Patent Policy and American Innovation After eBay:

An Empirical Examination

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Abstract: The 2006 Supreme Court ruling in *eBay vs. MercExchange* removed the presumption of injunctive relief from infringement and marked a sea change in U.S. patent policy. Subsequent legal and policy changes reduced the costs of challenging patent validity and narrowed the scope of patentable subject matter. Proponents of these changes argue that they have made the U.S. patent system more equitable, particularly for sectors such as information technology, where patent ownership is fragmented and innovation highly cumulative. Opponents suggest the same reforms have weakened intellectual property rights and curtailed innovation. After reviewing the legal background and relevant economic theory, we examine patenting, R&D spending, venture capital investment and productivity growth in the wake of the *eBay* decision. Overall, we find no evidence that changes in patent policy have harmed the American innovation system.

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JEL Codes: O3, O34, O31.

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The 2006 Supreme Court ruling in *eBay vs. MercExchange* marked a sea change in U.S. patent policy. Prior to that decision, if a court found that a patent was valid and infringed, its owner could almost always obtain injunctive relief. In *eBay*, however, the court adopted a four-part test to determine whether the appropriate remedy is injunctive relief or monetary damages. Five years after *eBay*, the America Invents Act (AIA) created the Inter Partes Review procedure, which defendants can use to challenge a patent's validity before a specialized USPTO tribunal, as opposed to a district court. And in the years immediately following passage of the AIA, several Supreme Court decisions narrowed the scope of patent eligible subject matter.

Some patent-system participants argue that post-*eBay* U.S. patent policy has harmed American innovative performance. For example, one former judge claims "eBay has crimped patent rights and thereby diminished investment incentives in the United States. The result: reduced research and development, less job creation, lower economic growth, and diminished American global competitiveness."[1] On the other hand, prior to the *eBay* decision many observers were sounding alarms about a flood of low quality patents, particularly in computer-related fields, where the threat of an injunction could provide patent holders with tremendous leverage even if their claimed invention was just a small part of a much larger system.[2]

Our paper makes two contributions to this debate. First, after providing some legal background on the decision, we summarize relevant economic theories in order to help clarify the main arguments. Basic economic logic suggests that replacing automatic injunctions with monetary damages will reduce incentives to innovate whenever injunctions yield more profit to the inventor. However, in models where innovation is intrinsically cumulative and complementary (Scotchmer, 1991), or property rights are poorly defined (Calabresi and Melamed, 1972; Kaplow and Shavell, 1996), automatic injunctions create a holdup threat for downstream

[1] The quote is from Michel and Dowd (2017). For similar arguments, see for example Jones (2007), Chao (2008) and Sidak (2017).
[2] See Jaffe and Lerner (2004) inter alia.

innovators, and the effects of a policy-change from automatic injunctions to discretionary damages become less clear. Thus, although economic theory does not provide definitive predictions, our discussion highlights how recent models of innovation reject the simplified view that removing the automatic injunction necessarily leads to less innovation.

The paper's second main contribution is to provide novel empirical evidence regarding the link between post-eBay patent policy and American innovation. In particular, we examined data on patenting, research and development (R&D), venture capital investment and productivity growth for evidence of an "eBay effect." Because it is difficult to measure the causal impact of the eBay decision without a compelling natural experiment, our more modest objective is to check for any indication that post-eBay patent-policy has produced a measurable decline in American innovative performance, consistent with the strong claims made by some opponents of the eBay decision. In general, we find no evidence of a decline in American innovation – whether measured as patents, R&D, venture capital or productivity growth – relative to the pre-eBay baseline.

