

Antitrust, Patents, and Cumulative Innovation: Evidence from Bell Labs

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Abstract

How large is the impact of intellectual property on cumulative innovation in electronics, computers and communications? Following an antitrust lawsuit against Western Electric and AT&T, Bell Labs had to license all patents published by 1956 for free. We find that this removal of patent rights increased subsequent citations to Bell's patents by 9%. Patenting in affected patent subclasses increased by 23%. The effect comes from young and small firms in fields in which Bell did not remain commercially active. Placebo regressions support the identification assumption of parallel trends in citations.

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1 Introduction

Innovation is a key driver of economic growth. A major tool to foster innovation are patents. Patents correct for the lack of market incentives for innovation resulting from the public-good nature of ideas (Arrow, 1962; Nelson, 1959). Yet, recently patents have come under attack. The concern is that patent protection hampers the use of patented innovation in future inventions. This problem is particularly likely to arise in complex product industries such as electronics, computers and communications, because in these technologies new inventions require a large number of components and thus cumulative innovation is thought to be very important. The concern that patents might impede follow-on innovation in mobile communication technology was raised for example in the public debate on the “Smartphone wars”.¹ Many argued that small entrepreneurial companies might be unwilling to build on current patented mobile technologies if they have to fear diverse patent claims from various incumbent companies. This fear could eventually prevent market entry and thus innovation.

But is this indeed the case? Up to now our knowledge about the effects of patents on cumulative innovation in electronics, computers and communications is limited. The reason is that there is very little variation in patent rights that can be used to learn about the effects. The only variation comes from cases where patents have been invalidated in court (Galasso and Schankerman, 2015b). However, the sample of patents challenged in court is very selective and we do not know whether we can generalize the findings from this sample to the policy-relevant case of large scale patent rights removals.² Furthermore, we know from surveys that patents work very differently in discrete product technologies than in complex product technologies (Cohen *et al.*, 2000). As a consequence, we cannot generalize other findings in the literature that are often based on discrete product technologies such as pharmaceuticals, biotechnology or chemicals (Moser and Voena, 2012; Williams, 2013).

In this paper we provide empirical evidence on how the removal of patent rights from Bell Labs, one of the most innovative companies of all times, influenced subsequent innovation. Researchers at Bell Labs were responsible for groundbreaking innovations in the fields of computer electronics and communications, such as the transistor, the laser, information theory and the basis of the cellular phone technology. In the 1950s, Bell Labs, AT&T and Western Electric constituted the Bell System, which had an 85% share in the

¹Refer for example to Eduardo Porter, “Tech Suits Endanger Innovation”, New York Times, May 29, 2012, page B1 or Charles Duhigg and Steve Lohr “The Patent, Used as a Sword”, New York Times, Oct 7, 2012, Page A1

²Yet, the sample of patents invalidated in court is a very interesting sample, because the estimated effect is immediately policy relevant and the selection might be based on the value of patents.

US telecommunication market. In response to this dominant position, the Federal Communications Commission (FCC) filed an antitrust suit against Western Electric in 1949, suggesting that the Bell System should be broken up and all patents should be licensed for reasonable rates. After some wrangling, Bell agreed in 1954 to the compulsory licensing of their patents in return for the monopoly in the telephone market. This concession was the basis of the consent decree in 1956: all existing patents became freely available to other companies and all future patents had to be licensed for reasonable licensing fees. In addition, Bell Labs was required to provide complementary technical information relating to the compulsorily licensed patents and had to leave all industries unrelated to the telecommunication industry.

At the time, most observers thought of the consent decree as an ineffective antitrust remedy: The magazine *Business Week* wrote that the decree was “hardly more than a slap on the wrist of the world’s biggest company”. In a later investigation the House Subcommittee on Antitrust found that the “cozy” consent decree of the Bell System “failed the purpose of the Sherman Act” and that it was a “blot on the enforcement history of antitrust laws”. Over the years, opinions on the consent decree changed - but mainly because of its effect on other companies: For example, the co-founder of Intel, Gordon Moore, called the consent decree one of the most important developments for the commercial semiconductor industry, which started the growth of the Silicon Valley. David Teece opined in 1997, that “[s]haped by antitrust policy (...) [AT&T’s liberal licensing policy] remains one of the most unheralded contributions to economic development – [it] possibly far exceeds the Marshall plan in terms of wealth generation capability established abroad and in the United States“ (Grindley and Teece, 1997).

This paper sheds light on what really happened. In particular, we look at patent citations of other companies to Bell Labs patents published before 1949 and compare them with citations to a control group of patents that are identical with the treated Bell Labs patents in terms of technology class, publication year and number of citations up to 1949. We find that after the consent decree, the number of citations to Bell Labs’ patents increased by about 9% or a total of 1,400 citations.³ The timing of the effect mirrors the timeline of the antitrust suit against Bell: Measured by the application year of the citing patent, the impact is first measurable in 1954, peaks between 1956 and 1959 and reverts to baseline by 1965. The positive effect on citations by other companies is accompanied

³In further analysis we show that there is a similar increase of 23% in the total number of patents in patent classes where Bell was active before the consent decree.

The estimate of 1,400 additional citations is calculated based on the number of Bell patents (7698), the average effect per year excluding self-cites (0.0183) and for a period of 10 years, which is the remaining patent lifetime at the beginning of the effect.

by an equally large negative effect on self-citations, suggesting Bell changed its research focus in response to the invalidation of their patents. This is in line with recent findings by Galasso and Schankerman (2015a).

The increase in the number of follow-on citations is driven by additional citations of young and small companies outside the technological field of electrical communications. This points to the importance of market entry of entrepreneurial companies for cumulative innovation. The consent decree restrained Bell from entering and operating in any industry unrelated to telecommunication. Thus, it opened up the possibility for young companies to enter uncontested markets with the help of free technology. In line with the idea that the consent decree spurred entry of new companies, we show that technology subclasses with compulsory licensed Bell patents grew around 23% more than other subclasses. This long-lasting increase in the scale of innovation is again driven in particular by young and small companies.

Arguably the most important invention of Bell Labs was the transistor, which was invented in 1947 and published as a patent in 1951. The transistor and follow-on inventions based on the transistor effect such as the integrated circuit invented by Texas Instruments in 1958 spurred the growth of whole industries. Looking at transistor patents separately, we find effect sizes at least 10 times larger than for the average Bell patent. Yet, we cannot attribute this large increase in this particular subsample solely to the consent decree. Recognized as path-breaking and in response to the ongoing antitrust suit and pressure by the military, Bell started in 1951 to actively promote the diffusion of the transistor technology with a licensing program and by organizing conferences to explain the technology (Misa, 1985; Solo, 2000; Mowery, 2011; Brock and Brock, 2009). As a consequence, the large increase of follow-on innovation for transistor patents might also be due to these complementary policies. Despite the large size of these effects, the impact in the main sample is not driven by the transistor patents: It is about the same magnitude and statically significant even if all transistor patents are left out.

The effect on citations is identified under the assumption that the citations to the patents of Bell Labs and to the control patents would have followed a parallel trend in the absence of the consent decree. This seems plausible as citations followed parallel trends from 1949 to 1953 before compulsory licensing became known. Furthermore, we conduct two additional tests of the identification assumption: First, we look at a subsample of citing companies that were explicitly excluded from compulsory licensing in the consent decree: RCA, Westinghouse, General Electric and ITT. Re-doing our analysis with citations of these companies only, we find no effect. This speaks in favor of parallel trends. Second, the assumption of parallel trends might be violated if the FCC anticipated strong follow-

on research based on Bell’s most important inventions and as a consequence initiated the compulsory licensing. In this case, the effect would be driven by the most important patents affected by the consent decree. We show that our effect is robust to dropping all transistor patents, the top 5% and top 10% of Bell’s patents as measured by their citations before the beginning of the antitrust suit.

This paper contributes to the growing literature on the effect of intellectual property on cumulative innovation in two important ways. First, we complement the recent literature on the impact of patents on cumulative innovation. Consistent with the findings of Galasso and Schankerman (2015b), our findings suggest that patents prevent knowledge spillovers and follow-on research in the computer and electronics industry.⁴ However, with an increase of 9% we find a much smaller impact in citations than they do in their sample of litigated patents: Following the invalidation of a patent in the field of computer and electronics they find an increase of at least 150% in the number of patent citations.⁵ Second, to arrive at our result we look at variation from a highly policy relevant case, namely the large-scale removal of patent rights following an antitrust lawsuit for one of the largest innovators in US economic history. In a follow-on paper we look at the effect of all consent decrees in US post war history.

The rest of this paper is organized as follows. In the next section we look at the history of Bell Labs and the consent decree. Then we describe the data and in section 4 the empirical set-up. In section 5 we discuss our results and their interpretation. Section 6 concludes.

2 The history of AT&T, Bell Labs and the consent decree⁶

In 1876, Alexander Graham Bell, then a professor for Vocal Physiology and Elocution at Boston University’s School of Oratory, was granted a patent for the first telephone device. Shortly afterwards, he founded the “Bell Telephone Company of Massachusetts”. 80 years

⁴Patent citations are an often used measure of knowledge flows albeit with known imperfections (Alcacer and Gittelman, 2006; Lemley and Sampat, 2012).

⁵The size of our measured effects appear consistent with Murray and Stern (2007) and Williams (2013), who find an overall impact of patent removal on innovation of about 10-20% in biotech and medical instruments. Moser and Voena (2012) find that domestic patenting increases by 20% after the compulsory licensing of German chemical patents in World War I. Given that the effectiveness of patents is thought to be much stronger in these areas, the smaller magnitudes in our study seem reasonable (Cohen *et al.*, 2000).

⁶This history largely follows the final report to the Antitrust Subcommittee of the House on the Bell Consent Decree Program (Celler, 1959).

later, this company had developed into the Bell System, the largest US company of its time, providing telephone services to 46 million telephone lines or 85% of the total market.

