

Technology giants in patent wars: competition, litigations and innovation¹

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Abstract

Between the years 2007 and 2012, there was a dramatic upsurge in the patent infringement cases involving major technology companies, particularly those competing in the smartphone markets. We use quarterly data from 2005 to 2014 to empirically explore the relationship between the patent litigations and the quantity and quality of patent applications filed in the USPTO by 20 major technology companies. In most U.S. patent infringement cases, large technology companies were the defendants or targets of patent litigation. The empirical estimation results do not provide support for the suggestion of prior literature that the fragmented ownership of patents tends to generate patent portfolio races. Our data suggest that patent races among technology giants are rather driven by aggressive patent litigations or an increase in the number of patent infringement litigation cases in the firms' major geographical market area. Our data further provide support for the view that patent portfolio races driven by the threat of legal disputes are not generating more valuable patented inventions. Instead, though the stock of patents filed by large technology companies due to patent wars are larger, their quality tends to be lower measured both by forward citations and patent family size.

JEL codes: D22, L2, O3

Key words: patent wars, litigation, innovation, strategic behavior

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1. Introduction

Patent wars involving aggressive intellectual property disputes and patent litigations generate substantial costs for parties involved in them. In 2012, The American Intellectual Property Law Association estimated that for cases with more than \$25 million at stake, the average cost of U.S. patent litigation was close to \$6 million per party through trial, and even higher for those cases with retrials or appeals. Also, the damages to those that the jury finds to be liable for patent infringement may be massive. Median damages awarded for the U.S. patent holders in the telecommunications industry exceeded \$50 million during the years 1995 – 2012 (PricewaterhouseCoopers, 2013). The damage awards of top cases were much higher. For instance, in 2012, Samsung was ordered to pay over \$1 billion to Apple for its patent infringements.

Given the order of magnitude of damages caused by patent wars for companies involved, it seems evident that they affect firm strategy. Previous studies suggest that a firm may not only react to its own patent infringement lawsuits but also the intellectual property litigation cases of its competitors may have strong impact on the firm's strategic behavior (see, e.g., Galasso, 2014; Paik and Zhu). The economic literature, however, lacks empirical evidence on how patent wars impact on firms' behavior, e.g., concerning their innovative activities. Our study uses quarterly firm-level data over the years 2005 - 2014 from 20 major technology companies that were also among the top United States Patent Office (USPTO) patentees in technology areas covering communications and software to investigate how large technology companies respond by their patenting strategy to i) patent wars involving the company directly, ii) patent wars not involving company but emerging in their geographical market area, and iii) higher fragmentation of patent ownership. We empirically explore whether and to which extent each of these elements contributes to a) the patent portfolio races among technology giants and b) the quality of their patented inventions.

Closest to our study is the empirical investigation of Paik and Zhu (2016) analyzing how 67 smartphone vendors not directly involved in any smartphone patent lawsuit strategically responded to an increased litigation risk. They find that when patent wars intensify, firms tend to shift their business to countries with weaker intellectual property protection. Our study, instead, addresses the question of the impact of patent wars on large technology companies involved in patent litigations. Paik and Zhu (2016) use the number of media articles on smartphone patent lawsuits as the patent war intensity measure. We, instead, use a more precise patent war measure: statistics on patent litigation cases of large technology companies in the United States and all patent litigation cases in the United States both before the outbreak of patent wars and after the peak of the war. We can thus

distinguish the intensity of patent wars at the level of individual firms and at level of geographical market area.

Our data show that the sample large companies were in almost all patent lawsuits the targets of litigation. We do not find support for the suggestion of prior literature that the fragmented ownership of patents would as such generate patent portfolio races among technology giants. Instead, it seems that an increase in the number of patent infringement cases in the companies' major geographical market area clearly relates to the generation of patent races among large technology companies. Though the stock of patents filed by companies due to patent wars are larger than it would be otherwise, the quality of patented innovation tends to be lower measured both by forward citations and patent family size.

The rest of the paper is organized as follows. Section 2 provides a conceptual framework for our empirical exploration. Section 3 introduces the data and illustrates some descriptive findings. Section 4 first motivates the econometric models used in the empirical analysis and then discusses the estimation results. Section 5 concludes.

2. Patents, wars and fragmentation of ownership: conceptual framework

Patent gives its holder a right to exclude others from making, using or selling the invention for a limited period of time, typically 20 years. In various markets - such as those involving communications technologies - innovation is cumulative. In such markets, patents not only provide their holder with a monopoly right for a single invention but also a means to potentially block follow-on innovation. *Patent races* have gained substantial interest in the economic literature shedding light on firms' strategies in markets for technologies (see, e.g., Reinganum, 1982). The central assumptions of the game-theoretic models concerning patent races are that firms compete to be the first inventors of a certain technology, and the winner of the race then obtains monopoly profits from its innovation via patent while the loser receives nothing.