To be clear, we do not claim to measure the causal impact of eBay. In fact, our estimates may partially capture the effect of other changes in economic conditions contemporaneous and correlated to eBay. However, failing to find any evidence of a large contraction in innovation activity across so many different measures contradicts those claiming that the post-eBay patent policy caused major harms to American Innovation. In other words, even allowing for unobserved factors, the absence of any change in innovation implies that patent policy and any other contemporaneous shocks have more-or-less cancelled each other out. Given some objective benefits of eBay on patent enforcement, this result arguably shifts the burden of proof back to those claiming that eBay and post-eBay patent policy are harming American innovation to explain what factors are producing an equal and opposite effect.[3]

Our baseline analysis examines changes in innovation and patent policy over time, before and after the eBay decision. We also make some efforts to isolate the impact of the policy by exploiting the assumption that the impacts of eBay (and later patent policy shifts) were largest in the information and communication technology sector. Specifically, we estimate difference-in-difference models that compare changes in computer-related innovation before and after eBay to changes in "control group" innovation before and after eBay, where the control group consists of firms in either life sciences or other non-health non-ICT manufacturing industries. Although these regressions are vulnerable to the same omitted variable critique we just described, the difference-in-difference results also provide no evidence that *eBay* had any impact on aggregate innovation, consistent with our other analyses of patenting VC-investment, and productivity growth.

We interpret these results as evidence that the *aggregate* impact of post-eBay U.S. patent policy on American innovation has been modest. In particular, there is essentially no evidence that legal changes led to a dramatic contraction in innovation activity, as some experts have argued. This finding is relevant to ongoing policy debates. For example, in 2017 legislation was introduced in the U.S. Congress that would effectively overturn eBay by instructing courts to presume that injunctions are necessary to prevent patent holders from suffering "irreparable injury."[4] In Europe, various parties are advocating for the new Unified Patent Court

[3] Throughout the paper, we focus on omitted variables that stimulate innovation and would therefore offset a negative "eBay effect." However, it is also possible that unobserved factors have created increasing headwinds for innovation over the last decade (e.g. Bloom, Jones, Van Reenen and Webb 2018). Under that assumption, our estimates would imply that eBay and post-eBay patent policy had a *positive* impact on aggregate innovation.

[4] See Section 106 of the STRONGER Patents Act of 2017 (S.1390, 115th U.S. Congress). available at https://www.congress.gov/bill/115th-congress/senate-bill/1390

to embrace an eBay-like "principle of proportionality" instead of treating injunctions as the default remedy for patent infringement.[5]

Although we conclude that eBay had (at most) a modest impact on aggregate innovation, our analyses do not rule out the possibility that patent policy changes affected particular industries or firms. Other studies using natural experiments and focusing on specific margins of change may help to better characterize the implications of eBay and post-eBay patent policy. For instance, Mezzanotti (2017) finds that eBay had a positive impact on innovation for companies that were more exposed to patent litigation in the prior period. Overall, we think that our paper represents an important complement to that type of analysis, since it adds new empirical evidence and provides a general theoretical framework that may be useful to think about these issues from a policy perspective.

The remainder of the paper is structured as follows: Section I provides legal and economic background related to the eBay decision, Section II discusses economic theories about the link between patents and innovation, Section III presents our empirical analysis and Section IV concludes.

I. Injunctions, eBay, and the Evolution of US Patent Policy

In patent law, an injunction is a legal remedy that compels a defendant to stop making, using or selling any item that infringes a patent. Before 2006, courts routinely granted injunctions when a patent was found to be valid and infringed. The near-automatic availability of injunctions originated with the 1908 U.S. Supreme Court decision in *Continental Paper Bag vs. Eastern Paper Bag*, which drew

[5] For example, the IP2Innovate coalition is lobbying the EU on behalf of this position. Examples of its advocacy can be found at http://ip2innovate.eu/advocacy/.

a clear analogy between patents and real property.[6] For the next 98 years, there were few exceptions to the general rule that infringement led to injunctive relief.

By the early 2000s, however, many observers viewed "automatic" injunctions as contributing to a broader crisis within the U.S. patent system (e.g. Lerner and Jaffe, 2004; Bessen and Meurer 2008; Boldrin and Levine 2008; Burk and Lemley 2009). During the 1980s, US utility patent applications began to steadily increase in response to a variety of factors, including the creation of a unified appellate court, expansion in the scope of patentable subject matter, and a broad shift towards more applied Research and Development (Kortum and Lerner 1999). The increase in patents naturally led to an increase in litigation, and by the late 1990s Bessen and Meurer (2015) estimate that US public companies had lost about $16 billion in market value – or roughly 10 percent of annual private R&D investment – on patent lawsuits. Moreover, as litigation activity increased, specialized patent assertion entities, known colloquially as "patent trolls," began to play an increasingly important role in enforcement (Cohen et al., 2014).