The Bell System consisted of AT&T, a holding company managing the Bell System, Western Electric, which produced telephone equipment, the Bell Telephone Laboratories, which engaged in basic and applied research and the regional Bell operators, which delivered telephone services in particular regions. In 1955, the operating revenue of the Bell System was around USD 62 Billion (in 2015 Dollars) and it employed 745,000 people.

The most remarkable part of the Bell System were the Bell Laboratories (Bell Labs) in Murray Hill, New Jersey. Bell Labs was one the most innovative company of all times, producing path breaking basic and applied research. Scientists at Bell are credited for the development of radio astronomy (1932), the transistor (1947), the cellular telephone technology (1947), information theory (1948), the solar cells (1954), the laser (1957), and Unix (1969). Often, these inventions were based on breakthroughs in basic research such as understanding the fundamental nature of semiconductors, of cosmic radiation and the nature of electrons. In total, 8 Nobel Prizes were awarded for work done at Bell. The 1955 staff of Bell Labs alone would go on to win three Nobel Prizes in physics, one Turing Award, five US National Medals of Science and 10 IEEE Medals of Honors for work at Bell Labs. In the early 1960s, Bell Labs employed 11,000 people, of whom one third were professional scientists and engineers (Nelson, 1962).

In January 1949, the government started to move against the monopoly of AT&T and filed a 73 page antitrust suit with the aim to break up the Bell System. It charged extensive violations of the Sherman Antitrust Act in the manufacture and sale of telephone equipment beginning in 1900. It proposed three remedies: First, Western Electric should be split into at least three companies. Second, AT&T should be required to buy telephone equipment only under competitive bidding. And third, Bell Labs should be required to license its patents non-discriminatorily for a reasonable royalty rate.

Bell answered in April 1949 to the effect that the allegations were groundless. There was no further contact between the Bell and the government till August 1951, when the government served a request for documents relating to the case to Bell. In early 1952 the Bell System decided to seek a freeze of the antitrust suit due to the Korean War, claiming it would distract key executives from the war efforts. The Department of Defense (DoD) strongly supported Bell with this request and even requested an indefinite postponement. The Attorney General granted a two year freeze in December 1952.

In January 1953 the Republican Dwight D. Eisenhower took office. The Justice Department was now much less keen on going after Bell than the previous Truman administration. In March 1953 the new Attorney General, Herbert Brownell Jr, announced publicly “that

he was reviewing the pending antitrust cases in the Department for the purpose of deciding whether any of them should be dismissed.” Under these circumstances, AT&T saw the chance to settle all antitrust claims once and for all.

After several staff meetings, Herbert Brownell and AT&T’s general counsel T. Brooke Price met privately at a judicial conference in White Sulphur Springs, West Virginia on June 27, 1953. Price argued for dismissal of the case. In response, Brownell gave Price the hint that minor concessions would suffice to “get rid of the case”. What is more, Brownell urged the defendant’s counsel to review their practices and instead of seeking dismissal to submit concessions that would cause “no real injury to (A.T. & T.’s) business” in order to settle (Celler, 1959, p.55).

In May 1954 AT&T presented and in June 1954 submitted a checklist of concessions to Herbert Brownell that would be an acceptable basis for a consent decree. The only suggested major remedy was the compulsory licensing of all Bell patents on reasonable terms. The proposal did not require severance of Western Electric, it did not limit the role of Western Electric as supplier to the Bell System, and it did not require operating companies of the Bell System to purchase under competitive bidding. In the end - after several further interventions of the Department of Defense - this proposal served as general framework for the final decree.

Negotiations continued through 1954 and 1955. Some voices in the DOJ wanted to press for divorcement of Western Electric from the Bell System till they agreed to drop this matter in November 1955. In December 1955 the DOJ communicated with AT&T that it was ready to consider a decree of the “general character suggested (by A. T. & T.) in its memorandum (...) dated June 4, 1954” with a few additional constraints (Celler, 1959, p.92). Bell agreed.

On January 24 1956 the final judgement was handed down and the consent decree of 1956 took effect. The decree contained four major provisions affecting Bell: First, Bell had to license all its published patents to all applicants royalty free and all future patents at reasonable rates. Second, it had to give technical information to all US companies licensing the patents. Third, it had to get out of all business not directly connected to the communications field. Fourth, it had to introduce uniform cost accounting for Western Electric.

Although hailed as a victory by antitrust officials, posteriority begged to differ: According to Business Week “the consent decree (...) [is] hardly more than a slap on the wrist for the biggest corporation in the world”. A Western Electric official said, that the decree “grants a legalized monopoly” and “in effect the decree constitutes an admission for the government that the way we are doing our Bell System job is a legal and proper

way (...) - in effect a blessing of the present set-up” (House, 1958, pp.2020). Furthermore, the decree “made no change of any importance as regards Western” outside of the “patents and technical information fields”. The permissive nature of the consent decree led to extensive Hearings in Congress on the Consent Decree program in general and on the consent decree of AT&T. It concluded that “the consent decree entered in the A. T. & T. case revealed as devoid of merit and ineffective as an instrument to accomplish the purposes of the antitrust laws.” Furthermore, it considered the decree as a “blot on the enforcement history of the antitrust laws” (Celler, 1959, pp. 290).

3 Data

For our study we use comprehensive patent data for the US from the “Worldwide Patent Statistical Database” (Patstat) of the European Patent Office (EPO).⁷ The bibliographic data starts in 1920 and comes from the United States Patent and Trademark Office (USPTO). The citation data is complete from 1947 onwards. In 1947 the USPTO started to publish citations of prior art on the front page of the patent and therefore citation data is publicly available only from this date (Alcacer *et al.*, 2009).⁸

At the time of the consent decree in 1956, the Bell System was one of the major innovative companies in the US and played an important role in all technology fields connected to electric communication. Figure 1 shows the share of patent applications filed by the Bell System on all patents filed in the US for five patent classes (3-digit level IPC) in which Bell was most active. In the 1930s and 1940s, Bell virtually dominated electric communications with around 30% of all US patents. In 1956, it filed between 5 and 10% of all patents in “Electric Communication Techniques”, “Basis Electric Elements” and “Basic Electric Circuitry”.

Due to the size of the Bell System, the consent decree had a vast impact: It reduced the royalty rate for 7,698 patents, which corresponds to 1.3% of all unexpired US patents.⁹ We identify all affected patents with a list of patent numbers published in the “Hearings before the Antitrust Subcommittee” of the US Congress on the consent decree of AT&T in May 1958 (House, 1958).¹⁰ 5,417 of these patents were filed by Bell Laboratories (Bell

⁷Patstat contains patent data from more than 100 countries.

⁸The first patent to include prior art was issued on February 4, 1947. Yet, inventions were evaluated against the prior art already since passage of the Patent Act of 1836. Prior to 1947, however, the prior art was available only from the “file history” of the issued patent, which is not contained in Patstat.

⁹The consent decree concerned all unexpired patents published before January 1956. As the patent duration was 17 years all patents before 1939 were expired.

¹⁰The list is the complete list of all patents owned by the Bell System in January 1956. It also includes patents of Typesetter Corp. which are explicitly excluded from compulsory licensing in Section X of the

Figure 1: Share of Bell System patents by class and application year

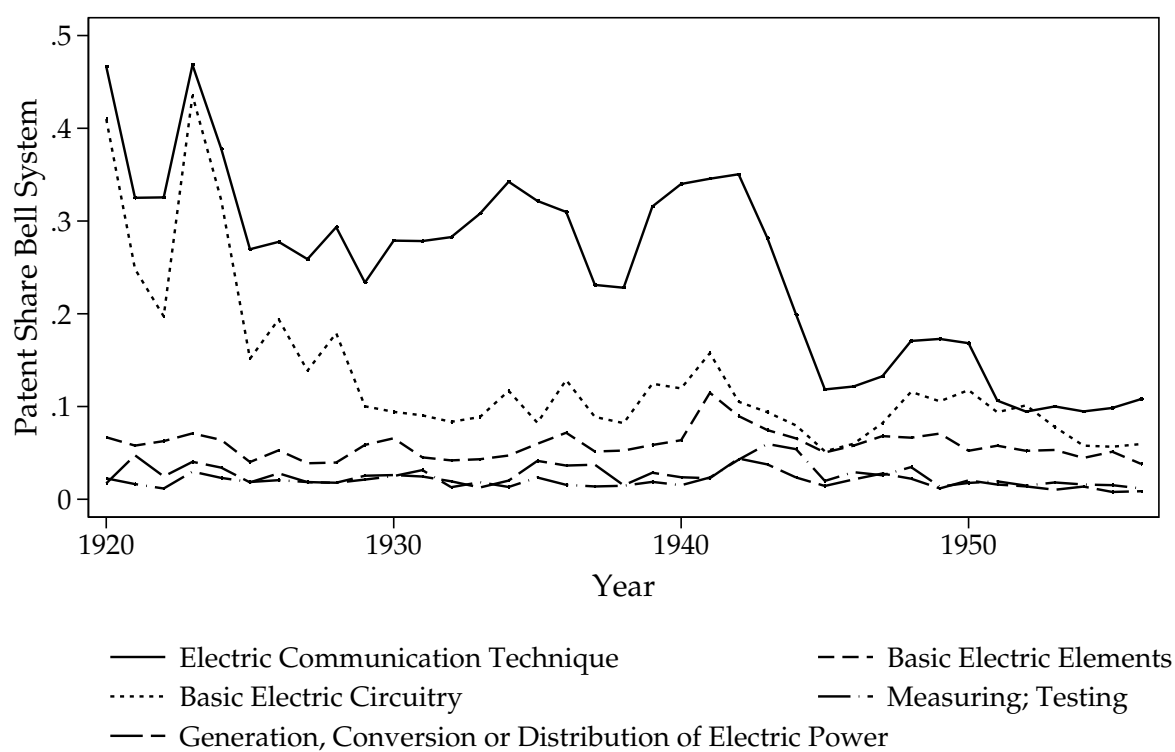


Table 1: Citations statistics

| | All Other | Bell System | AT&T | Bell Labs | Western Electric |
|---|-----------|-------------|--------|-----------|------------------|
| | mean | mean | mean | mean | mean |
| Filing Year | 1944.2 | 1943.5 | 1942.1 | 1943.4 | 1944.0 |
| Publication Year | 1947.3 | 1946.5 | 1944.5 | 1946.5 | 1947.1 |
| Years after 1956 in patent protection | 8.3 | 7.5 | 5.5 | 7.5 | 8.1 |
| Citations by other companies | 4.2 | 5.3 | 3.4 | 6.1 | 3.5 |
| Citation by other companies prior to 1949 | 0.8 | 1.2 | 1.2 | 1.4 | 0.6 |
| Self Citations | 0.2 | 0.7 | 0.1 | 0.9 | 0.3 |
| Total Citations | 4.4 | 6.1 | 3.5 | 7.1 | 3.8 |
| Observations | 301835 | 7698 | 342 | 5417 | 1959 |

Notes: Data for all US patents published between 1939 and 1956. "All Other" includes all patents of non-Bell System companies in technologies where a Bell System company published at least one patent. A citation is identified as a self-cite if the applicant of cited and citing patent is the same.