Patents are not, however, only used for securing monopoly rights for commercialized inventions but they are also transferable assets in the intellectual property transactions. Firms license, cross-license and sell patents, and they also file them strategically, building patent portfolios to obtain bargaining power in potential patent disputes. More realistically and more often, in various markets relying on cumulative technologies, firms' innovation races focus rather on *patent portfolio races* - than patent races concerning individual inventions - in which firms aim at accumulating vast patent portfolios

that can be used as assets in intellectual property rights (IPR) disputes and negotiations (see, e.g., Choi and Gerlach, 2016).

Large technology companies, particularly smartphone manufacturers, have been criticized for their massive investments in patent infringement lawsuits and accumulation of patent portfolios to secure patents for litigation. It is argued that in such *patent wars* firms file patent applications rather to make sure that they will not be accused of infringing when they bring their own products to markets than to ensure that copycats do not use their innovation in their own products (Yang, 2014). This is called defensive patenting. The resource-based point of view further suggests that an increase in the number of a firm's patent infringement litigation cases results in a socially wasteful use of corporate resources for IPR competition instead of using resources for developing new products and services (see, e.g., Feldman and Lemley, 2015). A firm's involvement in patent litigation transfers its R&D personnel time use from innovation activities to patent infringement investigation and litigation bureaucracy. Consequently, a firm's participation in patent disputes may reduce the quality of its patented ideas. Such resource constraints may not, however, be as relevant for large companies than for smaller firms.

The underlying forces of patent portfolio races and via what channels patent wars contribute to individual firm's accumulation of patent portfolios lack empirical evidence though. We particularly address here the questions on how technological competition, large companies' involvement in patent infringement litigations and their indirect involvement via intensifying patents wars in relevant technology fields affects large market players' behavior. A firm may not only react to its own patent infringement lawsuits but also the intellectual property litigation cases in its geographical market area may strongly affect the firm's patent strategy (see, e.g., Galasso, 2014; Paik and Zhu). Paik and Zhu (2016) suggest that merely an increase in patent infringement suits among a firm's competitors may affect its strategy even if the firm is not directly involved in patent disputes. They analyze how 67 smartphone vendors not directly involved in any smartphone patent lawsuit strategically respond to an increased litigation risk. They find that when patent wars intensify in a country with strong intellectual property protection, firms tend to shift their business to countries with weaker intellectual property protection.

For firms active in the U.S wireless markets, intensifying wireless patent war in the United States credibly meant a higher risk to get involved in costly and time consuming patent litigation (see Annex 1 for a description of legal framework for patent infringement cases in the United States). The costs of patent litigations for firms involved are substantial. In 2012, The American Intellectual

Property Law Association estimated that “*the average cost (per party) of U.S. patent litigation for cases with more than \$25 million at stake is \$3.9 million through the end of discovery and \$5.9 million through trial. Costs increase significantly if there are appeals or retrials and adjudications in multiple jurisdictions.*” (Teece et al, 2014). Consequently, when there is more aggressive competition over intellectual property rights, it may lead the firm defensively to file more patents to secure its position in the markets for the technology even though the firm would not be directly involved in patent wars. This kind of strategic patenting behavior seems particularly likely in the technology or markets areas in which the firm expects to have a substantial future growth (and thus sales revenue) potential. The empirical question we aim at answering is whether and to what extent does a firm’s involvement in patent litigations vs. the intensity of patent war not directly involving the firm generate patent portfolio races among the major technology companies.

Secondly, we are not only interested in the drivers of patent portfolio races. From the welfare point of view, a relevant question is whether competition in markets for technologies and/or patent wars affects the quality of patented inventions. Prior to litigation, patents are characterized by various uncertainties related to their enforceability and quality (Lemley and Shapiro, 2004). Information concerning patent quality is, however, likely to be asymmetric in such a manner that a patentee can more precisely assess the value of its patented idea than other parties in markets for inventions (i.e. non-practicing entities or NPEs) or competitors. Thus, intensifying competition and patent wars may induce technology giants aware of this information asymmetry to file a large stock of (almost) worthless patents to merely signal their bargaining power in IPR disputes. In other words, patent wars may induce patentees to file applications for patents left unapplied without the pressure generated by patent wars.

Another possibility is that the threat of litigations and/or increased competition provokes large technology giants to invest more in innovating in technology areas important to them in which patent disputes are arising or competition is intensifying to secure their future market share or leading position. Consequently, firms may ingenuously increase their innovation efforts and file applications for more high quality or valuable inventions. This would mean that there is a real increase in innovation. Another possibility is that more intense competition in the technology area and/or more intense patent war enforces large technology companies to file patent applications to certain inventions they had otherwise rather kept secret but now need to strengthen their patent portfolio. This option means that there would be a disclosure of information concerning new technology that may be valuable for a society as whole (i.e., via spillovers) but had no effect on firms’ innovation behavior as such.