In this context, some observers began to suggest that nearly-automatic injunctions were encouraging frivolous patent litigation by offering patent holders the prospect of outsized rewards for patents of limited value. The basic economics of this argument are explained in Shapiro (2010). With the USPTO issuing over 100,000 new utility patents each year, the patent landscape in some technical fields, such as software and semiconductors, became very crowded. Given the large number of patents, their often vaguely worded claims, and pendency lags (i.e., the amount of time a patent application spends in examination) stretching to 4 or 5 years, it become common for companies operating in these fields to unknowingly infringe patents covering relatively minor inventions. When it is costly to undo such infringement after the fact, injunctions provide a patent holder with considerable

[6] Perhaps the most quoted part of the *Continental Paper Bag* decision states that, "exclusion may be said to have been of the very essence of the right conferred by the patent, as it is the privilege of any owner of property to use or not use it, without question of motive."

bargaining leverage, because the alternative to a costly design-around is to abandon an entire product or line of business. Thus, the threat of injunction can lead to settlements that far exceed what an infringer would have paid in up-front negotiations. The divergence of prices under pre- and post-infringement negotiation is a variant of the hold-up problem originally described by Williamson (1984).

Three features of the patent system can exacerbate the hold-up problem. First, complementarity among the various technologies used in a product will increase the expected costs of an injunction, making hold-up more profitable (Lemley and Shapiro, 2007). Second, the probabilistic nature of patents, whose scope and validity are unknown before being tested in court, allow strategic plaintiffs to hold-up an alleged infringer even with relatively weak patents (Lemley and Shapiro, 2005). And third, prior to changes in the Federal Rules of Civil Procedure made in 2016, it was relatively easy for a patent holder to file suit and impose potentially large discovery costs on an alleged infringer, particularly if the patentee was a non-practicing entity facing no symmetric threat. Indeed, Chien and Lemley (2012) reports that patent assertion entities were extensively leveraging the threat of injunction during settlement negotiations before 2006.

Many of these concerns about injunctions and patent hold-up crystallized in a 2001 lawsuit filed by the patent-assertion entity NTP against Research in Motion (RIM) – the provider of the Blackberry system. In that case, NTP alleged that RIM infringed on several of its patents covering wireless communication technologies. The trial court ruled that the patents were valid and infringed, ordered RIM to pay $54 million in past damages, and issued a permanent injunction, which was not immediately implemented pending the appeal. Because the injunction threatened the entire Blackberry system, RIM was forced into an intense out-of-court negotiation with NTP. In 2005 the two companies reached a settlement wherein RIM agreed to pay NTP $612.5 million plus legal costs – an amount representing almost half of RIM's annual revenue at the time.

The RIM vs. NTP case encapsulates several controversial aspects of the pre-2006 system. First, the patents infringed by RIM covered only a small fraction of the technologies necessary to produce the Blackberry system. However, because of the strong complementarity between the components in that system, the negative effects of an injunction affected the entire business, enabling NTP to obtain a settlement that likely exceeded the intrinsic value of the underlying technology. Second, the pending injunction forced RIM to settle despite concerns about the validity of NTP's claims. Indeed, after a lengthy review, several claims in the NTP patents were ultimately found to be invalid by the Board of Patent Appeals and Interferences.

The eBay Decision

The eBay case occurred around the same time as the dispute between RIM and NTP. In 2001, MercExchange sued the online auctioneer eBay for infringing its patents, including one that covered the popular "Buy It Now" function on eBay's website. In 2003, the Virginia Circuit Court awarded $30 million in damages, but denied MercExchange's request for a permanent injunction. On appeal, the Federal Circuit reversed the latter decision, arguing that injunction should be considered automatic "absent exceptional circumstances." eBay petitioned the U.S. Supreme Court, which agreed to hear the case in 2006.

