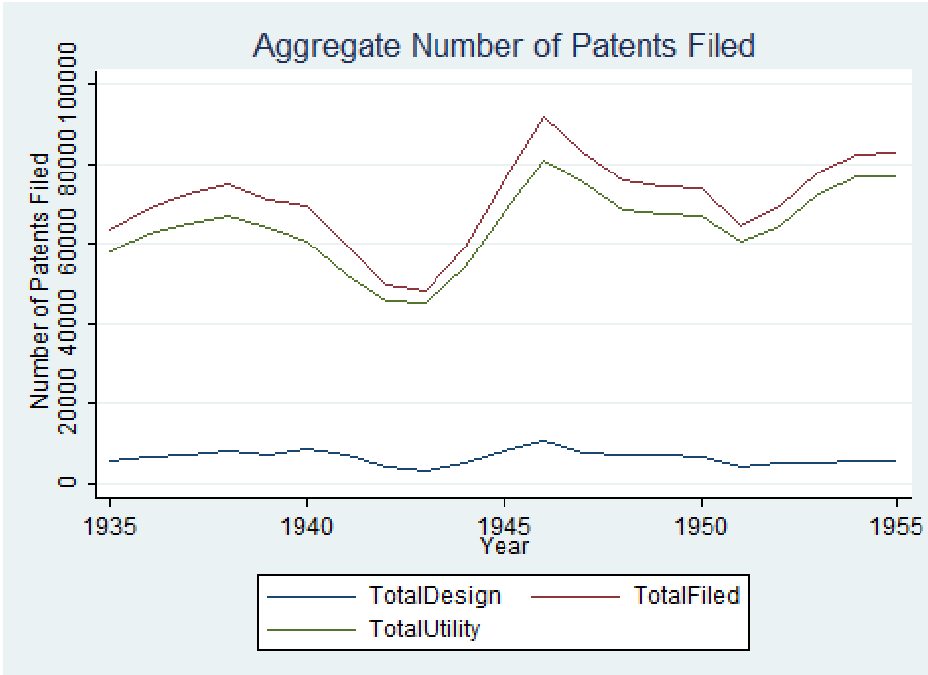


Figure 5: Total Number of Patents Filed (1935 – 1955) per USPTO

Note: Figure 5 shows the aggregate number of patents filed between 1935 and 1955 as reported by the United States Patent and Trademark Office, excluding plant patents. The blue line depicts the number of total design patents, the green line represents the number of total utility patents filed and the red the is sum of the two.
Source: Data used in the graph is obtained from the United States Patent and Trademark Office's data on the annual U.S. Patent Activity since 1970 (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm)

It is uncertain how World War II impacted innovation from a simple glance at the total number of patents filed by each company. Furthermore, it can be seen that the total number of design and utility patents dipped during World War II and spiked upwards after World War II. Despite this, some companies increased in patent filing during the war, while others followed other trends, including the trends of the aggregate utility and design patent. The same pattern exists using the list of the top 10 companies with government defense contracts between 1940 and 1944.

Thus far, it is uncertain whether or not World War II impacted all firms or sectors equally. For instance, certain corporations showed an increase in the mean number of patents during World War II, where some of those have a higher mean number of patents during the period where the United States was actively involved in the war. As well, the mean number of patents decreased throughout the periods of some companies (e.g. ALCOA), while it increased for others (e.g. U.S. Steel). From this, it could simply be that certain firms belonging to the same industry had an increase in innovation and/or patents as a result of World War II. Furthermore, since all the corporations of interest are relatively large in their respective sectors, and due to their size, it is likely some of these companies only specialize in output while others can do both. Thus, it would be interesting to investigate to see how industries changed, regarding innovation, as a result of World War II occurring.

Table 1: Summary Statistics of Companies from Higgs' List (1935-1955)

Company	Total Patents	1935-1955 Mean	GD Mean	WWII Mean	US WWII Mean	Post-WWII Mean
ALCOA	592	28.19	42.60	34.67	31.75	17.10
Bethlehem Steel	246	11.71	12.80	15.33	12.50	9.00
Chrysler	1116	53.14	46.00	58.67	47.00	53.40
Curtiss-Wright	750	35.71	17.20	44.83	56.25	39.50
Ford	660	31.43	13.60	25.17	27.75	44.10
GE	94	4.48	3.40	3.00	1.00	5.90
GM	87	4.14	3.00	4.33	3.75	4.60
Henry J Kaiser	13	0.62	0.00	0.67	1.00	0.90
United Aircraft	1017	48.43	28.00	56.50	71.00	53.80
US Steel	674	32.10	5.60	2.50	2.75	63.10

Note: GD Mean represents the mean during the tail end of the Great Depression (1935-1940). WWII Mean represents the mean during the World War II (1940-1945). US WWII Mean represents the mean during the time the US was actually involved in the World War II. Post-WWII Mean represents the mean during 1945 to 1955.
Source: Data obtained through the process detailed under the Raw Data Collection Process section and then aggregated through the Data Manipulation section.