The order of magnitude of technological competition in a certain technological field affects a firm's innovation activities and patenting strategy. The prior literature suggests that fragmented ownership of patents related to the higher number of competitors in a certain technological field tend to generate patent portfolio races. The rationale behind this is that when the ownership of patents is distributed among large number of parties, it becomes more difficult for a firm to detect all relevant patents it may potentially infringe in its products. Thus, when there are more potential candidates originating patent disputes, a firm's transaction costs rise (see, e.g., Noel and Schankerman, 2014). Consequently, when the ownership of patents is fragmented, firms tend to defensively build up patent portfolios to forearm against infringement suits (see, e.g., Ziedonis, 2004). The idea is not only to avoid infringement suits when a firm brings its new product to the market, but a firm may also use its patent portfolio to countersue its potential plaintiffs and/or use it in negotiations and settlements involving licensing and cross-licensing of technologies. A massive patent portfolio may also raise the expected litigation costs of practicing entities due to the risk of being countersued. For instance, the empirical study of Ziedonis (2004) using the sample of 67 semiconductor firms indicates that capital intensive firms tend to patent more aggressively when patent rights are more widely distributed.

3. Data and descriptive findings

We focus on large technology companies' patenting activities in the United States as it is among the biggest market areas for smartphones and a single largest software market in the world. Also, as the US patent law enables patentability of software and algorithms, we can cover a broader range of innovation relevant for technology companies in our empirical analysis. Our data comprise information concerning 20 major technology companies (see Figure 1 for list of companies and their patent litigations) active in communications and software technology areas. These companies belong to the categories of firms involved with smartphones and wireless technologies subject to patent wars such as smartphone manufactures, wireless carriers, operating systems designers and app developers.

The sample companies were among the top patentees measured by the number of patent applications filed in the USPTO from time period January 2005 to December 2014 i) in technology areas covering communications and software (i.e., IPC classes H04 and G06) and ii) comprising words "cellular" or "mobile" in the abstract, title or description of their patent application. We selected these IPC classes H04 and G06 for our empirical exploration as the majority of

smartphone related patents are covered by IPC class H04 (Paik and Zhu, 2016) and as IPC classes H04 and most software-related patents are covered by ICP class G06. This is also illustrated by the fact that the share of patents published in IPC classes G06 and H04 of major technology companies' total number of U.S. patents is notable. For instance Google, Amazon and Facebook had – respectively – 65 (26) percent, 70 (29) percent and 74 (41) percent of their U.S. patents published in IPC class G06 (H04) during the sample years.

We use two measures for the value of a firm's patents applied at time t : forward citation counts and patent family size. Forward citations (i.e., later patents citing the subject patent) are a commonly used measure of patent quality as they are associated both to inventions with greater private returns to the inventors as well as to inventions with greater social welfare (Trajtenberg, 1990; Lerner and Seru, 2015). A high forward citation count suggests that patented innovation is likely to be a building block for an important technology area or a new market with substantial growth potential. Also, patent family size that indicates the number of countries in which patent protection is sought is a widely used measure of patent quality (see, e.g., Lanjouw and Shankerman, 2004b). The literature suggests that due to relatively high costs of expanding patent protection (widely) abroad, firms tend to internationally protect only those patentable ideas of which expected value for the firm is sufficient. The literature also provides substantial evidence on the positive relationship between patent family size and firm value (see, e.g., Harhoff et al., 2002).

Our major explanatory variables measure i) the ownership fragmentation of patents published in IPC classes H04 and G06 and ii) the intensity of patent war measured by the aggressiveness of patent rights enforcement. We measure the ownership fragmentation of patents in technology areas covering communications and software (i.e. IPC classes H04 and G06) by the number of patentees with published patents in this technological area during the past quarter. The intensity of patent war is measured by two variables: a) the number of *new* patent infringement cases against a firm during the previous quarter and b) the number of all *new* patent infringement cases in the US during the previous quarter.

The sample patented technologies are among those that have higher than median damages awarded in the U.S. courts. The analysis of PwC (2016) shows that during the years 1996 – 2016, the patent disputes related to telecommunications, computer hardware/electronics and software industries had higher median damages awarded than industries overall. The overall all median damages award for all industries was less than \$6 million. Median damages awarded for patented technology associated

with computer hardware/electronics industry were \$73 million, with telecommunications about \$34 million and with software industry \$37 million.