The Supreme Court's decision in *eBay Inc. vs. MercExchange, LLC* (U.S.C. 2006) overturned the 98 year-old presumption that the owner of a valid and infringed patent was entitled to a permanent injunction. According to the Court, the application of a "near-mandatory" rule is contrary to the principles of the Patent Act, which instead requires the application of equitable principles in determining the remedy in a patent case. Specifically, the Court highlights how these equity considerations should be examined within the context of a four-factor test that is usually employed to evaluate the award of injunctive relief in other contexts. In particular, following Beckerman-Rodau (2007), "(…) a patent owner can only obtain a permanent injunction as a remedy for infringement if he or she can demonstrate: (1) that the patent owner suffered an irreparable injury due to the infringement; (2) that remedies available at law, such as monetary damages, are inadequate to compensate for that irreparable injury; (3) that, considering the balance of hardships between the patent owner and the infringer, a remedy in equity is warranted; and (4) that the public interest would not be disserved by a permanent injunction."

Although courts considered public interest when granting injunctions before eBay, the other three factors gave courts new flexibility in determining the appropriate remedy. In practice, there are two dimensions to consider. First, the tests for irreparable harm and inadequate monetary damages imply that the court will first search for reasonable royalties that can fully compensate the plaintiffs for any harm caused by the infringing activity.[7] Several factors can influence the existence and size of a reasonable royalty. Many experts immediately noted that under this part of the analysis, injunctions should be more likely when litigants are direct competitors. On the other hand, the presence of pre-existing license agreements between the plaintiff and a third party can provide evidence that monetary compensation provides a sufficient remedy. These factors tend to weigh against awarding injunctions to PAEs, who are often active licensors that do not compete in downstream product markets (Tang, 2006).

The second dimension of the post-*eBay* analysis – the balance of hardship test – requires courts to consider the consequences of an injunction for both plaintiff and defendant. This factor provides a "backdoor" for introducing firm- or case-specific factors. For example, the balance of hardships may be relevant for cases where the infringed patent represents a minor component of a much larger product or system.

[7] As pointed out by Shapiro (2016), the first two factors can be generally considered jointly, because of the difficulty (or impossibility) to distinguish an irreparable harm from a situation where monetary damages would be inadequate.

In the *eBay* decision, the Supreme Court noted that no categorical application of the four-factor test should be considered correct, thereby over-ruling both the District Court and the Federal Circuit. While the District Court presented its decision as an application of the four-factor test, its interpretation was erroneous because it assumed that plaintiffs that do not practice their patent commercially should automatically fail (Myers, 2007). At the same time, the Federal Circuit was wrong in claiming that injunction should always be granted, outside exceptional circumstances. Ultimately, the Justices made clear, the four-factor test for granting patent injunctions should be applied in a case-by-case manner.

Effects on Patent Enforcement

Between 2005 and 2015, *eBay vs. MercExchange* was the second-most cited Supreme Court patent case, and legal experts overwhelmingly agree that it had a substantial impact on legal practice (e.g. Bessen and Meuer, 2008).[8] It remains difficult, however, to quantify the effects of the eBbay decision given the underlying selection problem: parties change their litigation strategies in response to expected outcomes, including the probability of obtaining injunctive relief. There is nevertheless an empirical literature that describes how outcomes in patent cases changed before and after the eBay decision.

In one influential paper, Chien et al. (2012) find that *conditional on filing a motion to enjoin*, the probability of receiving a permanent injunction in a patent case fell from nearly 100 percent before eBay to around 75 percent afterwards. Grumbles et al. (2009) find similar estimates in an earlier study. These findings suggest that although injunctions remain available, the eBay decision did produce a sizable decline in plaintiffs' rate of obtaining them. Moreover, if some patent plaintiffs are less likely to seek injunctions following *eBay*, the 25 percent drop measured by Chien et al. (2012) represents a lower bound on the actual impact of the decision.