Labs), 1,959 patents by Western Electric Company (Western) and 342 patents by American Telephone and Telegraph Company (AT&T).¹¹ As Bell Labs filed more than 80% of all affected patents, we use in the following Bell Labs as pars pro toto for the Bell System.

In this study we use patent citations as a way of measuring how many other patents build on the knowledge of Bell Labs for two reasons. First and in contrast to most alternative measures of innovative activity such as new products or R&D spending, patent citations are consistently available from 1950 to today. A second advantage of patent citations is, that they allow a precise measurement of effects due to their relative high frequency. This comes with the caveat that some citations might have been added by the patent examiner, decreasing the signal to noise ratio of patent citations (Alcacer and Gittelman, 2006; Alcacer *et al.*, 2009). Table 1 shows summary statistics for all patents in our dataset from 1939 to 1956.¹² The average non-Bell patent in our data set receives 4.4 citations per patent and 4.5% of these citations are self-citations. Bell System patents receive on average 6.1 citations and 11.4% of these citations are self-citations.¹³

4 Identification strategy

By ensuring the right of any company to receive a license and technical information for free for patents published before 1956, the consent decree may or may not have increased the

consent decree. We mark these patents as unaffected.

¹¹5 patents were assigned to Bell Labs and Western and 15 patents were assigned to Bell Labs and AT&T.

¹²To make the statistics comparable for affected and not affected patents we only consider technology classes in which Bell is active.

¹³Except when explicitly mentioned in the text we correct in all our regressions for self-citations because we are mainly interested to which extend other companies built on Bell Labs patents.

equilibrium rate of subsequent research. Before the consent decree Bell demanded royalty rates in the range from 1% - 6% of net sales price and shaded these royalties if a cross-license was agreed upon (House, 1958, p. 2685).¹⁴ On the one hand, reducing the royalty rate to zero should increase the demand for Bell's technology. Furthermore, by taking away discretion to grant or to not grant a license the agreement potentially reduced ex-post hold up situations between Bell and inventors successfully building on Bell's technology. Yet, on the other hand, Bell already licensed patents to other companies. This implies that the effect might be zero if licensing worked reasonably smooth prior to the decree.

To evaluate these hypotheses, we must address the fundamental problem of causal inference, namely that we can only observe the realized but not the counterfactual outcomes of the consent decree. Ideally, we would like to compare the realized number of follow-on innovations based on Bell patents with and without the consent decree. As this is not possible, we need to find a control group whose evolution of follow-on innovation over time is comparable to the evolution of follow-on innovations based on Bell patents in the counterfactual absence of the consent decree.

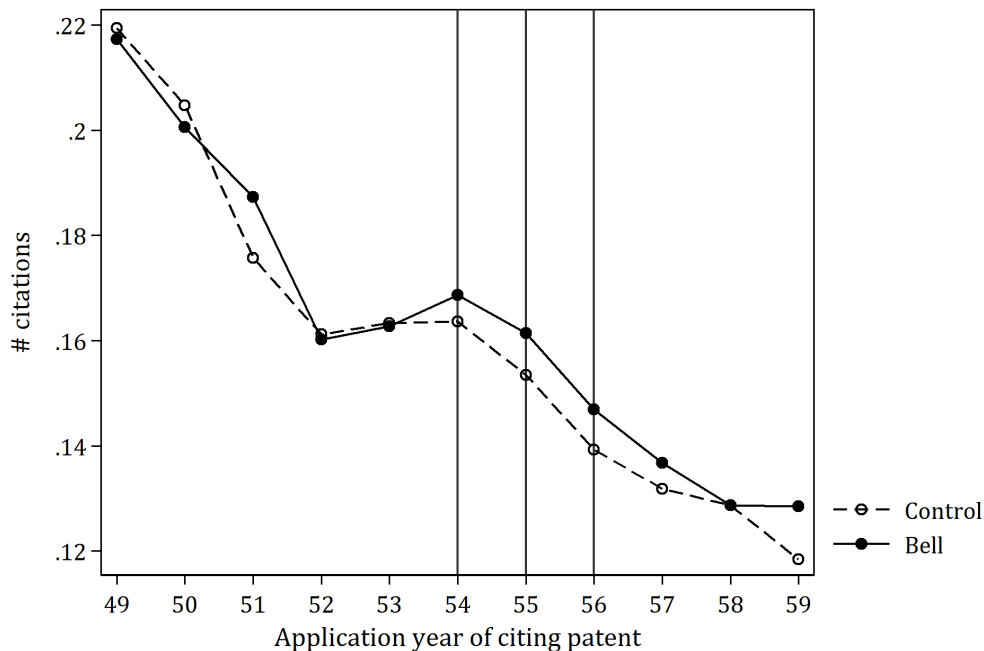
Our research design allows us to measure follow-on innovations and to find a suitable control group: The consent decree made Bell patents published before January 1956 freely available in form of a free license to all companies. Yet, although the patents could be freely used, other patents that built on the patented innovations of Bell still had to cite them. Thus we can use patent citations as a measure for follow-on innovation despite the fact that the patents lost their power to exclude competitors (Williams, 2015).

In order to rule out anticipation effects we use only patents *published* by 1949, the year the lawsuit against Bell started. The consent decree stated that only patents published before 1956 were to be compulsorily licensed. As a consequence of this cut-off date in publication years, more than 98% of the patents affected by the consent decree were filed before 1953, and 88% in 1949 or earlier. This implies that the characteristics of the majority of the affected patents were fixed before the antitrust department filed its initial plea. To be on the safe side, we use only patents published in 1949. Thus we can be sure that there is no direct link from the consent decree to the characteristics of the patents under consideration.

As control group we select patents that have the same total number of citations as the Bell patents prior to the start of the lawsuit in 1949, that are published in the same year and in the same technology class. The identifying assumption is that the control patents

¹⁴For example, prior to the decree to get access to the transistor patents each licensee had to pay non-refundable advance payment of \$ 25,000 (around \$ 220,000 in today's Dollar) which was credited against royalty payments (House, 1958, p.2957). Royalty payments amounted to 5% percent of the net selling price in 1950 which was reduced to 2% in 1953 (Celler, 1959, p. 117).

Figure 2: Average number of citations of Bell and control patents published before 1949



have the same number of follow-on citation as the Bell patents would have had in absence of the consent decree. This assumption is untestable but we show that it is plausible: In addition to various falsification checks, we can observe the evolution of follow-on citations to treatment and control patents, before the consent decree took effect and find very similar trends.

5 Results

5.1 Impact of the consent decree on patent citations

We begin our analysis by graphically comparing the evolution of patent citations of patents published before 1949 in every year after publication of the treated patents and patents in the same publication year and the same four digit technology class in Figure 2. From 1949 to 1953, the average number of citations of treatment and control patents track each other very closely. This implies that there seems to be no effect in the first 4 years after the plea. Furthermore, the control patents appear to be a good control group as they exhibit parallel trends. There is a clear increase of citations to Bell patents in 1954, which converge again in 1961/1962. This is *prima facie* evidence for an effect from 1954 onwards.

In a second step we use regressions to quantify the effect. Our baseline regression measures the effect of compulsory licensing of Bell Labs' patents on subsequent citations. We use a difference-in-differences estimator that identifies the average difference between treatment and control patents. Specifically, we use the following estimation equation

$$\#Citations_{i,t} = \alpha + \beta_t \cdot Bell_i + YearFE + \varepsilon_{i,t} \quad (1)$$

where $Citations_{i,t}$ is the number of follow-on citations of other companies to the treated and the control patents. $Bell_i$ is an indicator if the patent is owned by the Bell System and therefore treated. To avoid contamination we use as treated patents only the 4732 patents of Bell published before the antitrust suit was filed in 1949. Control patents belong to the same technology class on the four-digit IPC level, have the same publication year and the same number of citations up to the year 1949. In total we can match 4509 (95%) Bell patents to 55160 control patents. To estimate an average treatment effect on the treated, we use weights from the coarsened exact matching algorithm provided by Iacus *et al.* (2009) in order to adjust for the imbalance in the number of treatment and control patents.