Table 1. Descriptive statistics

Variable name	Description	Data source	Mean	S.d.	N	Median
Applications	Count of patent applications filed in USPTO in IPC classes H04 and/or G06 by firm <i>i</i> at quarter <i>t</i>	Patent Inspiration – Patent analytics engine www.patentinspiration.com Accessed: 2.12.2016 (based on European Patent Office's worldwide bibliographic database)	279,04	319,87	858	166,00
AvgFwC	Average count of forward citations of patent applications filed in USPTO in IPC classes H04 and/or G06 by firm <i>i</i> at quarter <i>t</i>	Patent Inspiration	6,87	8,50	855	5,24
AvgFamsize	Average family size of patent applications filed in USPTO in IPC classes H04 and/or G06 by firm <i>i</i> at quarter <i>t</i>	Patent Inspiration	4,57	4,84	855	3,87
ln_Ownership_fragmentation	(log) Quarterly count of patentees with published U.S. patents in IPC classes H04 and/or G06 by firm <i>i</i> at quarter <i>t</i>	Patent Inspiration	8,85	0,10	858	8,84
Litigation_direct	Quarterly count of patent infringement lawsuits filed in the U.S. District Courts or U.S. Courts of Appeal in which the company <i>i</i> acts as defendant in the United States.	Justia Dockets - public litigation records from the federal appellate and district courts https://dockets.justia.com/ Accessed: 27.8.2016 & 12.12.2016	4,22	4,81	858	3,00
Litigation_US	Quarterly count of all other patent infringement lawsuits filed in the U.S. District Courts or U.S. Courts of Appeal.	Justia Dockets	986,05	370,16	858	776,00
ln_RD	(log) Annual research and development expenditures of firm <i>i</i> (or similar expenditures). Inflation and exchange rate adjusted (into USD)	Annual reports of the 2005-2015 provided by the sample firms, taken from their investor relations or respective webpages. Accessed: 26.9.2016 & 1.12.2016	7,61	1,08	741	7,69

We use a firm's (log) annual R&D expenditures to control the order of magnitude of financial resources company directs into innovative activities. Pre-sample (i.e., the years 2001 -2004) average patent quality and quantity variables are used as additional explanatory variables in the estimations of random effects model (see Section 4.1 for discussion).

Furthermore, we use 8 dummy variables indicating the firm's primary industrial sector to control for differences in firms' propensity to patent in different sectors. These sectors are covered by 3 digit level SIC (Standard Industrial Classification) codes 357 (i.e., Computer and Office Equipment), 365 (i.e. Household Audio and Video Equipment), 366 (i.e., Communications Equipment), 481 (i.e., Telephone Communications), 573 (i.e. Radio, Television, Consumer Electronics, And Music Stores), 596 (i.e., Non-store Retailers), 737 (i.e., Computer Programming, Data Processing, and other Computer Related Services), and 738 (Miscellaneous Business Services). The dummy variables for each year capture annual variation related to patenting in the sample technological field.

Figure 1. Sample firms' number of patent litigations in the United States, 2005-2015