[8] See PatentlyO blog on March 11, 2015, which can be accessed to this link: https://patentlyo.com/patent/2015/03/supreme-court-cases.html

Consistent with this argument, Gupta and Kesan (2015) find that the probability of a patent plaintiff seeking either a preliminary or permanent injunction falls from 7.7 percent before eBay to 4.3 percent under the new standard.[9]

Seaman (2016) analyzes 218 U.S. District Court decisions after eBay, focusing on heterogeneity in the rate at which different types of plaintiffs receive a permanent injunction. He finds that a motion for permanent injunction succeeds in 86% of cases where the two parties are competitors, compared to only 21% when they are not, consistent with the idea that it is easier to show irreparable harm when there is competition. In cases with a PAE plaintiff, the probability of a permanent injunction was 16 percent (4 out of 25 motions succeeded). Finally, Seaman finds that 93 percent of the motions for a permanent injunction filed by a plaintiff in the pharmaceutical or biotechnology sector were successful (27 of 29 cases), compared to only 53 percent (19 or 26 cases) for software patent plaintiffs. This last result is relevant to the empirical analysis below, where we compare pre and post-eBay innovation outcomes in the information technology and life-science sectors, under the maintained assumption that the decision had a larger impact on IT patent holders.[10]

Post-eBay U.S. Patent Policy

In the wake of the eBay decision, several legislative and judicial changes to U.S. patent policy lowered the costs of challenging patent validity and narrowed the scope of patentable subject matter. Although a full account of post-eBay U.S. policy lies beyond the scope of this paper, we briefly mention a few of the most significant changes.

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[9] This is based on calculations using figures reported in their Table 1 of 1,275 motions out of 16,617 pre-eBay cases, and 908 motions out of 22,979 post-eBay cases. These figures may overstate the drop in injunction-seeking to some extent because a change in joinder rules (i.e. rules for combining related lawsuits) led to a surge in the number of cases after 2011.

[10] We note here that Seaman also found a low success rate for Medical Devices (65 percent, or 22 of 34 cases). However, the "pharmaceutical" control group we construct below will focus on the chemical sector, whereas medical device innovations are typically in the mechanical areas.

The America Invents Act of 2011 created of a new set of administrative procedures for challenging patent validity. One of these procedures is the *Inter Partes Review* process, in which a specialized administrative judge appointed by the USPTO conducts an expedited trial focusing on validity challenges under Section 102 (novelty) or Section 103 (non-obviousness) of the patent act. The first IPR proceeding was held in 2012, and its use grew rapidly, with the USPTO conducting 512 such proceedings in 2013 and 1,700 in 2015. While the overall impact of IPRs remains hotly debated (e.g. Dreyfuss 2015), it seems clear that the proceeding is popular among defendants in patent lawsuits, in part because it provides a low-cost method for adjudicating patent validity (relative to a full trial that would also decide questions of infringement and damages).

On the judicial front, a series of three Supreme Court cases decided between 2012 and 2014 reduced the scope of patentable subject matter. The first of these cases was *Mayo vs. Prometheus* (2012), which held that “laws of nature” – in this case, a threshold for clinical efficacy of a drug – are not patent eligible. The second case was *Association of Molecular Pathology vs. Myriad* Genetics (2013), which held that isolated DNA sequences are not eligible because they are “products of nature” (though synthetic complementary DNA sequences are patent eligible). The final eligibility decision came in *Alice Corp vs. CLS Bank International* (2014), where the Supreme Court held that an “abstract idea” – in this case, an electronic escrow service for clearing financial transactions – is not patent eligible merely because it is implemented on a computer.

Some observers see the eBay decision, Inter Partes Review procedures, and limitations on patentability as part of a sharp turn in U.S. patent policy. For example, one prominent patent attorney describes the historical evolution of patent law in terms of a pendulum that oscillates around a balance of interests:

> "Generally the pendulum swinging takes a decade, or a generation. Now over the last few years things have really started to unravel and the pendulum is swinging very wildly, and quickly, in a decidedly anti-patent direction. I think we are at about the furthest point where the pendulum can swing without the little ball at the end flying clear off."[11]

The natural implication of this argument is that these policy shifts have been bad for U.S. innovation. Indeed, Michel and Dowd (2017) claim that the eBay decision has harmed Research and Development, job creation and economic growth, and in a recent speech the head of the USPTO has stated that, "our law surrounding patentable subject matter has created a more unpredictable landscape that is hurting innovation and, consequently, investment and job creation."[12]