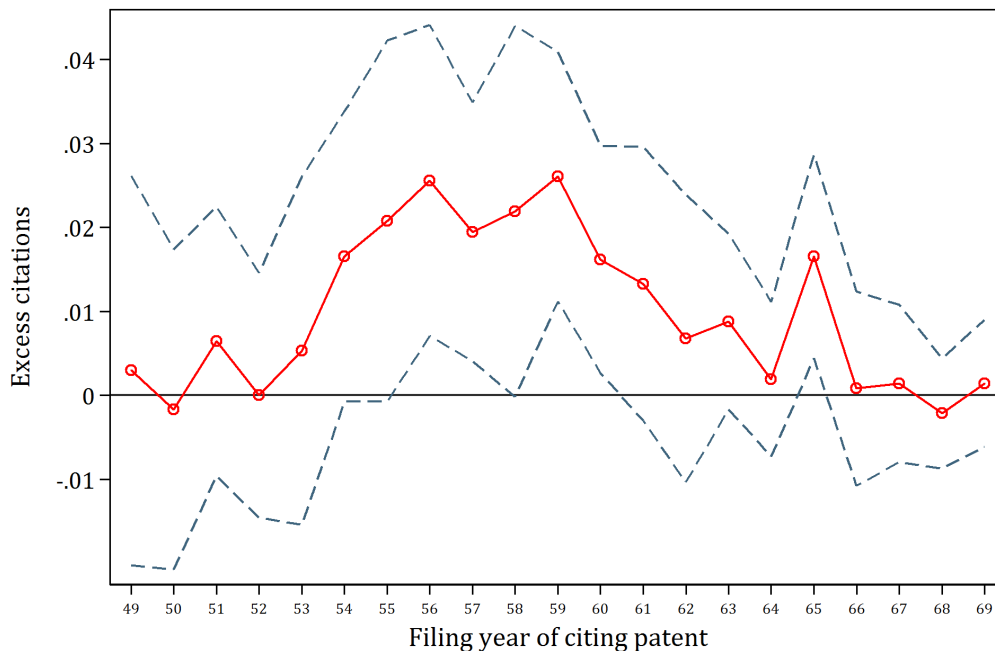
The results for the estimation of the time-varying treatment effect, β_t in Equation (1) is shown in Figure 3. There is no significant difference between treatment and control group in the years 1949 up to 1953. As in the simple comparisons of means in Figure 2 this implies that in the first four years the patent citations of treatment and control patents exhibit similar trends. In 1954 and 1955, there is an increase to 0.02 excess citations. The coefficients are significantly different from zero on the 10 percent level. Starting in 1956, the year of the consent decree, the increase becomes statistically significant on the 5% level. From 1954 to 1960 the size of the effect is almost constant at 0.02 excess citations per patent per year. Afterwards the year-by-year coefficient converges, with one outlier in 1965 - back to baseline.

In Table 2 we estimate a uniform effect of the consent decree for the years 1949 to 1960, using the following equation

$$\#Citations_{i,t} = \beta_1 \cdot Bell_i + \beta_2 \cdot Bell_i \cdot I[1954 - 1960] + PeriodFE + \varepsilon \quad (2)$$

where $I[1954 - 1960]$ is an indicator for the treatment period from 1954 to 1960 and $PeriodFE$ is a fixed effect for the treatment period. In the first column, we look at the effect of the consent decree in the pre- and post-treatment period with the citations of other companies to Bell patents as dependent variable. There is no significant baseline effect while in the treatment period the effect is 0.018 additional citations relative to the

Figure 3: Effect of compulsory licensing on subsequent citations



mean of 0.2, an increase of around 9%. The second column looks at self-citations which decrease by 0.009 citations. This points either to a lower propensity to exploit the already existing technology by Bell after the consent decree or to a shift in the patent strategy towards using secrecy as a way to protect its intellectual property. The effect on own citations is large enough to reduce the effect on total citations to statistical insignificance (column 3).

5.2 Counterfactual Regressions and Robustness

Dropping the most important patents

One threat for identification of the effect is that the government singled out AT&T for compulsory licensing because of Bells outstanding inventions. If public officials enacted the consent decree as a reaction to the great inventions of the Bell Labs, the effect of the consent decree should not be observable for patents which were “by chance” part of the consent decree.

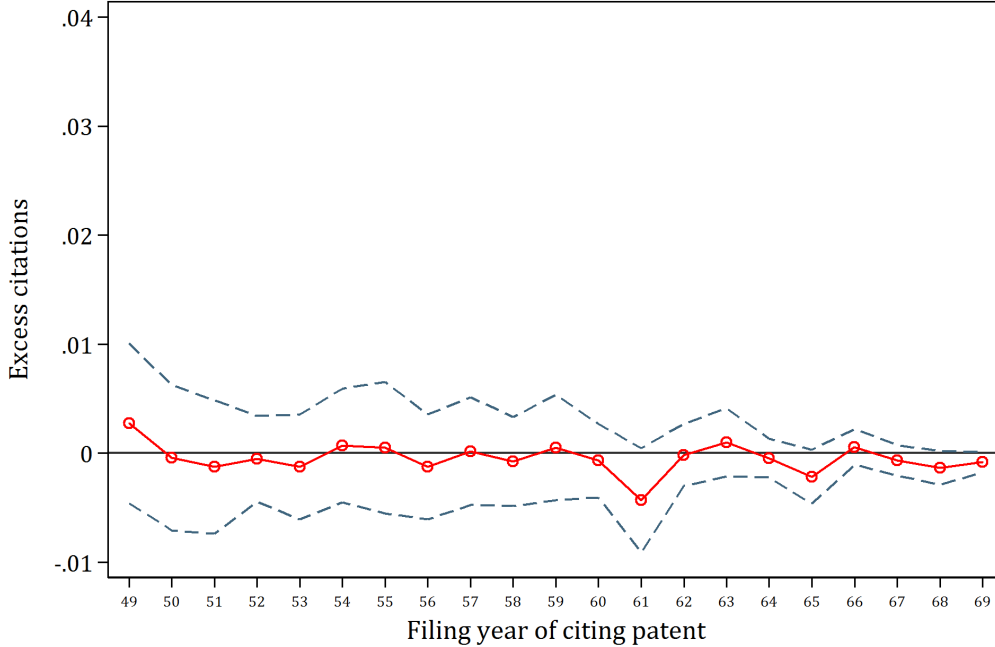
To see if this is the case we drop in the last three column of Table 2 all patents related to the transistor, the top 5% and top 10% of all Bell Labs patents measured by their citations up to 1949 and repeat the analysis. The effects are not significantly different from the effects in the main specification.

Table 2: The effect of compulsory licensing on subsequent citations

| | (1) Non-Self- Cites | (2) Self- Cites | (3) All Cites | (4) wo Transistor | (5) wo Top 5% | (6) wo Top 10% |
|-----------------|---------------------------|-----------------------|---------------------|-------------------------|---------------------|----------------------|
| Bell | 0.26 (0.64) | 1.69*** (0.29) | 1.95*** (0.74) | -0.84 (0.59) | -1.93** (0.75) | -4.14*** (1.03) |
| Bell x I(54-60) | 1.83** (0.79) | -0.86*** (0.28) | 0.98 (0.98) | 2.04*** (0.75) | 2.90*** (0.87) | 3.82*** (0.93) |
| Constant | 19.29*** (1.65) | 1.33*** (0.15) | 20.62*** (1.73) | 19.28*** (1.64) | 19.29*** (1.65) | 19.29*** (1.65) |
| Clusters | 259 | 259 | 259 | 259 | 259 | 259 |
| Obs. | 716028 | 716028 | 716028 | 716028 | 716028 | 716028 |

Notes: This table shows the results from a difference-in-difference estimation with years 1949 to 1953 as pre-treatment period and 1954 to 1960 as treatment period. The variable "Bell" is an indicator if a patent is published by a Bell System company before 1949 and therefore treated by the consent decree. As control patents we use all patents which were published in the US matched by publication year, four digit IPC class and the number of citations up to 1949. As dependent we use in the first column all citations by other companies than the filing company, in the second column we use all self-citations and in the third column all citations as dependent. In the fourth column we exclude patents which are connected to the transistor, the most prolific invention of Bell Labs. All coefficients are multiplied by 100 for better readability.

Figure 4: Effect of compulsory licensing on subsequent citations among companies that were exempt from the consent decree



Counterfactual regressions

Our main results are also compatible with a positive shock on the potential for follow-on inventions of Bell but not for control patents around the time of the consent decree. If this is indeed the case, such a shock should positively affect the patenting of all companies building on Bell’s technology - independently of whether they could license for free from Bell or not.

The 1956 consent decree singled out three companies for not receiving the benefits of free compulsory licensing of Bell patents. These companies were the General Electric Company, Radio Corporation of America and Westinghouse Electric Corporation. The reason was that these companies already had a general cross-licensing agreement in place, the “B2-agreements” dated July 1, 1932. A fourth company, the International Telephone and Telegraph Company was not affected by the decree as it had a patent pool with Bell.

In Figure 4 we re-estimated equation (1) using only the citations of the B2-companies as dependent variable. We do not find any effect. As these companies make up in total 10% of all citations to Bell patents, this is not due to a lack of measurability. In Appendix B we show that we also find smaller effects for foreign companies which did not receive technical assistance and for companies that already had a licensing agreement in place.

Timing of the effect

The measured effect in Figure (3) starts in 1954. This is plausible because on May 28, 1954, Bell suggested a consent decree including the compulsory licensing of Bell System patents. As a consequence, starting in May 1954, both the Bell Laboratories and companies building on the patents of Bell could have known that compulsory licensing was in the cards (Celler, 1959). This timeline is supported by the stock market performance of AT&T in 1953 and 1954 and by Bell's own actions.¹⁵

Figure 5 shows cumulative abnormal stock returns of the AT&T Corporation stocks starting in January 1948. The pattern of abnormal returns is consistent with traders being informed about the consent decree in 1954 at the latest. Up to the Eisenhower election cumulative abnormal returns were centered around zero. Beginning in 1953 and ending at the start of 1954 cumulative abnormal returns increase to around 9%. The transition period coincides with the period of negotiations from the freeze of the antitrust case at the end of 1952 to the offer of compulsory licensing by AT&T in April/May 1954. In particular the large uptick at the end of February/beginning of March 1954 is synchronized with the meeting on the consent decree of AT&T on March 3, 1954 (House, 1958, p. 1956).¹⁶ Afterwards there is no persistent positive or negative abnormal return till 1959. Even the consent decree in 1956 did not seem to have any informational value.

We can also infer from the behavior of Bell that the dating from the hearings of the agreement to prior 1955 is accurate: According to the consent decree all patents were compulsorily licensed for free if they were published before January 24, 1956. If they were published after this cut-off date, they were licensed under a reasonable and non-discriminatory basis. So starting from the date when Bell became aware of the clause, it had an incentive to delay the publication of its patents beyond the cut-off date.