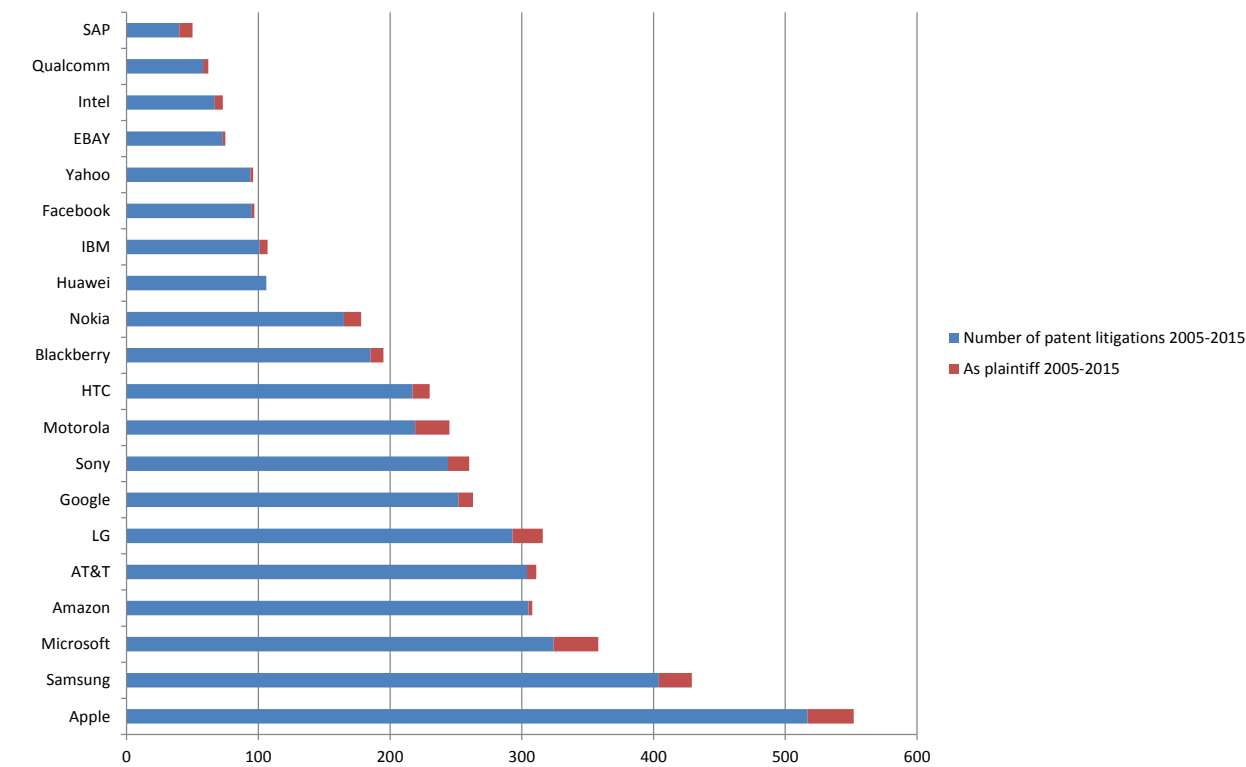


Figure 1 illustrates the total number of U.S. patent litigations of sample companies from 2005 to 2010, and the share of the cases in which the companies have acted as plaintiffs. The data comprises patent case filings from U.S. District Courts and U.S. Courts of Appeals. It shows that these large technology companies have primarily been the targets of patent infringement lawsuits rather than the instigators of legal procedures.

Figure 2 shows that from 2007 to 2012 there was a dramatic upsurge in the patent infringement cases involving the major technology companies. In the majority of these cases, the top technology companies were targets of patent infringement litigation, i.e. acting as the defendants in the court cases.

Figure 2. Total patent litigation encountered and initiated by sample firms in the US, 2005-2015



After 2011, there was a clear drop in the number of patent litigations. This decline in the number of legal battles coincides with the conclusion of one of the most high-profile patent disputes between companies on wireless or smartphone markets. June 2011, Nokia won a long-running legal dispute for intellectual property Apple used in its iPhone⁴. The settlement of the case was done through a licensing agreement that enforced Apple to make one-time payment to Nokia and to become its licensee paying regular royalties. The end of this major legal dispute was also a turning point for various players in the industry as they began choosing licensing and cross-licensing deals over litigation (iRunway analysis, check the reference). For instance, November 2012 HTC and Apple made an announcement of ten-year license agreement and the dismal of all patent litigation between

⁴ See, e.g., <https://www.ft.com/content/9a858e36-9661-11e0-afc5-00144feab49a>.

each other globally.⁵ The empirical observation that a period of fierce, repeated patent litigations increases parties' incentives to cooperatively (rather than by filing lawsuits) settle disputes is also consistent with the game theoretical predictions (see, e.g., Lanjouw and Schankerman, 2004a).

5. Empirical results

5.1 Econometric modeling

The general rule of the USPTO is to publish patent applications promptly after the expiration of 18 months from their earliest application filing date (latest)⁶. Therefore, our data concerning the number of patent applications for the years 2005 - 2014 shouldn't suffer from major truncation problem. Instead, patents forward citations tend to cumulate over a relative long period of time, leading to a tail-off in citations in more recent patents irrespective of their innovativeness.

To tackle the truncation problem in patent citations, we estimate two different models for the quality variables (i.e., forward citations and patent family size). First, we estimated a model in which we used the average number of forward citations (family size) of the patent applications of a firm filed in IPC classes H04 and/or G06 per quarter as the dependent variable. Secondly, we used the method pioneered by Hall et al. (2001), adjusting a firm's quarterly average number of forward citations (family size) of the patent applications dividing it by the quarterly average number of all forward citations in patent applications filed in IPC classes H04 and/or G06, thus scaling patent citation counts according to benchmark.

We estimated the following equations for the patent application count and the quality of patent applications of a firm i filed at time t :

$$PAT_{it} = \alpha_0 + \beta_1 \sum_{t-1}^{t-3} Ownership_fragmentation_{it-1} + \beta_2 \sum_{t-1}^{t-3} Litigation_direct_{it-1} + \beta_3 \sum_{t-1}^{t-3} \sum_j Litigation_US_{it-1} + \beta_4 RD_{iy} + \beta_5 X_{it} \quad (\text{MODEL 1})$$

, where PAT is the number/quality of patent applications filed in the USPTO by firm i at each quarter; $Ownership_fragmentation$, $Litigation_direct$ and $Litigation_US$ are our three major explanatory variables discussed in the previous section. RD_{iy} measures the firm's R&D investment at the given year and X comprises a set of other explanatory variables.