Table 2: Summary Statistics of Top 10 Companies with Government Defense Contracts (1935-1955)

Company	Total Patents	1935-1955 Mean	GD Mean	WWII Mean	US WWII Mean	Post-WWII Mean
Bethlehem Steel	246	11.71	12.80	15.33	12.50	9.00
Chrysler	1116	53.14	46.00	58.67	47.00	53.40
Convair	6	0.29	0.00	0.83	1.25	0.10
Curtiss-Wright	750	35.71	17.20	44.83	56.25	39.5
Douglas Aircraft	258	12.29	6.00	16.83	21.00	12.70
Ford	660	31.43	13.60	25.17	27.75	44.10
GE	94	4.48	3.40	3.00	1.00	5.90
GM	87	4.14	3.00	4.33	3.75	4.60
Lockheed Aircraft	433	20.62	1.00	29.00	32.00	25.40
United Aircraft	1017	48.43	28.00	56.50	71.00	53.80

Note: GD Mean represents the mean during the tail end of the Great Depression (1935-1940). WWII Mean represents the mean during the World War II (1940-1945). US WWII Mean represents the mean during the time the US was actually involved in the World War II. Post-WWII Mean represents the mean during 1945 to 1955.
Source: Data obtained through the process detailed under the Raw Data Collection Process section and then aggregated through the Data Manipulation section

Methodology and Interpretation

The change in the number of patents filed by the top ten corporations who earned the largest portion of government contracts (i.e. GOCO facilities and Defense contracts) will be used as an estimate of the impact World War II had on U.S. innovation. The relationship can be estimated from a simple difference-in-difference to estimate the impact World War II had on patenting in the United States

$$p_{ct} = \beta_0 + \beta_1 \log(con_c) + \beta_2 post_t + \beta_3 con \times post_{ct} + \epsilon_{ct} \tag{1}$$

where p_{ct} is the number of patents in year t by corporation c, $\log(con_c)$ is the log value of the contract earned by corporation c during World War II[42], while $post_t$ is a dummy variable that equals 1 if the year is after World War II and equals 0 elsewhere. The first variable can be generalized to represent factors and characteristics that are unique to each

[42] Rose et al. *Economic Concentration and World War II*

corporation, while the second variable can be generalized to represent unique features of the periods after World War II. The third term in equation 1 is the interaction term between the first two terms and represents the impact that World War II had on patenting.

Alternatively, instead of using patent counts as a proxy measurement for innovation, the number of citations a patent has can be a proxy. This is because the number of citations a patent has represents the number of future innovations that used ideas from the patent. In essence, patent citations reflect how impactful the patent is to future innovation, as well as, the quality of the invention[43]. From this, equation (1) can be adjusted and becomes

$$c_{ct} = \beta_0 + \beta_1 \log(con_c) + \beta_2 post_t + \beta_3 con \times post_{ct} + \epsilon_{ct} \tag{2}$$

where the only difference is the dependent variable, c_{ct}, which is the aggregate number of citations from corporation c's patents in year t. Therefore, the interaction term measures the impact World War II had on the quality of new inventions, rather than the quantity.

Though equations (1) and (2) captures the impact World War II had on post-war innovation, it can be expanded to include the immediate impact of World War II on innovation. Hence, both equation (1) and equation (2) can be expanded to

$$p_{ct} = \beta_0 + \beta_1 \log(con_c) + \beta_2 post_t + \beta_3 WWII_t + \beta_4 con \times post_{ct} + \beta_5 con \times WWII_{ct} + \epsilon_{ct} \tag{3}$$

$$c_{ct} = \beta_0 + \beta_1 \log(con_c) + \beta_2 post_t + \beta_3 WWII_t + \beta_4 con \times post_{ct} + \beta_5 con \times WWII_{ct} + \epsilon_{ct} \tag{4}$$

respectively, where $WWII_t$ is a dummy that equals 1 if the year was in World War II and 0 elsewhere. As well, there are now two interactions, where both can be interpreted as difference-in-difference variables. More specifically, β_4 represents the relative impact

[43] Griliches, "Patent Statistics as Economic Indicators: A Survey"

World War II had on post-war innovation, while β_5 represent the immediate impact World War II had on innovation relative the pre-World War II period.

An issue with the regression equations so far is that it implicitly assumes that the error term, ϵ_{ct}, is independently, identically distributed (hereafter i.i.d.). This assumption is not necessarily valid in this case because it hard to impose i.i.d. with real data due to the uncertainty of the true data generating process. The correction for heteroskedasticity is to use a heteroskedastic-consistent covariance matrix estimator (hereafter HCCME), which even in the event the errors are i.i.d., is still a consistent estimator of the actual covariance matrix when sample sizes are large. Since there are 210 observations in this study, the number of observations is large enough to invoke the Central Limit Theorem, implying the HCCME would be consistent. Hence, the errors are adjusted for heteroskedasticity. Another issue is that the regressions thus far are clustered by corporation, which in this case means there are ten clusters, each with 21 observations. Therefore, not only are the number of clusters small, but the number of observations within clusters are small as well. The issue with having a limited number of clusters is that the results may not necessarily be accurate. In particular, with small numbers of clusters, even cluster robust errors will tend to over-reject. To correct for the small number of clusters, while considering an unknown form of the heteroskedasticity present in the data set, the wild cluster bootstrap method is applied. From the wild cluster bootstrap, p-values are reported to see whether or not the explanatory variables are statistically different from zero[44]. For the wild cluster bootstrap to report sensible results, a specific number of replications must be picked such

[44] A. Colin Cameron, Jonah B. Gelbach and Douglas L. Miller, "Bootstrap-Based Improvements for Inference with Clustered Errors", *Review of Economics and Statistics* 90, no. 3 (2008): 414-427.

that observations would not be renumerated. Hence, the wild cluster bootstrap method is applied in this study to equation (1) through (4) as a robust check.