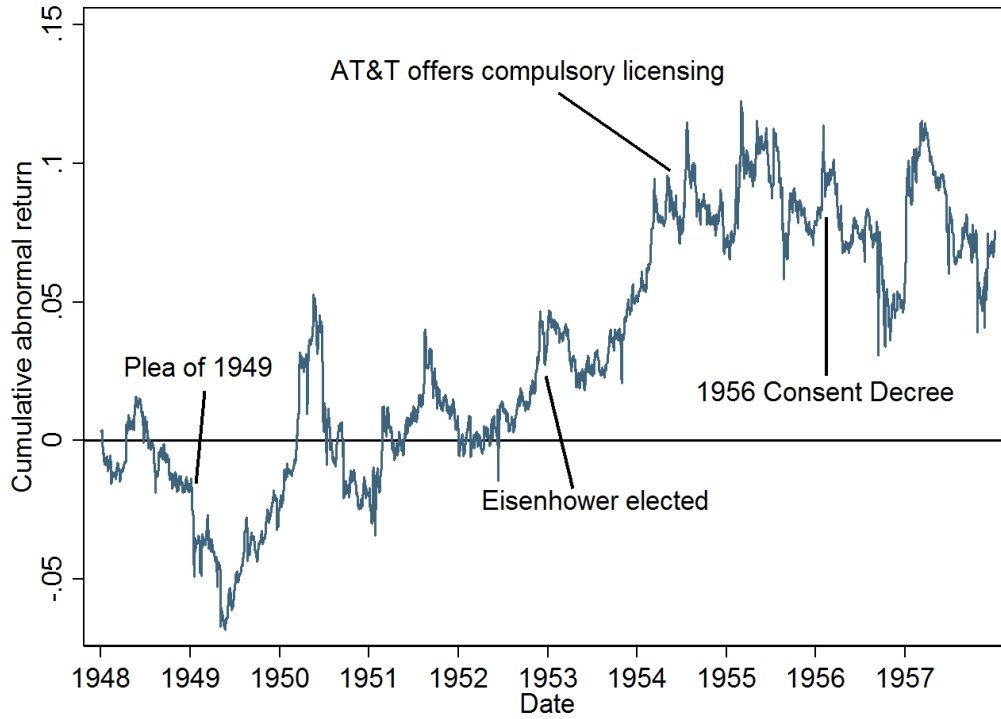
According to the data, Bell started to delay its patents at the patent office beginning in the first half of 1955. To pin down the date we compare for a given filing year the propensity of a Bell patent to be published with the propensity that control patents are published. In Figure 6, we show these hazard rates of publishing for the years 1949 and 1953.¹⁷ In 1949, the publishing rates per year are very similar for Bell patents and patents from other companies. If at all, Bell patents were published a bit earlier. In 1953, this picture is reversed: Starting in the first half of 1955, Bell patents had a significantly

¹⁵The first media mentioning that a consent decree for Bell was about to happen was on May 13 1955 in the New York Times. Public officials confirmed that top level negotiations are ongoing "looking towards a settlement of the AT&T case".

¹⁶The content of the meeting could not be cleared up despite intense questioning. In Appendix A.2 in Figure 11 is a transcript of the questions and answers.

¹⁷The years 1951 and 1956 in Appendix A.3 and all other years are available from the authors on request.

Figure 5: Abnormal returns of AT&T stocks



lower probability of being published. This is consistent with Bell trying to delay the publications of its patents and having credible information about the general outline of the consent decree in the first half of 1955 at the latest.

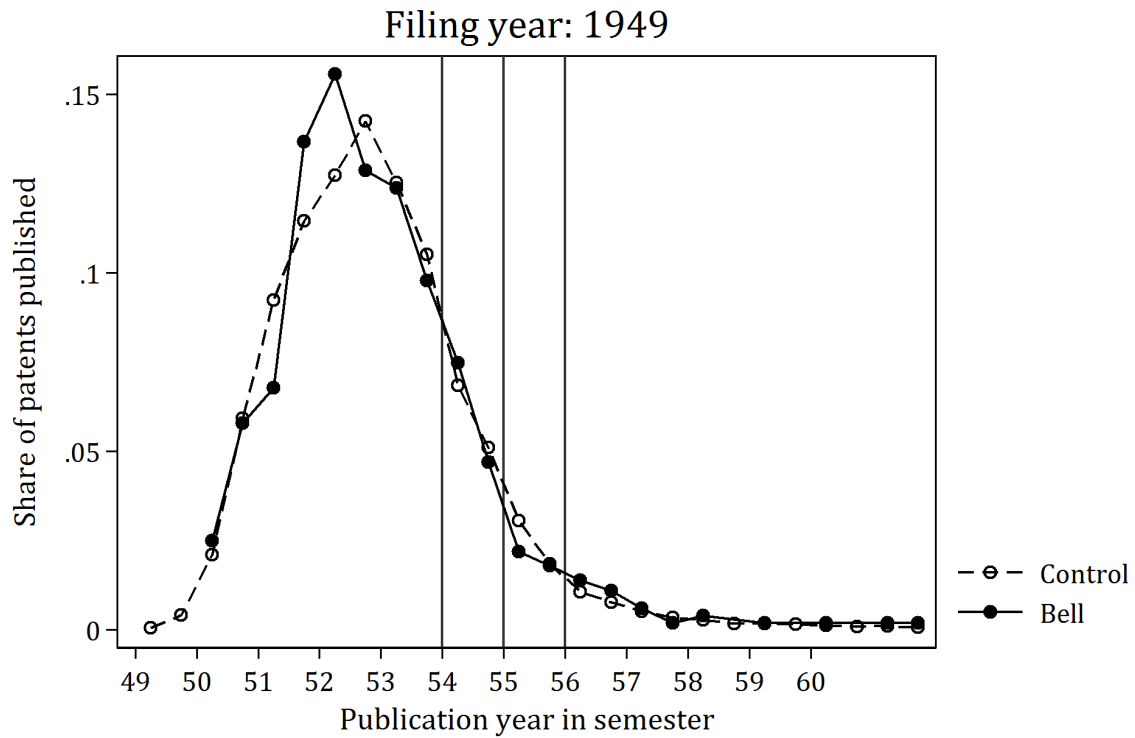
5.3 The role of the transistor

Arguably the most important invention of Bell Labs' research was the transistor. John Bardeen, Walter Brattain and William Shockley demonstrated the first functional transistor December 1947, they filed patents in June 1948 that were published in 1950 and 1951.¹⁸ Bell Labs announced the invention on July 1st, 1948. As the most basic element of modern computers, the transistor was instrumental in creating entire industries and heralded the beginning of the information age. The transistor is recognized as the paramount general purpose technology of our time and its invention earned John Bardeen, Walter Brattain and William Shockley the Nobel Prize in Physics in 1956 (Helpman, 1998).

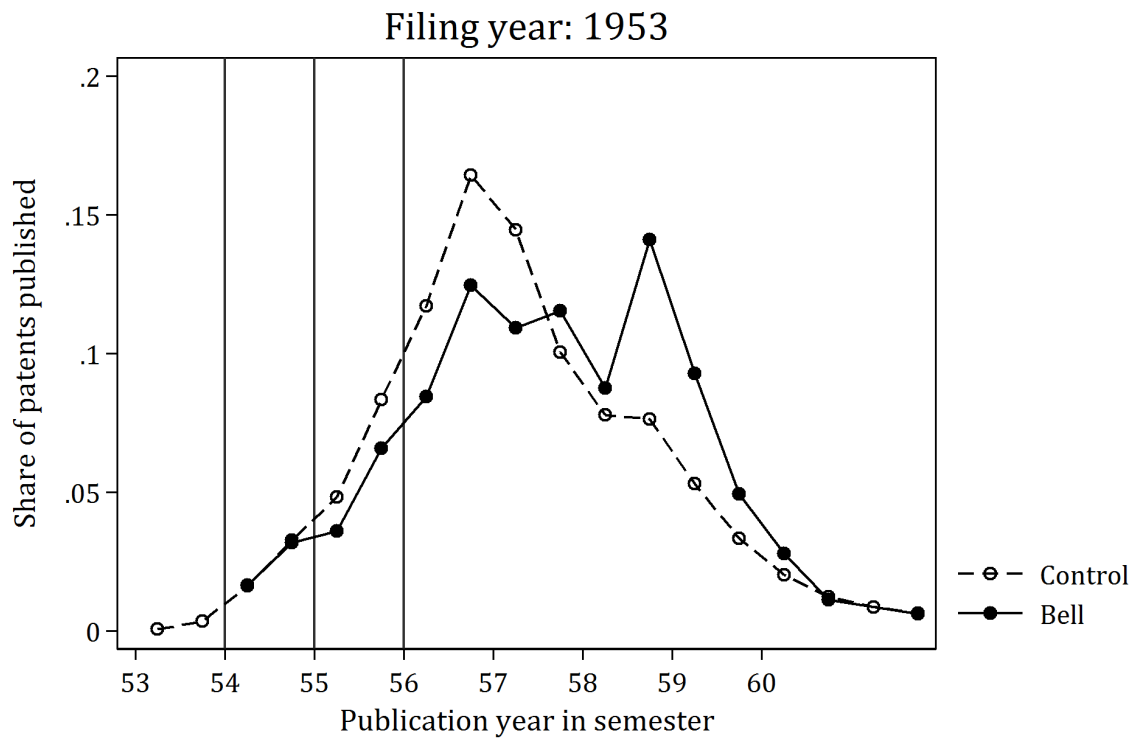
¹⁸The two main transistor patents are: Patent # 2,524,035 with the title "Three-Electrode Circuit Element Utilizing Semiconductive Materials" applied for on June 17, 1948, and granted on October 3, 1950 to John Bardeen and Walter Brattain and Patent # 2,569,347 with the title "Circuit Element Utilizing Semiconductive Material" applied for on June 26, 1948, and issued to William Shockley on September 25, 1951.