⁵ Source: <http://www.ipwatchdog.com/2012/11/28/the-beginning-of-the-end-for-the-smart-phone-patent-wars/id=30479/>.

⁶ See <https://www.uspto.gov/web/offices/pac/mpep/s1120.html>.

We estimated two different panel count data models for the patents applications: i) negative binomial random effects model and ii) Poisson fixed effects model. Negative binomial model results in consistent parameter estimates only when the strict exogeneity assumption holds. In other words, feedback from patenting at time t to future values of R&D expenditures or other explanatory variables is not allowed. Given that such feedback effects in our model are possible as patents may not only induce future R&D expenditures but they may also be related to the number of patent infringement lawsuits a firm enters, we relax this strict exogeneity assumption by applying the linear feedback model of Blundell et al. (2002). Following their approach, we include the log of a firm's patents from a pre-sample period as an additional dependent count variable to approximate the fixed effects. For the quality variables (i.e., forward citations and patent family size) we estimated the random effects model.

5.2 Estimation results

We first estimated Model 1 for the quarterly counts of patents the sample firms filed in the USPTO in IPC classes H04 and G06 during the years 2005 – 2014. The estimated random effects negative binomial model and Poisson fixed effect model provide very similar results. The estimation results clearly indicate that the major technology companies tend to file more patent applications after encountering a higher number of patent infringement cases in the major geographical market area. Interestingly, general intensification of patent wars in the United States explains a subsequent increase in a firm's patent applications better than an increasing number of patent infringement litigation targeted towards the firm itself. Instead, more fragmented ownership of recently published patents does not relate strongly to the firms' patenting behavior.

Our estimation results do not thus provide support for the previous studies suggesting that fragmented ownership of patents generates patent portfolio races. The RD variable gets a positive and statistically significant coefficient as expected: higher R&D investments relate positively to the number of firms' patent applications filed in the USPTO.

Table 2. The estimation results for patent count models

Patent application count

	Negbin RE Applications	Poisson FE Applications
L.ln_Ownership_fragmentation	-0.383 (-1.20)	-0.430 (-1.17)
L.Litigation_direct	0.00240 (0.71)	-0.00187 (-0.38)
L.Litigation_US	0.000360*** (2.82)	0.000522*** (5.06)
ln_RD	0.589*** (17.00)	0.618*** (5.54)
PresampleAvg_Appl	-0.000656* (-1.94)	
_cons	0.664 (0.24)	
ln_r	0.353 (1.11)	
ln_s	3.242*** (8.13)	
Time dummies	Yes	Yes
SIC dummies	Yes	No
Company fixed effects	No	Yes
Log pseudolikelihood	-4152.449	-1.60e+04
Chi2	820***	421***
Number of obs.	722	722
Number of firms	20	20

z statistics in parentheses

I) Random effects negative binomial model

II) Fixed effects Poisson model

* p<0.1, ** p<0.05, *** p<0.01

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We further investigated the relationship between patent litigation cases and patent ownership fragmentation and the number of forward citations and family size of sample firms' patents. The relationship between the number of patent infringement cases in the US and the family size of their subsequently filed patent applications is negative and statistically significant. Our data thus suggest that large technology companies respond to an increase in patent litigation cases by filing patent

applications in fewer countries. The variable LITIGATION_US is also negatively and statistically related to the forward citation variable. These two empirical findings together, indeed, hint that patent wars reduce the quality of patented innovation. In other words, during the patent wars firms tend to seek patent protection for less valuable inventions than otherwise.

Table 3. The estimation results of Random Effects models for patent family size

Average Family size per patent		
	Random effects Avg Famsize	Random effects Adj avg Famsize
L.ln_Ownership_fragmentation	7.201*** (2.64)	1.897*** (3.25)
L.Litigation_direct	-0.000248 (-0.00)	0.000456 (0.03)
L.Litigation_US	-0.000958*** (-2.60)	-0.000170** (-2.02)
ln_RD	-0.490 (-1.58)	-0.101 (-1.59)
PresampleAvg_Famsize	0.834*** (7.74)	
Adj_PresampAvg_Famsize		0.779*** (8.47)
_cons	-56.60** (-2.43)	-15.17*** (-3.04)
Time dummies	Yes	Yes
SIC dummies	Yes	Yes
R2 overall	0.157	0.189
Number of obs.	722.000	722.000
Number of firms	20	20

t statistics in parentheses

I) Random effects with with average family size per patent.

II) Random effects with with average family size per patent in relation to total average in IPC classes H04&G06.

Random effects models with standard industry classification (SIC) dummies provide similar results as models with company fixed effects.