The biggest issue with the regressions thus far is that both the variables of interest, p_{ct} and c_{ct}, are count variables. Furthermore, from a quick inspection, 10.48 percent of all observations reported zero patents, while 22.86 percent of patents received zero citations. This implies that both variables are non-negative integers and that the regressions done may not be an appropriate estimation for the values observed are cut off at zero. Since the methods so far do not account for count data, the underlying distribution must be corrected. A common method to correct for the non-negativity is to use a Poisson regression model, where the underlying distribution is a Poisson distribution, which is non-negative[45]. Hence, the regressions become

$$E(p_{ct}) = e^{\beta_0+\beta_1 \log(con_c)+\beta_2 post_t+\beta_3 WWII_t+\beta_4 con\times post_{ct}+\beta_5 con\times WWII_{ct}} \tag{5}$$

$$E(c_{ct}) = e^{\beta_0+\beta_1 \log(con_c)+\beta_2 post_t+\beta_3 WWII_t+\beta_4 con\times post_{ct}+\beta_5 con\times WWII_{ct}} \tag{6}$$

where equations (5) and (6) are a log-linearized transformation of equations (3) and (4). Using the Poisson regression, it corrects for the non-negativity in count data. However, because the Poisson distribution imposes that the variance must be equal to the mean, and if this is not the case, then the issue of overdispersion arises. This can be corrected by using either a quasi-maximum likelihood estimation with the Poisson distribution or a negative binomial distribution[46], thus giving justification to use the negative binomial distribution.

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[45] Russell Davidson and James G MacKinnon, *Econometric Theory and Methods* (New York: Oxford University Press, 2004).

[46] A. Colin Cameron and Pravin K Trivedi, "Count Panel Data", in *The Oxford Handbook of Panel Data*, Badi H Baltagi ed. by, (Oxford: Oxford University Press, 2015), 233-256.

Empirical Results

Difference – in – Difference Regression Results

Table 3: Difference-in-Difference Regression (with Higgs' List)

	Without WWII Immediate Impact (1)	(2)	With WWII Immediate Impact (3)	(4)
log(Contract)	-6.09 (13.33)	-54.12 (111.57)	-3.43 (11.63)	-36.45 (89.38)
Post – WWII	-42.63 (133.08)	-48.27 (1078.68)	-4.86 (155.47)	217.27 (1406.99)
log(Contract) * Post	3.98 (10.92)	10.66 (87.08)	1.32 (12.62)	-7.02 (112.35)
WWII			69.25 (97.02)	486.82 (877.92)
log(Contract) * WWII			-4.88 (7.65)	-32.41 (69.74)
Constant	98.53 (171.80)	845.21 (1435.85)	60.76 (148.68)	579.67 (1146.08)
Standard Errors adjusted for Clusters by Firm. $*** \, p < 0.01$, $** \, p < 0.05$, $* \, p < 0.10$				
N	210	210	210	210
Obs. per Cluster	10	10	10	10
R^2	0.0294	0.0475	0.0406	0.0627

Note: The column numbers correspond to the same equations listed in the Methodology section. Column (1) and column (3) uses patent count as the dependent variable. Column (2) and column (4) uses patent citations as the dependent variable.
Source: Data obtained through the process detailed under the Raw Data Collection Process section and then aggregated through the Data Manipulation section

Table 3 reports the difference-in-difference results both including and excluding the immediate impact of World War II for both the quality and quantity of patents for the top ten companies based on Higgs' list. The results depict that the unique factors of the different corporations had on both the quality and quantity of patents were not significant. It seems that characteristics specific to the years after World War II had an adverse impact on the number of patents, while there was a positive impact made by World War II on the number of post-World War II patents. Both relations held true when including the immediate impact of World War II. The quality of patents followed similar relations depicted by the quantity of patents. However, these relations are reversed when including the immediate impact of World War II. In particular, there is a large positive impact by characteristics unique to years after World War II, and an adverse impact by World War II on post-World War II innovation quality. The results also show that for both the quality and quantity of patents, there was a positive impact by characteristics unique to the WWII and a negative impact on the immediate impact of World War II. Despite all these findings, none of these relations are statistically significant, thus implying that World War II did not have any influence on the quality or quantity of patents.

All of the relationships for the companies in Higgs' list are the same when the companies are switched with the top ten defense contractors during World War II. In particular, no factors were statistically significant. Corporation specific characteristics had no impact on either quality or quantity of patents. As well, relative to the other periods, there was no significant difference in patents, both quality and quantity, post-World War II or immediately during World War II. This relation maintained to be true even when considering the immediate impact of World War II. There was no significant impact by characteristics unique corporations, the years during World War II and the years after the war. As well, there were no significant differences in innovation quantity and quality immediately during World War II and after World War II.

Table 4: Difference-in-Difference Regression (Top Ten Defense Contractors)

	Without WWII Immediate Impact		With WWII Immediate Impact	
	(1)	(2)	(3)	(4)
log(Contract)	-10.64	-109.31	-8.13	-69.70
	(9.49)	(83.76)	(7.94)	(63.44)
Post – WWII	1.81	400.44	29.80	807.90
	(31.47)	(422.95)	(62.64)	(820.85)
log(Contract) * Post	0.38	-37.84	-2.13	-77.45
	(3.74)	(48.45)	(7.34)	(94.40)
WWII			51.31	747.02
			(64.44)	(752.18)
log(Contract) * WWII			-4.60	-72.62
			(7.53)	(87.05)
Constant	109.90	1092.19	81.92	684.73
	(83.39)	(729.50)	(71.06)	(565.55)
Standard Errors adjusted for Clusters by Firm. $*** p < 0.01$, $** p < 0.05$, $* p < 0.10$				
N	210	210	210	210
Obs. per Cluster	10	10	10	10
R^2	0.0496	0.0953	0.0886	0.1450

Note: The column numbers correspond to the same equations listed in the Methodology section. Column (1) and column (3) uses patent count as the dependent variable. Column (2) and column (4) uses patent citations as the dependent variable.
Source: Data obtained through the process detailed under the Raw Data Collection Process section and then aggregated through the Data Manipulation section

The results from the difference-in-difference regression show that there was no significant change in the quantity or the quality of patents as a result of World War II. Despite this, it is uncertain whether the findings from a simple difference-in-difference method provide an accurate estimation of the relationships. This can be reflected by the large standard errors for all variables compared to the coefficients reported. As well, another issue is that though the regressions have accounted for heteroskedasticity, the exact type of heteroskedasticity is of unknown form. Moreover, due to the small number of clusters, the significance may not be correctly tested. Therefore, as mentioned, the wild cluster bootstrap must be implemented to obtain more accurate results. The other issue is that the models used thus far are not correctly specified, or there are factors omitted in the study, which is represented by the low R-squared values. Both the low R-squared values and the possible model specification can be corrected if the models are transformed to consider that both the quantity and the quality of patents are measured through count variables. Another factor to consider is that these results may be biased since the data is not obtained through random sampling. However, as mentioned in the Data section, these results are still representative of the investments made by the United States government. In particular, these corporations of interest earned the largest portion of the government contract values and are large entities whose actions have large implications in their respective industries.