Figure 6: Hazard rate for patent publication by filing year

(a) Application year 1949



(b) Application year 1953



Studying the transistor technology in greater detail is interesting for three reasons: first, it is one of the few opportunities to study the impact of intellectual property on the diffusion of a general purpose technology.¹⁹ Second, to identify the effect of compulsory licensing we must make sure that not the complete effect is driven by the transistor technology. Third, as the importance of the transistor patents was recognized at this time, the licensing of the transistor patents followed a different regime than other Bell patents: Bell actively promoted the diffusion of the transistor technology by introducing a standardized licensing contract and by organizing conferences in 1952 to explain the technology.²⁰

Our original sample excludes all patents published after 1948. So to include the transistor technology we extend our sample period to patents published up to 1951 and match on the number of citations up to 1952. To identify all patents related to transistor we collect all patents of all researchers at Bell Labs that worked towards the development of the transistor from public sources (e.g. Nelson, 1962).²¹ Then we add all patents from all co-authors. With this procedure we identify 294 “transistor” patents affected by the consent decree, i.e. held by Bell Labs. The aim of this method is collect as completely as possible all patents related to the transistor. But as researcher worked in multiple fields this procedure results in selecting also unrelated patents. This should work against finding an effect.²² The median publication year of the patents in the transistor sample is 1946 and 194 of these patents are also included in our original sample.

In Figure 7 we show the results of estimating yearly coefficients starting with the year of the invention of the transistor in 1947. We find that the effect on forward citations are at least ten times larger than the effect we measure for the consent decree. It starts in 1952 and is spread over the next 15 years. The strong effect might be due to the importance of the underlying technology or the complementary knowledge provided by Bell Labs during the conference or in scientific publications.

Despite the large effects, the transistor patents do not drive the effect in our main sample. In column (4) of Table 2 we drop all transistor related patents published up to

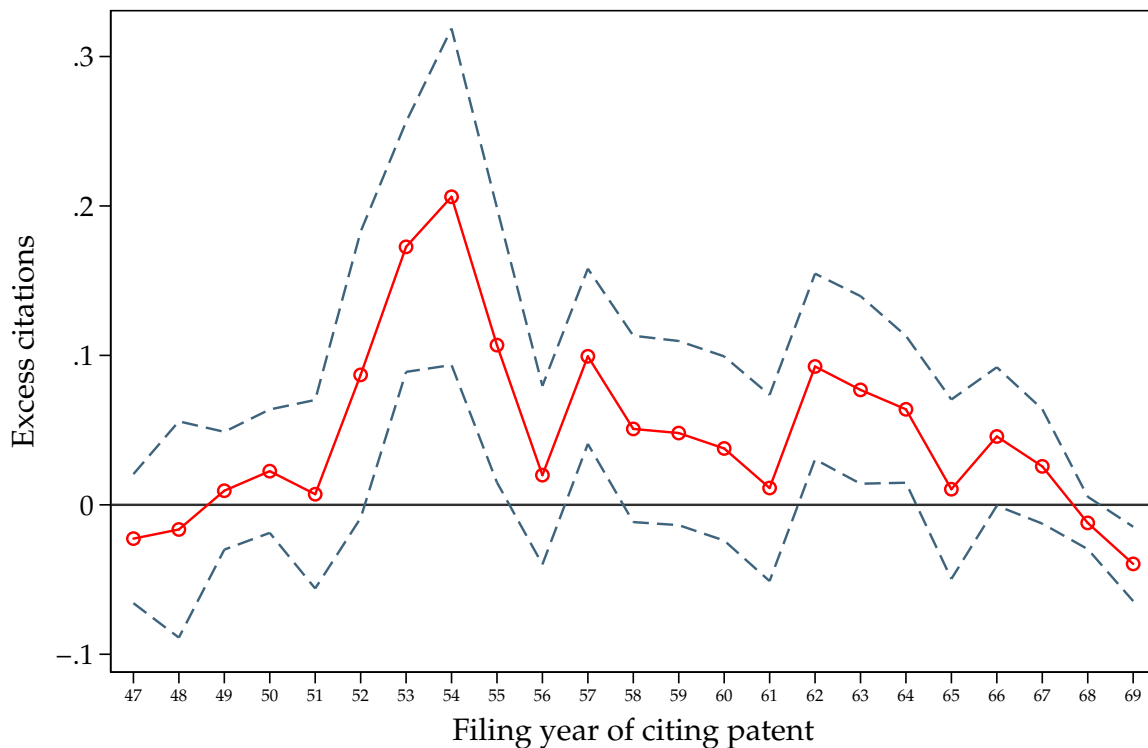
¹⁹There are case studies about the importance of patents for the diffusion of the steam engine Boldrin *et al.* (2008).

²⁰The two-volume proceedings of Bell’s symposium on the topic in 1952 were nicknamed “Ma Bell’s cookbook” as its “recipes” found widespread application in transistor manufacturing. After the conference 30 companies decided to license the transistor technology for a non-refundable advance payment of \$ 25,000 (around \$ 220,000 in today’s dollar) that was credited against royalty payments (House, 1958, p.2957). Royalty payments amounted to 5% percent of the net selling price in 1950 which was reduced to 2% in 1953 (Celler, 1959, p. 117).

²¹Researcher which we classify to actively contribute to the transistor at Bell Labs were in alphabetical order Bardeen, Bown, Brattain, Fletcher, Gardner Pfann, Gibney, Pearson, Morgan, Ohl, Scaff, Shockley, Sparks, Teal and Theurer.

²²For example it includes patent # 2,402,662 with the title “Light sensitive device” of Russell Ohl, the original patent of the solar cell.

Figure 7: Annual Treatment Effects of transistor patents



1949 and still find a significant effect. In Appendix A.1 we show the time-varying effects in the sample with and without transistors for patents that were published by 1949 and patents published by 1951. We find significant effects in all samples without transistor patents.

5.4 Where does the effect come from?

Our results show that the consent decree increased the number of citations to Bell's patents. But what drives these effects? Understanding the mechanism behind the increase in follow-on innovation is important to be able to tailor policies accordingly. In this section, we show evidence that the effect is predominantly driven by market entry and that this led to an increase in the scale of innovation in the US.

Young companies start to cite Bell patents more

Anecdotal evidence suggests that the consent decree spurred large scale market entry creating whole new industries such as the semiconductor industry. For example, Gordon Moore

Table 3: The effect of compulsory licensing on subsequent citations of companies by company type

| | Base-line | Company type | | | | | |
|-----------------|--------------------|--------------------|-------------------|--------------------|-------------------|--------------------|-------------------|
| | | New | Young | Old | Small | Large | Y & S |
| Bell | 0.26 (0.64) | -0.70*** (0.20) | -0.35 (0.31) | 0.64 (0.42) | -0.75** (0.31) | 0.84* (0.48) | -0.59** (0.30) |
| Bell x I(54-60) | 1.83** (0.79) | 0.68*** (0.20) | 0.93*** (0.35) | 0.69 (0.52) | 1.49*** (0.34) | 0.17 (0.59) | 1.16*** (0.31) |
| Constant | 19.29*** (1.65) | 3.63*** (0.29) | 7.27*** (0.42) | 11.21*** (1.33) | 6.23*** (0.42) | 11.25*** (1.36) | 6.13*** (0.41) |
| Clusters | 259 | 259 | 259 | 259 | 259 | 259 | 259 |
| Obs. | 716028 | 716028 | 716028 | 716028 | 716028 | 716028 | 716028 |

The dependent variable is the number of subsequent citations of other companies to patents affected by the consent decree in 1956 by citing company characteristics. Small: less than 10 patents. New: first patent. Young: less than 10 years since first patent. The coefficients are multiplied by 100 for better readability. Standard errors in parentheses are adjusted for clustering at IPC4: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

acknowledged that “There is a direct connection between the liberal licensing policies of Bell Labs and people such as Gordon Teal leaving Bell Labs to start Texas Instruments and William Shockley doing the same thing (...), Shockley Semiconductors in Palo Alto. This started the growth of Silicon Valley (...)”.

To see if this is indeed the case, in Table 3 we analyze separately the impact of the consent decree on citations of young and old as well as small and large firms. New companies are citing companies for which the citation is their first patent, young companies are those that filed their first patent in the 10 years before they cited the Bell patent and old companies are all others. Small companies are defined as companies with less than 10 patents before 1949. We find that the effect primarily comes from new, young and small companies. The coefficients for old and large companies are not significantly different from zero on conventional levels. Combining citations from young and small firms shows that around 2/3 of the overall increase comes from this type of company.

One provision in the consent decree was that Bell had to exit all industries that were not related to the field of communication. Thus Bell preserved its monopoly in the telecommunication market but ceased to be a player in all other industries. This restriction potentially improved the conditions for start-ups in all industries except in communication where it was effectively blocked (Gertner, 2012; Celler, 1959, p.108). According to Celler (1959) this conclusion was already apparent during the negotiations: “The patent and technical information requirement have efficacy only so far as they permit independent

manufacturer to avail themselves of patents in fields that are unrelated to the common carrier communication business carried on by the Bell System companies, and nothing more.” It was suggested that a liberal licensing policy is “only good window dressing” but would do no good because Western had already “achieved an exclusive position (...) and liberal licensing would not permit competitors to catch up” in the communication business (Celler, 1959, pp. 108).

To investigate if the measured effects are consistent with a mechanism of firm entry, we repeat our baseline analysis for each technology class separately. Figure 8 shows the estimates for our main parameter of interest for all technology classes where Bell had more than 10 patents. The impact of the consent decree on follow-on innovation is positive throughout in patent classes in which Bell substantially contributed to technological progress (above 50-70 patents). Among the subclasses that were important for Bell, the impact seems to be largest for Basic Electronic Circuitry and Basic Electric Elements. Importantly however, the effect is not present for Electric Communication Technique, where Bell continued operating and thus entry was effectively blocked.

Our results are therefore consistent with the interpretation that the effect of compulsory licensing on follow-on innovation to a large degree depends on the entry of new companies.

The scale of innovation increases

There are two potential reasons why the cumulative innovation based on Bell patents increased following the consent decree. One is that the consent decree stimulated an increase of the absolute scale of innovation. Another is that the compulsory licensing induced firms to substitute more costly technologies with Bell technologies that were now free of charge. Arguably, only the first alternative would speak for a long-lasting effect of Bell’s antitrust case on the US economy.