This claim that eBay has harmed American innovation starts from a reasonable premise: when an alleged infringer's outside option in a licensing negotiation is the threat of imminent injunction, removing that threat almost certainly shifts some rents from the patentee to the infringer. However, as we emphasize below, the impact on aggregate innovation is unclear. Reducing access to injunctions could harm innovation by reducing inventors' expected profits. But if the alleged infringers also innovate, or if the rents produced by a threatened injunction represent windfall profits rather than returns to R&D, taking away that threat could stimulate innovation. By weakening the presumption of injunctive relief, without removing the possibility that it is granted, the eBay decision gave U.S. courts more flexibility to try and choose the most appropriate remedy in a given case.

Our goal in this paper is to evaluate the claim that eBay (and to a lesser extent, subsequent changes in U.S. patent policy) have harmed the American innovation system. We begin by considering economic theory, which is useful for clarifying the

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[11] Gene Quinn speech to Association of Intellectual Property Firms (October, 2014): http://www.ipwatchdog.com/2014/10/01/dark-days-ahead-the-patent-pendulum/id=51475/

[12] Speech by Andrei Iancu to U.S. Chamber of Commerce Patent Policy Conference: https://patentlyo.com/patent/2018/04/director-andrei-patent.html?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+PatentlyO+%28Dennis+Crouch%27s+Patently-O%29

potential mechanisms that link patent policy to innovation outcomes, but cannot ultimately answer our question. We then turn to the empirical evidence, which (though admittedly imperfect) shows continued growth in patenting, R&D and productivity – particularly in those sectors most likely to be influenced by the eBay decision. Thus, although we cannot separate upstream from downstream innovation in our empirical analysis, our estimates of the aggregate impact of eBay and post-eBay U.S. patent policy suggest either that both impacts were small or they tend to cancel out.

II. Injunctions and Innovation in Economic Theory

The most basic economic view of patents is that they offer inventors a degree of market power in return for disclosing their invention, thereby creating incentives to invent and to disseminate new ideas. In this simple model, eliminating automatic injunctions reduces the market power of a patent owner that could otherwise choose between seeking injunctive relief or monetary damages according to whichever is more profitable, and therefore reduces innovation incentives.

Although the framework described above is often invoked to argue that stronger patents necessarily produce more innovation, things are generally more complicated. Both Arrow (1962) and Aghion and Howitt (1992) highlight a fundamental problem with the most basic view of patents and innovation. In particular, they note that competition can also spur innovation, and because patents insulate firms from competition, there can be circumstances where strengthening patent protection leads to less innovation. In their models, where patent protection could be either too weak or too strong, the effects of a policy change will depend on where we are located relative to the "sweet spot."

Further complications with the standard view arise when we start considering innovation as a cumulative process, where each new invention builds upon a series of previously patented ideas. Scotchmer (1991) shows that is impossible to create a decentralized system that yields the socially optimal level of investment in this setting, essentially because of a double marginalization problem. Theoretically, a solution would be to have companies write contracts before either party has made their R&D investment. However, this solution has obvious practical barriers, since in many cases the two inventors are not even aware of one another when the first one invests. Shapiro (2001) highlights the potential magnitude of these contracting problems in industries where patent rights are highly fragmented.

Bessen and Maskin (2009) developed a model of cumulative and complementary innovation, where inventors each pursue a different line of research, but nevertheless build on each other's ideas. In their model, as long as imitation is not perfect and instantaneous – therefore allowing firms to profit from the idea at least for a time – society and even inventors themselves may be better off without patent protection. Their key insight is that although imitation is costly to an inventor, it can also bring benefits if the inventor can turn around and borrow the imitator's ideas.

To be clear, we do not think that any of these papers provides the "right" economic model of patents. Rather, the theories collectively illustrate two points. First, the idea that stronger patents imply more innovation is not as obvious as the simplistic view would suggest. As with many important questions in economics, the answer is "it depends." Secondly, the simplistic view may be well suited to industries where there are large fixed costs of R&D, stand-alone inventions, and rapid imitation with little room for product differentiation. In settings where innovation is cumulative and complementary, or where firms can effectively differentiate in other ways, the effects of "stronger" patents on innovation are ambiguous.