Wild Cluster Bootstrap Results

Table 5: Wild Cluster Bootstrap Results

	Higgs' List		Top Ten Defense	
	(1)	(2)	(3)	(4)
log(Contracts)	0.77	0.61	0.33	0.29
Post – WWII	0.89	0.99	0.68	0.39
log(Contract) * Post	0.85	1.00	0.80	0.46
WWII	0.61	0.72	0.51	0.36
log(Contracts)* WWII	0.68	0.77	0.65	0.48
N	210	210	210	210
Adjusted R^2	0.045	0.067	0.093	0.149
Number of Reps	499	499	499	499

Note: Table 5 reports the p-values from the wild cluster bootstrap from equations (3) and (4)
Source: Data obtained through the process detailed under the Raw Data Collection Process section and then aggregated through the Data Manipulation section

Since the number of clusters is so small, the wild cluster bootstrap was implemented to get a more accurate depiction of how significant the variables are. Table 5 confirms that none of the variables of interest have any impact on the quality or the quantity of patents for both lists of companies. Furthermore, with very large p-values, it provides more evidence that there may be something drastically wrong with the models used. This is most definitely caused by not correcting for the fact the dependent variables are count variables. Thus, the regressions done should be disregarded for they do not add any significant information.

Count Data Adjusted Regression Results

Table 6: Count Data Adjusted Regressions (with Higgs' List)

	Poisson Distribution		Negative Binomial Distribution	
	(1)	(2)	(3)	(4)
log(Contract)	-0.28	-0.47	-0.75^{**}	1.12^{**}
	(0.80)	(1.24)	(0.38)	(0.48)
Post – WWII	-1.72	-1.81^{***}	2.73	10.24^{*}
	(1.26)	(0.49)	(3.66)	(5.68)
log(Contract) * Post	0.18^{*}	0.20^{***}	-0.18	-0.75^{*}
	(0.10)	(0.04)	(0.29)	(0.44)
WWII	2.85^{**}	1.38^{**}	4.66	14.10^{**}
	(1.40)	(0.54)	(4.22)	(6.42)
log(Contract) * WWII	-0.20^{*}	-0.07	-0.35	-1.08^{**}
	(0.11)	(0.04)	(0.33)	(0.50)
Constant	6.38	10.70	10.14^{**}	-14.53^{**}
	(10.15)	(15.79)	(4.84)	(6.16)
Standard Errors adjusted for Clusters by Firm. $***\ p < 0.01$, $**\ p < 0.05$, $*\ p < 0.10$				
N	210	210	210	210
Obs. per Cluster	10	10	10	10

Note: Column (1) and column (2) follow a Poisson distribution, while column (3) and column (4) follow a Negative Binomial distribution. Column (1) and column (3) uses patent count as the dependent variable. Column (2) and column (4) uses patent citations as the dependent variable.
Source: Data obtained through the process detailed under the Raw Data Collection Process section and then aggregated through the Data Manipulation section

Using a Poisson distribution, the results still depict that there is no corporation specific characteristics. However, there are characteristics unique to World War II that had a positive impact on both the quality and quantity of patents. The results also show that the quality of patents were adversely affected by characteristics unique to the years after World War II. As well, relative to pre-war innovation, it shows that World War II had an immediate negative impact but a positive post-war impact on both the quality and quantity of patents. However, for the quantity of patents, this relation is only slightly significant, and thus to err on the side of caution, it will be considered as statistically insignificant. It can be concluded that the Poisson regression shows that World War II had an adverse impact on immediate quality of innovation, but had a positive influence on the quality of innovation after World War II. However, these results may not necessarily be accurate for the underlying distribution may cause overdispersion.

To correct for overdispersion, the underlying distribution is changed from a Poisson distribution to a negative binomial distribution. Under a negative binomial distribution, corporation specific characteristics have significant impact on both the quality and quantity of innovation. However, the impact is different for the quality and the quantity of patents. In particular, the corporation specific features had an adverse impact on the number of patents, but a positive effect on the quality of patents. As well, other relations changed under the negative binomial distribution. For the quantity of patents, the characteristics unique to World War II no longer have a significant impact and even the interaction terms, which had a slight significance, are no longer significant. Meanwhile, there is an immediate negative impact on the quality of patents due to World War II. As well, both the characteristics unique to the years after World War II and the impact World War II had on post-war innovation quality, were slightly significant, but will be considered insignificant for cautious reasons.

For top ten defense contractors during World War II only some results were the same when applying a negative binomial distribution. The relationships depicted for the quantity of patents are not the same under Higgs' list as they are for the top ten defense contractors. Under the Poisson distribution, the number of patents is impacted by the characteristics unique to the years after World War II and the impact driven by World War

II, instead of characteristics unique to the years during World War II. Meanwhile, corporation specific characteristics no longer have an impact on the number of patents. Unlike the quantity of patents, there is a similar relationship under Higgs' list and the top ten defense contractors for the quality of patents. The only difference is that more variables have a significant relation with the quality of patents. Compared to the Poisson distribution, the negative binomial distribution shows that World War II had a negative immediate impact innovation quality and a negative influence post-World War II innovation quality, rather than a positive one.