To investigate this question we follow Moser and Voena (2012) and compare the change in absolute number of patents before and after the consent decree in technology subclasses with at least one Bell patent to subclasses without. Our sample consists of 201 classes with 2889 subclasses of which 653 are treated.²³

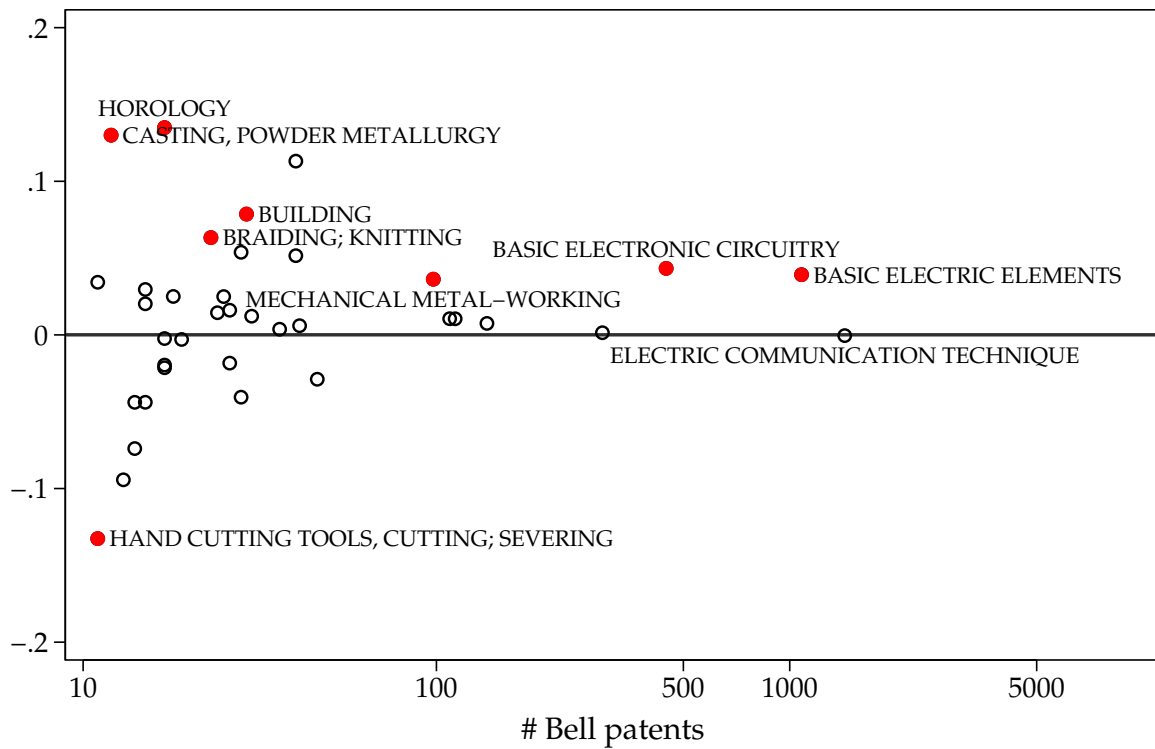
To see if the scale of innovation increased we estimate the following model

$$\#Patents_{s,t} = \alpha + \beta_t \cdot Bell_i + YearFE + TechFE_s + \varepsilon_{i,t} \quad (3)$$

where the dependent variable is the number of patent applications per subclass in a

²³We exclude subclasses which did not have any patents at all before 1956 and we include only patent classes (4-digit IPC level) which contain subclasses that were treated and subclasses which were not.

Figure 8: Effect of compulsory licensing on subsequent citations across patent subclasses



Note: This figure shows the coefficient for the impact of the consent decree on citations for patents in all IPC 3 classes where Bell had in more than 10 patents. A full dot signifies that the coefficient is significant on the 10% level.

Figure 9: Annual Treatment Effects on the Number of Patent Applications

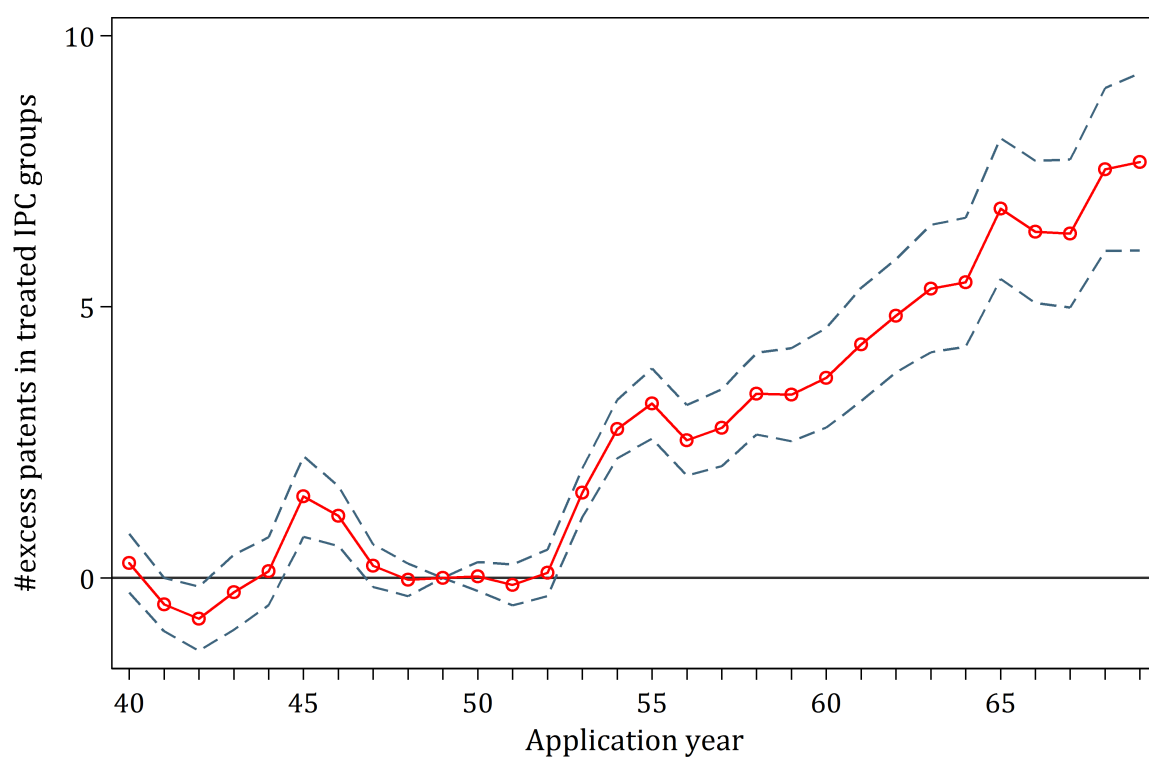


Table 4: OLS regressions of patent applications per subclass and year by company type

| | Patent applications per year | | | | | | |
|--------------------|------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| | Baseline | New | Young | Old | Small | Large | Y & S |
| Treated | 7.89*** (0.55) | 1.75*** (0.18) | 3.13*** (0.26) | 4.76*** (0.37) | 3.03*** (0.29) | 4.86*** (0.39) | 2.52*** (0.24) |
| Treated x I(54-60) | 2.79*** (0.32) | 0.38*** (0.07) | 1.93*** (0.18) | 0.86*** (0.18) | 1.74*** (0.16) | 1.05*** (0.22) | 1.68*** (0.15) |
| Constant | 4.09*** (0.23) | 1.45*** (0.14) | 1.88*** (0.16) | 2.21*** (0.15) | 2.15*** (0.19) | 1.95*** (0.16) | 1.73*** (0.16) |
| Clusters | 319 | 319 | 319 | 319 | 319 | 319 | 319 |
| Observations | 54132 | 54132 | 54132 | 54132 | 54132 | 54132 | 54132 |

Notes: The dependent variable is the number of patent applications per subclass (IPC group) per year, excluding Bell System patents. A subclass is treated if it contains at least one Bell patent that was subject to compulsory licensing. This treatment variable is interacted with an indicator that is 1 for the period from 1954 to 1960. Columns 2 to 7 count only patent applications by specific company types, which are defined as in table 3. Standard errors are clustered at the class level (4-digit IPC). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

year.²⁴ Following the literature we use an indicator which is equal to one if there is at least one affected Bell patent in the subclass. As controls we include technology subclass and a year fixed effect. We find that the consent decree increased the scale of innovation in the US economy. In Figure 9, we show the annual treatment effects using the number of patent applications in a subclass as outcome. The effect starts in 1953 and shows no sign of abating.

To quantify the effect, Table 4 shows the results for the following difference-in-differences specification

$$\#Patents_{s,t} = \beta \cdot Treatment_i \cdot I[1954 - 1960] + Controls + \varepsilon \quad (4)$$

where $Treatment_i$ is an indicator if the subclass i contains at least one compulsory licensed Bell patent. The effect of the treatment variables is significant and positive in all regressions. Similarly as in the citation regressions the effect is mainly driven by young and small companies speaking in favor of market entry as causal mechanism.

²⁴We exclude Bell System patents for the entire sample. Patent applications are weighted according to the number of subclasses they are assigned to. If a patent is assigned to two subclasses, for example, it increases the size of each class by 0.5, such that the total increase is 1 for each patent.

6 Conclusion

In this paper we study the impact of the 1956 compulsory licensing of Bell Labs’ patents on follow-on innovation. Bell was forced to license all its patents as part of a consent decree that settled the antitrust suit of 1949 against its mother company AT&T. This case is particularly interesting as it focuses on one of the largest inventors in US history and the biggest inventor in computers and electronics at that time: Bell Labs owned 1.3% of all US patents protecting some of the central inventions in US post-war history such as the transistor. Our study analyzes the policy-relevant case of large scale patent rights removal, assessing the “case against intellectual property” advocated by some researchers (Boldrin and Levine, 2002).