In addition to theory that illustrates when we should generally expect a stronger link between patents and innovation, there are at least a few papers that focus directly on injunctive relief. In a seminal contribution to the law and economics literature, Calabresi and Melamed (1972) discuss optimal enforcement, contrasting property rules based on exclusion (or injunctive relief) to liability rules based on compensation (or monetary damages). Their analyses suggest that property rules are more likely to work well when the boundaries of property rights are clearly identifiable, as in the case of real estate. When the boundaries of a property right are harder to identify, as with patents, Kaplow and Shavell (1996) show that a hybrid system may perform better.

Hausman, Leonard and Sidak (2007) and Layne-Farrar (2016) both suggest that a monetary damages based on a "reasonable royalty" can harm innovation by creating incentives to infringe.[13] Specifically, they argue that defendants in a patent case will prefer to litigate and pay $X only if they lose, rather than negotiate and pay $X for certain. In practice, courts could solve this problem in a variety of ways, such as assuming (counter-factually) that a patent was known to be valid and infringed at the time of negotiation, awarding punitive damages, or having the loser of patent lawsuit pay the winner's legal expenses.

Many observers have noted that one advantage of automatic-injunction property rules is that they do not require a court to determine damages. But as we noted above, this comes at the cost of over-rewarding the owner of relatively minor patents that may be unintentionally infringed.[14] Shapiro (2016) develops a theory that explicitly highlights this trade-off. In his model, ongoing royalties are more desirable the more costly it is for an infringer to switch technologies (thereby avoiding the holdup problem) and injunctive relief performs better the more difficult it becomes for courts to ascertain the appropriate reward.

Nearly all of the formal models of patent damages that we have seen assume complete information bargaining, where injunctions do not occur in equilibrium because parties settle their disputes. However, access to injunctions can still alter

[13] In U.S. courts, a reasonable royalty is often determined by trying to simulate the outcome of a hypothetical negotiation between a "willing licensor" (patentee) and a "willing licensee" (infringer) at the time the infringement began.

[14] A 2011 Federal Trade Commission report on "The Evolving IP Marketplace" (FTC 2011) provides an extensive discussion of this tradeoff and why systematically over-rewarding patents in this manner is not a desirable approach to providing innovation incentives.

innovation incentives in these models by shifting the parties' threat points in a license negotiation. In particular, reducing access to injunctions will lower the patent holder's return when reasonable royalty or lost profits patent damages yield a higher payoff to the infringer, and consequently a lower equilibrium royalty. On the other hand, increased access to injunctions will lower the returns to downstream innovation when infringing a minor component-level patent places large (and often sunk) product- or system-level investments at risk.

Ultimately, as with the link between patent strength and innovation, economic theory can highlight key trade-offs in the choice of a property or a liability rule, but is not able to deliver clear predictions regarding the optimal patent remedies regime. Nevertheless, theory does suggest that a flexible approach – such as that envisioned in the eBay decision – can be appropriate when there is substantial heterogeneity in the clarity of claim boundaries, the importance of cumulative innovation, the likelihood of accidental infringement, and the difficulty of determining a reasonable royalty.

III. Has eBay Hindered American Innovation?

In economic theory, "innovation incentives" stand for a wide variety of different types of risky investment. In practice, these investments are notoriously difficult to measure well. Economists who study the subject tend to rely on three available measures: R&D, patents and productivity.[15] Each outcome has benefits and drawbacks. R&D investment is measured in dollars – a metric that is easy to interpret – but only captures inputs to the innovation process. While patents are arguably a better measure of innovative output, not all inventions are patented, and even when they are patented it remains hard to attach a dollar value to the underlying invention. Many economists would argue that the best measure of technological progress is productivity growth – changes in the amount of output

[15] There is also a literature that uses academic papers to measure basic research outputs, but we will not consider that outcome in our analysis.

produced for a given level of inputs. However, productivity growth is difficult to measure, and often requires the analyst to make strong assumptions.