Table 7: Count Data Adjusted Regressions (Top Ten Defense Contractors)

	Poisson Distribution		Negative Binomial Distribution	
	(1)	(2)	(3)	(4)
log(Contract)	-1.05	-1.60	0.16	2.17^{***}
	(0.91)	(1.84)	(0.41)	(0.50)
Post – WWII	-2.76^{**}	-1.93^{***}	4.23^{*}	8.66^{**}
	(1.25)	(0.50)	(2.38)	(3.61)
log(Contract) * Post	0.41^{***}	0.35^{***}	-0.41	-0.89^{**}
	(0.15)	(0.06)	(0.28)	(0.42)
WWII	-1.38	-1.39^{***}	4.81^{*}	10.58^{***}
	(1.33)	(0.53)	(2.60)	(3.94)
log(Contract) * WWII	0.24	0.27^{***}	-0.49	-1.13^{**}
	(0.16)	(0.06)	(0.31)	(0.46)
Constant	11.41	18.00	-0.53	-17.98^{***}
	(7.68)	(15.60)	(3.49)	(4.23)
Standard Errors adjusted for Clusters by Firm. $***\,p < 0.01,\ **\,p < 0.05,\ *\,p < 0.10$				
N	210	210	210	210
Obs. per Cluster	10	10	10	10

Note: Column (1) and column (2) follow a Poisson distribution, while column (3) and column (4) follow a Negative Binomial distribution. Column (1) and column (3) uses patent count as the dependent variable. Column (2) and column (4) uses patent citations as the dependent variable.
Source: Data obtained through the process detailed under the Raw Data Collection Process section and then aggregated through the Data Manipulation section

The similarities depicted in the quality of patents under a negative binomial distribution for the two different lists of companies and with different contract values provide an interesting result. In particular, both results depict that firm-specific characteristics had a positive influence on the quality of innovation. As well, characteristics unique to the years during World War II and after World War II had a positive impact on the quality of innovation. Meanwhile, World War II had an adverse impact on both the immediate quality of innovation and post-World War II innovation quality. Though some of the relationships are more significant for the top ten defense contractors than Higgs' list, it implies that these results are mainly driven by corporations that have more direct military involvement. As well, there are certain relations that are the same under both lists, such as the immediate negative impact on innovation quality due to World War II. The persistence of these results depicts there is a possible relation between innovation quality in the United States and World War II. It depicts that World War II caused an adverse impact on innovation quality relative to the quality before the war. Moreover, these results give more evidence to those who argue that World War II had an adverse impact on the United States, for the event did not impact the quantity of innovation, and instead, had an immediate negative impact on the innovation quality. Following from historical narrative, firms that had a direct military connection were expected to benefit from the presence of war. However, not only did these corporations not experience a significant increase in the quantity of new inventions, but their innovation quality both during World War II and after World War II decreased compared to before the war. The results depict that the United States were not producing quality inventions during the war, and most likely this notion remained after World War II.

Since the findings do not support the notion that World War II had a positive impact on U.S. innovation, it gives further evidence showing that World War II was detrimental to the United States. Moreover, the sacrifices in social welfare made during the war need to be considered when reviewing these findings. More importantly, they do not justify the sacrifices made, for there was no improvement in the quality of innovation nor did it induce a vast amount of inventions. Hence, it only provides more evidence that despite winning World War II, the war was detrimental to the United States. Finally, the findings also suggest that though historically it showed the United States were leaders in technology after World War II, other reasons may be driving their dominance as technological leaders. For instance, it may be the case that their lack of capital destruction was the cause of their superiority rather than their focus on innovation.

Alternative Explanations

There are alternative variables/factors that could have impacted innovation in the United States. Firstly, an issue to consider is the Trading with the Enemy Act enacted during World War I that had implications during World War II[47]. Another problem to consider is the impact of an influx of human capital from German Jewish immigrants immigrating to the United States[48]. Lastly, and most importantly, the issue that not every innovation or invention was patented and instead kept as a trade secret[49]. An obvious example of this would be the Manhattan Project. Despite this, there are reasons why none of these factors would play an impactful role to change the results of this study.

The Trading with the Enemy Act, created during World War I, essentially allowed for the violation of patent laws for patents belonging to enemy nations. More accurately, it

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[47] Petra Moser and Alessandra Voena, "Compulsory Licensing - Evidence from The Trading with the Enemy Act", *The American Economic Review* 102, no. 1 (2012): 396–427.
[48] Petra Moser, Alessandra Voena and Fabian Waldinger, "German Jewish Émigrés and US Invention †", *American Economic Review* 104, no. 10 (2014): 3222-3255.
[49] James Bessen and Michael James Meurer, *Patent Failure* (Princeton: Princeton University Press, 2008).

gave the Office of Alien Property Custodian the ability to distribute and/or sell enemy patents to United States firms[50]. An amendment of this Act allows for this to be applied whenever the United States is in involved in a war[51], which resulted in the Office of Alien Property Custodian having in their possession about "fifty thousand patents registered in [the United States] in the name of nationals of designated enemy countries" during World War II[52]. If patents from nationals of enemy nations were distributed in a similar way as in World War I, it could potentially cause an issue with the results. In particular, the Trading with the Enemy Act would have a positive influence on the number of patents in the United States during World War II[53]. However, since this Act is only applicable when the United States is at war, it would be a characteristic of World War II. Furthermore, since the focus is on the impact World War II had on U.S. innovation, this Act can also be interpreted as an investment made by the government in the form of reallocating enemy innovation to improve U.S. research and development. Therefore, the Trading with the Enemy Act is a characteristic of World War II and is captured in the effects of World War II. This narrative coincides with the positive impact by characteristics unique to World War II, depicted by the results.