* p<0.1, ** p<0.05, *** p<0.01

Table 4. The estimation results of Random Effect models for forward citations

Average count of forward citations per patent		
	Random effects Avg FwC	Random effects Adj avg FwC
L.ln_Ownership_fragmentation	-4.754*** (-2.87)	0.321 (0.74)
L.Litigation_direct	-0.0804 (-0.76)	0.000462 (0.04)
L.Litigation_US	-0.00214*** (-3.12)	-0.000366** (-2.35)
ln_RD	-1.160 (-1.40)	-0.163 (-1.11)
PresampleAvg_FwC	0.0982 (1.58)	
Adj_PresampAvg_FwC		0.425*** (3.30)
_cons	65.22*** (3.11)	-0.293 (-0.06)
Time dummies	Yes	Yes
SIC dummies	Yes	Yes
R2 overall	0.696	0.338
Number of obs.	722.000	722.000
Number of firms	20	20

t statistics in parentheses

I) Random effects with average forward citations per patent.

II) Random effects with average forward citations

in relation to total average in IPC classes H04&G06.

Random effects models with standard industry classification (SIC) dummies provide similar results as models with company fixed effects.

* p<0.1, ** p<0.05, *** p<0.01

More fragmented patent ownership that also reflects more intense technological competition (measured the number of patentees) is positively and statistically significantly related to patent family size. This may either mean that more intense competition with higher revenue expectations induces large technology companies to invest more resources in doing R&D in the technology field in question which is materialized as higher quality patented inventions, or that they strategically respond to tougher competition by expanding their patent protection to broader geographical area. The estimated model for the absolute values of (average) forward citations suggests that the OWNERSHIP_FRAGMENTATION variable is negatively and statistically significantly related to forward citations providing support for the latter interpretation. However, when the average forward citations of a firm's quarterly patents are divided by the average forward citations of patents in the same IPC classes, the estimated coefficient of the variable OWNERSHIP_FRAGMENTATION does not explain statistically significantly variation in the dependent variable. It seems thus that more intense competition does not materialize as higher quality patented inventions. Instead, we

find some weak evidence that large technology companies tend to apply protection for relatively less valuable patents.

Table 5. The estimation results of the fixed effects Poisson model for patents with no foreign filings and with no citations

	Count of patents with with no foreign filings	Count of patents with no citations
L.ln_Ownership_fragmentation	-1.896*** (-3.86)	-0.878* (-1.76)
L.Litigation_direct	0.00646 (0.87)	-0.00767 (-1.28)
L.Litigation_US	0.000891*** (3.18)	0.000324*** (2.89)
ln_RD	0.878*** (4.21)	0.727*** (6.50)
All_Avg_Famsize	-0.0343 (-0.45)	
All_Avg_FwC		-0.447*** (-5.11)
Time dummies	Yes	Yes
Company fixed effects	Yes	Yes
Log pseudolikelihood	-9292.854	-6130.686
Chi2	734***	4623***
Number of obs.	722	722
Number of firms	20	20

z statistics in parentheses
Fixed effects Poisson model
* p<0.1, ** p<0.05, *** p<0.01

Inspired by our empirical finding that patent wars are negatively related to patent quality, we further explored whether there is a relationship between patents wars and firms filing patent applications that are worthless or at least of very low quality measured by forward citations and family size. We estimated the fixed effects Poisson model for the count of a firm's quarterly patents with a) no citations and b) no foreign filings. The estimation results show that the variable LITIGATION_US is positively and statistically significantly related to both count variables (see Table 5). In other words, when the patent war intensifies, large technology companies tend to file more worthless or very low quality patents.

6. Conclusions

Our data suggest that high fragmentation of patent ownership does not form a sufficient threat of future patent infringement litigations to trigger patent portfolio races for large technology companies. The underlying mechanisms of patent portfolio races rather relate to the intensity of patent infringement cases emerging in the firms' major geographical market area. Our data show that in almost all U.S. patent infringement cases, the sampled large technology companies act as the defendants or targets of patent litigations. It seems that when the IPR battle gets more aggressive in the U.S. markets such that there is more patent infringement lawsuits, technology giants respond defensively by filing more patent applications in the USPTO to prepare for potential lawsuits.

Our estimation results further indicate that patent portfolio races driven by the threat of legal disputes are not generating more valuable patented inventions among technology giants. Instead, though the stock of patents filed by large technology companies due to patent wars are clearly larger than otherwise, the quality of their subsequently filed patent applications tends to be lower measured both by forward citations and patent family size. Given that the value of many inventions is highly uncertain at the time the patent application is filed and may not be determined prior to litigation, a company's massive patent portfolio may credibly signal its bargaining power and also its resources to countersue a potential plaintiff.

Overall, our empirical findings hint that patent wars are socially wasteful and that intensified competition over IPR related to them do not promote valuable innovation. Patent wars generate substantial burden for the legal system and waste firms' resources. Furthermore, they strain patent offices with the massive number of patent applications for inventions with little or no value at all other than (as part of a company's portfolio) to signal the patentee's bargaining power in potential future patent disputes. Disappointingly, our study indicates that the contemporary patent protection system suffers from a major system failure that is highly expensive for a society.