We find that the consent decree increased citations to Bell patents by over 9%. The effect is driven by young and small companies in fields where Bell was restrained from entering. Placebo regressions support our identification assumption of parallel counterfactual citation trends between treatment and control group. Our results are in line with current research suggesting a negative impact of patents on cumulative innovation.

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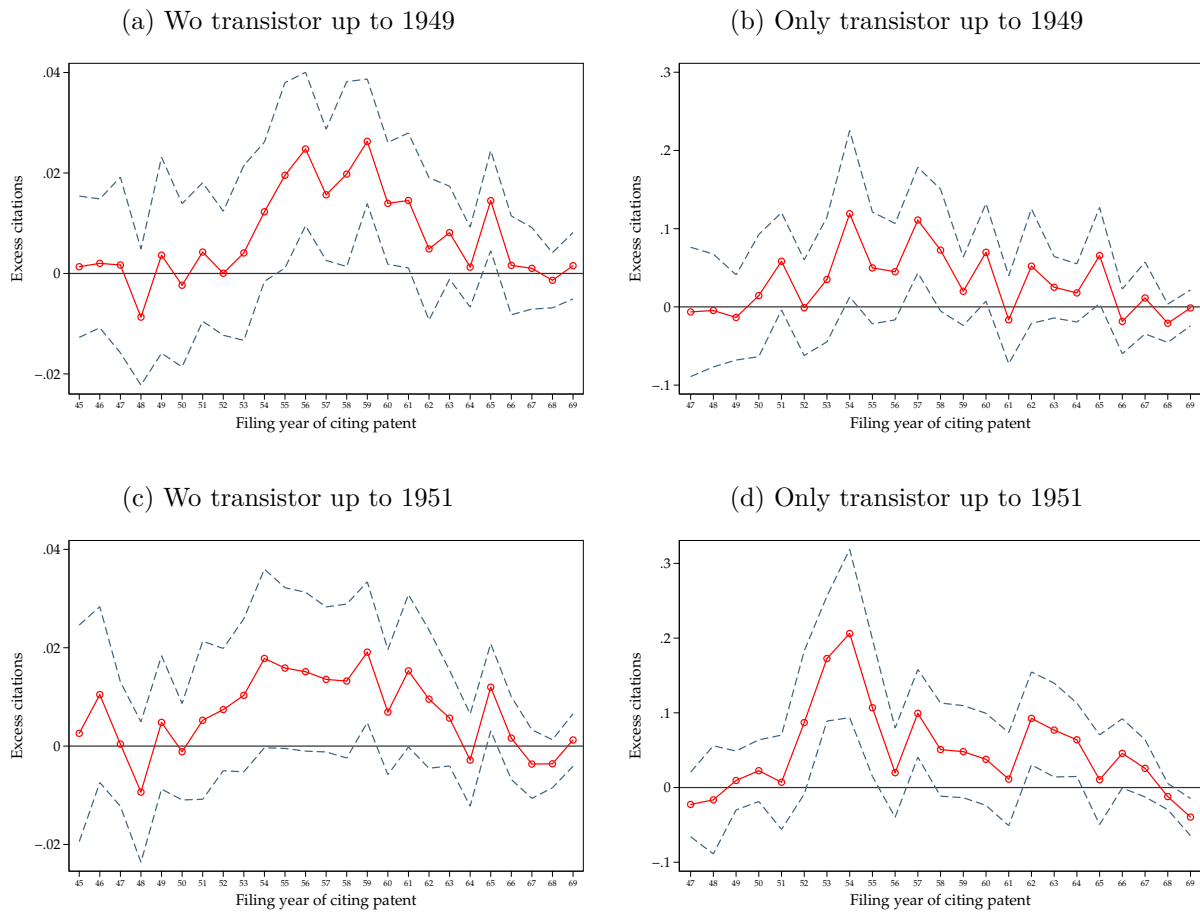
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A Additional Graphs

A.1 Impact without the transistor

Figure 10 shows the annual treatment effects for the subsample of transistor patents and the subsample without transistor patents. Panel 10a and Panel 10b show the subsample of our main regression with patents up to 1949. Panel 10c and Panel 10d include all patents published up to 1951. Patents that were published after the consent decree might already be influenced by the consent decree.

Figure 10: Annual Treatment Effects in the sample with and without transistor patents



A.2 Evidence on the Meeting on March 3, 1954

Figure 11: The meeting on March 3, 1954

Mr. MALETZ. I notice that the memorandum of your meeting with Mr. Brownell is dated March 3, 1954, notwithstanding that the meeting took place on June 27, 1953, is that correct?

Mr. PRICE. Yes. That puzzled me a little, too.

Mr. MALETZ. What was the occasion for your preparing on March 3, 1954 a memorandum of a meeting with the Attorney General which took place on June 27, 1953?

Mr. PRICE. Well, you know that puzzled me a little and I had to speculate about it. The best I can do is somebody wanted me to write out what I remembered about that talk I had had with Brownell at White Sulphur Springs and I sat down and did it.

Mr. MALETZ. Isn't it true that Mr. Dumas had arranged a second meeting with Mr. Brownell for April 1954 and wanted from you a written account of what had transpired at your meeting with Mr. Brownell in White Sulphur Springs in June?

Mr. PRICE. That is the best guess I could make of it but I don't know whether it is right or not.

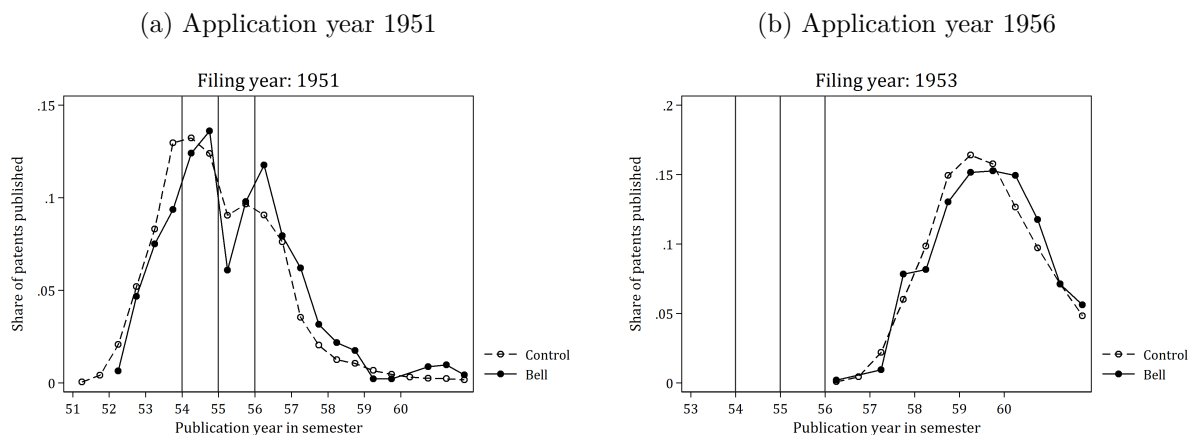
Mr. MALETZ. Do you recall now whether that was the occasion of your preparing this memorandum which has just been read into the record?

Mr. PRICE. I am afraid it is speculation rather than recollection but certainly that is the best explanation I can give and I think that is what happened.

The CHAIRMAN. Well, now we will adjourn and we will meet tomorrow morning at 10 o'clock.

A.3 Additional application years measuring the delay

Figure 12: Hazard to publish by filing year



B Additional Counterfactual Regressions

There were two other groups of companies that were to a lesser degree influenced by the consent decree: foreign companies and companies that already had licensing agreements in place. Foreign companies and companies in US controlled by foreign companies could license for free but did not receive any technical description or assistance from Bell.²⁵ Companies that licensed already before the consent decree from Bell were obviously able to get a license and build on the work of Bell and therefore seem to a lesser degree influenced by compulsory licensing. All companies with a license agreement are listed in the hearing documents (House, 1958, p. 2758). In Table we re-estimate the equation (2) using as dependent the citations from all (column 1), from the exempt B2-companies (column 2), from foreign companies (column 3) and for companies that had a license before the consent decree (column 4). In the last column we use data on all companies that did not have a license from Bell. We do not find an measurable effect for all the different types of non-treated companies and a positive effect for companies which had no license before the consent decree.

²⁵Verbatim in the consent decree “The defendants are each ordered and directed (...) to furnish to any person domiciled in the United States and not controlled by foreign interests (...) technical information relating to equipment (...)” .

Table 5: The effect of compulsory licensing on subsequent citations of unaffected companies

| | (1) Base- line | (2) Exempt companies | (3) Foreign companies | (4) Li- cense | (5) No license |
|---------------------|----------------------|----------------------------|-----------------------------|---------------------|----------------------|
| Bell | 0.26 (0.64) | -0.26 (0.22) | -0.03 (0.09) | 0.03 (0.06) | 0.52 (0.51) |
| Bell x I(54- 60) | 1.83** (0.79) | 0.27 (0.18) | 0.21** (0.10) | 0.12 (0.09) | 1.23* (0.66) |
| Constant | 19.29*** (1.65) | 2.70*** (0.51) | 0.81*** (0.08) | 0.91*** (0.16) | 14.88*** (1.06) |
| Clusters | 259 | 259 | 259 | 259 | 259 |
| Obs. | 716028 | 716028 | 716028 | 716028 | 716028 |

Notes: This table shows the results from a difference-in-difference estimation with years 1949 to 1953 as pre-treatment period and 1954 to 1960 as treatment period. The variable "Bell" is an indicator if a patent is published by a Bell System company before 1949 and therefore treated by the consent decree. As control patents we use all patents which were published in the US matched by publication year, four digit IPC class and the number of citations up to 1949. As dependent we use in the first column all citations by other companies than the filing company, in the second column we use all citations of companies exempt from the consent decree (GE, RCA, Westinghouse & ITT) and in the third column all citations of foreign companies. In the fourth column we use citations of companies which had no licensing agreement with any Bell company prior to the consent decree and in the last column we look at the citation of companies which had a licensing agreement. All coefficients are multiplied by 100 for better readability.