Additionally, similar to the Trading with the Enemy Act, the United States' Book Republication Program (hereafter BRP) allowed for U.S. entities to have access to enemy-owned science material, thus ignoring the copyrights for science books[54]. This program

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[50] Moser and Voena. "Compulsory Licensing – Evidence from the Trading with the Enemy Act"
[51] Martin Domke. *Trading with the Enemy in World War II* (New York: Central Book Co., 1943)
[52] Domke. *Trading with the Enemy in World War II.*
[53] Stephanie Lee. "Compulsory Licensing and Domestic Innovation: Evidence from the Trading with the Enemy Act after World War II". (Ph.D., Stanford, 2011).
[54] Barbara Biasi and Petra Moser, "Does Cheap Access Encourage Science? Evidence from The WWII Book Replication Program", *SSRN Electronic Journal* (n.d.).

was similar to the Trading with the Enemy Act for it allowed U.S. institutions to obtain knowledge from enemy nations. Furthermore, there is evidence that shows that patents were positively affected by the BRP[55], implying that the BRP program potentially could be driving an increase in patents. However, just like the Trading with the Enemy Act, the BRP program only occurred during World War II, implying that any influence the BRP had on innovation would be captured by the characteristic unique to World War II.

Another issue to consider that potentially impacted the number of patents filed was the influx of German – Jewish immigrants immigrating to the United States to escape genocide in Europe. The vast influx of human capital arriving into the United States could potentially impact innovation. In particular, near the end of the war, there were over "133,000 German – Jewish" immigrants, and of those immigrants "one fifth were university graduates", including "2,400 academics"[56]. Even if the large inflow of human capital did not impact the innovation directly, it could have indirect results. During World War II, the United States was not necessarily socially accepting to those of Jewish descent. The anti-Semitic beliefs resulted in the reallocation of domestic talents into the research fields of immigrants to impede the ability of German – Jewish immigrants to have access to promising areas of study. This resulted in an increase of 71 percent in patenting[57]. However, based on this factor alone, it is uncertain how it would necessarily impact this study as this study uses patents from firms as a proxy for innovation in the United States.

There is a relationship between independent inventors and companies, which could cause an impact to the number of patents by firms. In particular, "firms in technologically

[55] Biasi and Moser. "Does Cheap Access Encourage Science? Evidence from The WWII Book Replication Program"
[56] Moser et al. "German Jewish Émigrés and US Invention".
[57] Moser et al. "German Jewish Émigrés and US Invention".

progressive sectors" had a substantial connection with independent inventors and would purchase independent patents that would supplement the company's in-house research and development[58]. Therefore, the influx of the German – Jewish immigrants may impact the patents of the firms of interest in this study by making more independent patents available for purchase. Despite this, it was the case that those German – Jewish immigrants negatively selected to immigrate to the United States, since Allied nations such as Britain were closer geographically and relatively similar in academic culture[59]. This implies that relatively less productive scientists were attracted to the United States, and these immigrants would not be expected to have a direct impact on innovation in the United States. Furthermore, according to the United States Holocaust Memorial Museum, it was the case that Palestine was a location that was more favored than the United States[60]. As well, it was not until after President Truman's executive order near the end of 1945 that allowed a substantial amount of displaced persons to enter the United States, which was after World War II[61]. Thus, it can be assumed that the impact of German – Jewish immigrants during World War II may be negligible and rather have a larger impact after World War II, which is captured by post-war characteristics.

The biggest issue is that not all new inventions or innovations are patented and instead, they are kept as trade secrets. In particular, it is the case that most firms do not patent a significant portion of their inventions, implying that most of these inventions are

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[58] Nicholas. "The Role of Independent Invention in U.S. Technological Development, 1880-1930"
[59] Tom Ambrose. *Hitler's Loss: What Britain and America Gained from Europe's Cultural Exiles.* (London: Peter Owen in association with the European Jewish Publication Society, 2011)
[60] "United States Policy Toward Jewish Refugees, 1941–1952", *United State Holocaust Memorial Museum*, last modified 2016, accessed April 2, 2016, https://www.ushmm.org/wlc/en/article.php?ModuleId=10007094.
[61] "United States Policy Toward Jewish Refugees, 1941–1952", *United State Holocaust Memorial Museum*

kept as trade secrets[62]. This creates a significant issue because since trade secrets cannot be measured, then using patent counts and patent citations would provide an underestimation of innovation. Furthermore, it implies that the data may not provide a clear and accurate answer due to the uncertainty of the actual number of new inventions between 1935 and 1955. This suggests that patent count and patent citations may not be the best proxy to measure innovation.

An alternative to using patent count and patent citations would be the amount spent by the government on research and development. Between 1940 and 1945, the United States government research and development spending increased from 83.2 million to 1,313.6 million, in terms of 1930's U.S. dollar, where the research and development for the Department of Defense alone, increased by 394 million [63]. Despite the clear, substantial increase in expenditure by the United States government, the amount spent does not necessarily account for the change in costs of goods or services between 1940 and 1944. It could very well be the case that the cost of research and development increased during that time. Hence, using government expenditure as a measure of innovation without making additional assumptions may not project an accurate relationship on how World War II impacted innovation in the United States. However, it can be argued that even with additional assumptions, it is unclear how an increase in expenditure necessarily translates into new inventions, for research and development projects vary across the cost, research duration, and project size. Thus, government spending is a worse measure of innovation than both patent counts and patent citations. Moreover, despite the issue with trade secrets, patent count and patent citations still represents the best proxy for innovation. This is

[62] Bessen and Meurer. *Patent Failure*
[63] Mowery and Rosenberg. "The U.S. National Innovation System".

because the patent system was widely used for firms historically, and since the data used is historical data, it still provides a valuable historical measure of innovation for a company's research and development[64].