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Annex 1. Legal framework for patent infringement cases in the United States

For patent litigation in the United States, there are two principal sources of law: i) Federal laws enacted by the US congress and based on the US Constitution and ii) Federal courts with their judicial precedents. There are no specialized patent courts in the United States. Federal courts have exclusive jurisdiction over patent infringement actions, which can be filed in any federal district court that has personal jurisdiction over the defendant. The level of expertise in patent matters varies widely judge- and court-wise and thus the duration of the patent lawsuits in district courts is subject to high variance. Two years of processing is not uncommon, yet, so called “rocket docket”, which are known for fast processing times, also exist. The US federal district courts are bound by the decisions of the Court of Appeals for the Federal Circuit (CAFC) and the US Supreme Court, but not by the decisions of other federal district courts or judgments of foreign courts, although they can consider their decisions on similar issues.⁷

Basically the patent cases handled by the district courts can be divided into the questions on patent infringement and patent validity⁸. Patent infringement cases considered in this study involve the acts of making, using, selling, or offering to sell a patented invention, or importing into the United States a product covered by a claim of a patent without the permission of the patent owner (USPTO, 2016). This is assessed by comparing the allegedly infringing product or process to the asserted patent claims. Literal infringement occurs when the accused product or process includes every element of an asserted claim. If a claim element is literally absent, but only minor differences exist between the missing claim element and the corresponding element of the accused product or process, the accused product or process may still infringe under the doctrine of equivalents.

In general, only the patent holder (or co-owners together) can sue for infringement. An exclusive licensee can sue for patent infringement only jointly with the patent owner unless it has been granted *all substantial rights* under the patent. The enforcement options in civil proceedings include a declaratory judgment, a monetary judgment and/or an injunction. There is no criminal liability. In addition to the federal courts, also The US international Trade Commission (USITC) addresses the infringement of patents. If infringing goods are imported to US, then the patent owner may file a complaint with the USITC. If the case is valid, USITC can order exclusion that directs

⁷ Our overview of patent litigation in the United States is, by and large, based on the webpage of Practical Law, Thomson Reuters Legal Solution. <http://us.practicallaw.com/6-623-0657?q=&qp=&qo=&qe=> Accessed 10.2.2017

⁸ A patent can be invalidated due to a number of reasons such as: non-usefulness or non-patent-eligibility of the subject matter, non-novelty or non-obviousness of the invention, double patenting or indefinite claims.

customs to stop infringing products entering the US. However, should monetary awards be wanted, the patentee must file a related litigation in the federal district courts.

Patent infringement case appeals are handled by the Court of Appeals for the Federal Circuit (CAFC), which has exclusive appellate jurisdiction over patent appeals. Generally, appeals can only be taken when patent infringement has been determined by the court. The US Supreme Court hears appeals from the CAFC on a discretionary basis, yet while previously the Supreme Court would rarely touch patent matters, the trend has somewhat shifted and the Supreme Court has become more active in the last decade.

According 35 U.S.C. §284, a court may award adequate damages in patents cases, but Section 284 provides no guidance on what constitutes “adequate” damage or how this damage is determined. Lost profits and reasonable royalties are the major types of damages awarded in the U.S. patent cases. Lost profits mean amount money lost by the patent owner due to patent infringement. Lost profits from sales that patent owner missed due to infringement are the most commonly used measure for lost profits damages. The idea is to compensate the patent owner the monopoly profits it would have obtained from its patented invention without the infringement (Yang, 2014). Reasonable royalty is the minimum level of compensation due to the patent holder from an infringer. It is calculated by using established royalty, and when it’s not available, a reasonable royalty are estimated by the court based on the evidence concerning patent value (Yang, 2014).

The annual Patent Litigation Studies of PricewaterhouseCoopers (PwC) provide insights for the trends in patent litigations taking place in the Unites States. According to PwC (2016), the number of patent litigation cases has increased during the years 1996 – 2016. Also, during the same time period, the median time the parties have to wait for the trial to begin has prolonged from approximately two years to about two and a half years. The report of PwC (2014) shows that during the years 2005- 009 (2010-2013) reasonable royalties was used as a measure of damage in 80 (81) percent of cases in which the jury calculated awards for patent infringement. The share of lost profit awards increased from 29 percent to 37 percent from the time period 2005-2009 to 2010-2013. Lost profits damages are less commonly used than reasonable royalties due to various reasons. These include non-practicing entities ineligible for lost profits damages as plaintiffs, difficulties in calculating loss profits and unwillingness of patent holders to disclose confidential information concerning their costs and profits need for the lost profit calculations (PwC, 2014).