Conclusion

World War II was a significant historical event that left its mark not only on the people it impacted, but the nations as well. However, from the literature, it is inconclusive whether or not this impact was positive or negative. Some argue that World War II created an increased focus on research and development, and the event led the United States to come out as a technological leader[65]. Others argue that innovation was on the rise in the United States, but was disrupted by the Great Depression and World War II. Moreover, they claim that the increase in innovation after World War II is nothing more than a revival of the pattern before the Great Depression[66]. As well, during World War II, since the United States was not as technologically advanced as Nazi Germany, one would expect an increased focus on new inventions. Therefore, World War II could potentially impact innovation in the United States.

To study the impact World War II had on innovation in the United States, there first must be a method to measure innovation. An obvious measure of innovation are patents, and the patent's filing year provided a close approximation of the when the new invention was created. Therefore, for a given year, the total number of patents represented the inventions created in that year. As well, the number of citations a patent received can act

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[64] Tom Nicholas, "Did R&D Firms Used to Patent? Evidence from The First Innovation Surveys", Journal of Economic History. 71, no. 04 (2011): 1032-1059.
[65] Mowery and Rosenberg. "The U.S. National Innovation System".
[66] Field, *A Great Leap Forward*.

as a measurement for innovation quality[67]. Thus, it can be investigated to see if World War II may have impacted the quality of patents. However, even with these proxy measurements, there needed to be a variable representative of the United States, for it is hard to show patents created by the United States government. Therefore, two different lists of corporations that earned the largest portion of government contracts are used to represent the United States[68,69]. Thus, these companies represented the United States as well as specific industries within the United States.

Given the two lists of companies, patent data was obtained from Google Patents, which contained information about a patent such as the patent's filing date, priority date, grant date, publication date, as well as the number of citations the patent used and received. The data set for each list of companies was generated through data scraping from Google Patents using programs such as R, or manually. With the data set, a simple difference-in-difference regression was done to see the impact World War II had on innovation after World War II. As well, the simple difference-in-difference was expanded to include the immediate impact World War II had on innovation. However, the analysis must adjust for the fact that the number of patents and patent citations are count variables, which was corrected by adjusting the underlying distribution. Both a Poisson distribution and a negative binomial distribution were used for they are both solutions to count variables, but the latter corrects for the overdispersion.

The results showed that World War II did not have an impact on the number of patents, but it did have an adverse impact on the quality of patents immediately during

[67] Griliches, "Patent Statistics as Economic Indicators: A Survey"
[68] Higgs, *Depression, War, and Cold War: Studies in Political Economy*.
[69] Peck and Scherer. *The Weapons Acquisition Process: An Economic Analysis*

World War II and after World War II. This relationship holds true under both lists of companies, and thereby providing a result that can be generalized for the United States. This implies that though World War II induced no significant change in the number of inventions relative to before the war, the quality of these new inventions were relatively poor compared to those prior to the war. Thus, these findings give more evidence that World War II was not beneficial to the United States. Furthermore, it also provides an argument that the lack of capital destruction, due to the United States' geographical location, provided a platform for the United States to become leaders in technology.

Other factors such as previous policies or amendments, World War II induced immigration, and the patenting behavior of corporations are essential factors that need be considered. For instance, a previous United States amendment, known as the Trading with the Enemies Act, allowed U.S. corporations to obtain patents from enemy nations and may have impacted innovation[70]. Though this factor is not included explicitly, it is contained in the year terms for World War II implicitly. A similar argument holds true for World War II induced immigration of German – Jewish individuals, for there was not a large population of these immigrants let into the United States until after World War II[71]. Therefore, this factor is implicitly within the characteristics of the years following World War II. The most important factor that may impede the credibility of the findings is that corporations may not patent all new inventions, and instead, keep it as a trade secret[72]. However, historically, corporations tend to patent the majority of their inventions and thus patent data still provides the best measurement of historical innovation[73].

[70] Moser et al. "German Jewish Émigrés and US Invention"
[71] "United States Policy Toward Jewish Refugees, 1941–1952", *United State Holocaust Memorial Museum*
[72] Bessen and Meurer. *Patent Failure*
[73] Nicholas. "Did R&D Firms Used to Patent? Evidence from the First Innovation Surveys"

Though the findings are a result of using the top ten companies off two lists, it would be interesting to see if these relationships hold true when more companies are included. Though this may not be a solution reflective of all industries in the United States, it still reflects the investments made by the United States. Moreover, it would depict a more robust result of how World War II influenced innovation both during the war and after, relative to the pre-war period. Another interesting expansion is to see how this relationship holds given a longer time frame, such as expanding the years both prior to and after World War II. If the relationships depicted are still significant under these expansions, it would confirm the negative impact on World War II had and give more evidence that World War II was a detrimental event that set back nations including those far away from the front lines.

The findings provide further evidence that World War II was detrimental to the United States not only in terms of welfare. Not only did World War II not induce any significant increase in inventions, but it decreased the quality of innovation immediately during World War II and after World War II. It shows that despite the clear increased funding for research and development in the United States[74], it did not produce more inventions and instead produced poor quality inventions. Moreover, these innovations came at the cost of public welfare and it is uncertain how these innovations benefited the public. Therefore, the findings not only question the arguments made by those who claim World War II benefited the United States, but provides more evidence on why World War II was the driver of undesirable results and that sacrifices made for the war were not fruitful, in terms of innovation.

[74] Mowery and Rosenberg. "The U.S. National Innovation System".

References

"Alcoa in The USA: The Alcoa Story". *Alcoa.Com*. Last modified 2016. Accessed August 10, 2016. https://www.alcoa.com/usa/en/alcoa_usa/history.asp.

Ambrose, Tom. *Hitler's Loss*. London: Peter Owen in association with the European Jewish Publication Society, 2001.

Baime, A.J. *The Arsenal of Democracy*. Boston: Houghton Mifflin Harcourt, 2014.

Bessen, James and Michael James Meurer. *Patent Failure*. Princeton: Princeton University Press, 2008.

Biasi, Barbara and Petra Moser. "Does Cheap Access Encourage Science? Evidence from The WWII Book Replication Program". *SSRN Electronic Journal* (n.d.).

Cameron, A. Colin and Pravin K Trivedi. "Count Panel Data". In *The Oxford Handbook of Panel Data*, Badi H Baltagi ed. by, 233-256. Oxford: Oxford University Press, 2015.

Cameron, A. Colin, Jonah B. Gelbach, and Douglas L. Miller. "Bootstrap-Based Improvements for Inference with Clustered Errors". *Review of Economics and Statistics* 90, no. 3 (2008): 414-427.

"Company History". *Curtiss-Wright Corporation*. Last modified 2016. Accessed June 21, 2016. http://www.curtisswright.com/company/history/.

"Control Pedal Assembly". *Google Patents*. Last modified 2016. Accessed May 15, 2016. https://patents.google.com/patent/US2516397A.

Davidson, Russell and James G MacKinnon. *Econometric Theory and Methods*. New York: Oxford University Press, 2004.

Denison, Edward Fulton. *Why Growth Rates Differ*. Washington: Brookings Institution, 1967.

Domke, Martin. *Trading with The Enemy in World War II*. New York: Central Book Co., 1943.

"Electrical Transformer". *Google Patents*. Last modified 2016. Accessed July 15, 2016. https://patents.google.com/patent/USD179946S.

Field, Alexander J. *A Great Leap Forward*. New Haven: Yale University Press, 2011.

"General Information Concerning Patents". *United States Patent and Trademark Office*. Last modified 2016. Accessed May 15, 2016. http://www.uspto.gov/patents-getting-started/general-information-concerning-patents.

Griliches, Zvi. "Patent Statistics as Economic Indicators: A Survey". *Journal of Economic Literature* 28, no. 4 (1990): 1661-1707.

Higgs, Robert. *Depression, War, And Cold War Studies in Political Economy*. New York: Oxford University Press, 2006.

Higgs, Robert. "Wartime Prosperity? A Reassessment of the U.S. Economy in The 1940S". *Journal of Economic History* 52, no. 01 (1992): 41-60.

Kallen, Stuart A. *The War at Home*. San Diego: Lucent Books, 2000.

Lee, Stephanie. "Compulsory Licensing and Domestic Innovation: Evidence from The Trading with The Enemy Act After World War II". Ph.D, Stanford, 2011.

Lightbody, Bradley. *The Second World War*. London: Routledge, 2004.

Moser, Petra and Alessandra Voena. "Compulsory Licensing - Evidence from The Trading with The Enemy Act". *The American Economic Review* 102, no. 1 (2012): 396–427.

Moser, Petra, Alessandra Voena, and Fabian Waldinger. "German Jewish Émigrés and US Invention †". *American Economic Review* 104, no. 10 (2014): 3222-3255.

Mowery, David C and Nathan Rosenberg. "The U.S. National Innovation System". In *National Innovation Systems: A Comparative Analysis*, Richard R Nelson ed. by, 29-75. New York: Oxford University Printing Press, 2016.

Nelson, Richard R. and Gavin Wright. "The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective". *Journal of Economic Literature* 30, no. 4 (1992): 1931-1964.

Nicholas, Tom. "Did R&D Firms Used to Patent? Evidence from The First Innovation Surveys". *Journal of Economic History*. 71, no. 04 (2011): 1032-1059.

Nicholas, Tom. "The Role of Independent Invention in U.S. Technological Development, 1880–1930". *Journal of Economic History* 70, no. 01 (2010).

Painter, D. S. "Oil and The American Century". *Journal of American History* 99, no. 1 (2012): 24-39.

Peck, Merton J and Frederic M Scherer. *The Weapons Acquisition Process: An Economic Analysis*. Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1962.

Perett, Geoffrey. *Days of Sadness, Years of Triumph*. Wisconsin: The University of Wisconsin Press, 1985.

"Prize Cases 67 U.S. 635 (1862)". *Justia Law*. Last modified 2016. Accessed June 5, 2016. https://supreme.justia.com/cases/federal/us/67/635/case.html.

Rose, Matthew, Harrison F Houghton, and John Malcolm Blair. *Economic Concentration and World War II*. Washington D.C.: U.S. G.P.O., 1946.

"U.S. Patent Activity, CY 1790 To Present". *USPTO*. Last modified 2016. Accessed July 16, 2016. http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm.

"United States Policy Toward Jewish Refugees, 1941–1952". *United State Holocaust Memorial Museum*. Last modified 2016. Accessed April 2, 2016. https://www.ushmm.org/wlc/en/article.php?ModuleId=10007094.

Weinberg, Gerhard L. *A World at Arms: A Global History Of World War II*. 2nd ed. Cambridge: Cambridge University Press, 2005.

Wood, James B. *Japanese Military Strategy in The Pacific War*. Lanham: Rowman & Littlefield, 2007.

"World War II On the Home Front: Civic Responsibility". *Smithsonian in Your Classroom*, 2007. Accessed July 23, 2016. http://www.smithsonianeducation.org/educators/lesson_plans/civic_responsibility/smithsonian_siyc_fall07.pdf.