Despite these challenges, it is still worth considering whether data on R&D, patents or productivity provides any evidence that changes in patent law, starting with eBay, had a measurable impact on American innovation. As discussed above, our objective is not to provide a causal estimate of the impact of the eBay decision. Rather, given the rhetoric regarding eBay and subsequent changes in patent policy, we are asking whether the available evidence can support the strong claim that eBay had a large stifling impact on American innovation.

Ideally, we could rely on experimental evidence to evaluate claims that recent changes in patent law are leading to less innovation. However, a controlled experiment requires a control group, which presents serious challenges when the experiment involves randomly assigning current law to one set of firms (or economies) and a counterfactual legal regime to others. We consider two feasible alternatives that exploit variation in U.S. patent law over time.

The first alternative is to simply look for changes in the rate of innovation before and after the eBay decision. While a sharp decline in innovation (or its growth rate) around 2006 would be consistent with the hypothesis that recent U.S. patent policy changes have been harmful, we must be cautious about interpreting this type of evidence. A good experiment requires that we hold "all else equal," and in practice, there are many uncontrolled differences in the pre and post-eBay innovation landscape. Potentially confounding factors include changes in the business environment, including the rise of Non-Practicing Entities, and changes in the broader economic and technological environment, such as the great recession. Nevertheless, if we fail to find any evidence of an "eBay effect" in this type of pre/post analysis, it would suggest that confounding factors are at least as important to innovation as changes in patent policy.

Our second feasible alternative compares changes in innovation activity around the time of the eBay ruling across groups that may have been differentially affected by the decision. This type of analysis is similar to what economists call a differences-in-differences design. In this type of empirical analysis, the control group serves the same purpose as in the idealized experiment described above – it provides measures of counterfactual outcomes (i.e. the but-for world) that we would have expected for the treated. Because we could not randomly assign the treatment, however, the "but for" assumption is a much stronger one in our analysis below.

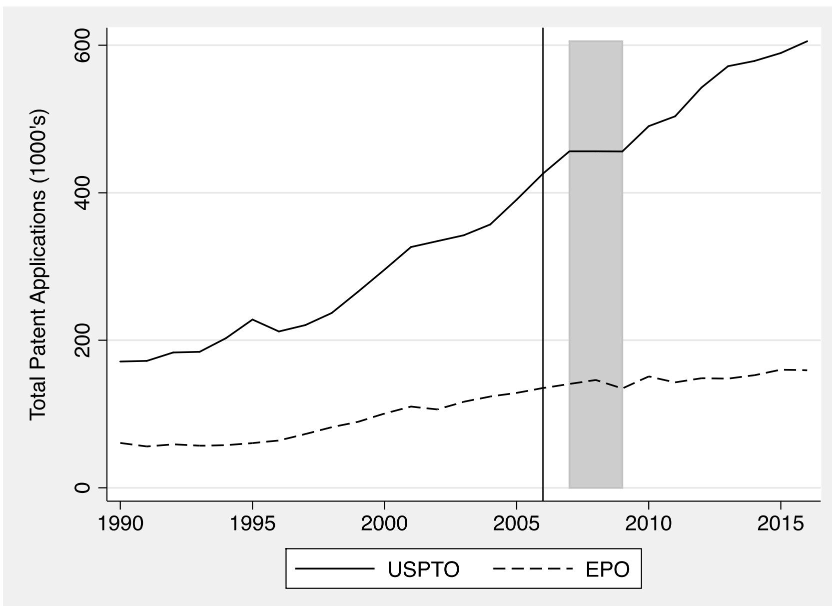
The choice of treated and control groups will vary according to the specific outcome we are studying, and the level of the analysis. For example, we begin by comparing trends in patent applications to the US Patent Office (USPTO) and the European Patent Office (EPO) before and after the eBay decision. For that comparison, US applicants are the "treated" group and EPO applicants are the "control." We also conduct firm-level analyses focusing on U.S. companies, where the "treated" group are firms in information and communications technology industries, and the "controls" are in the life-sciences or mechanical sectors. That choice is based on the assumption that eBay and other patent-law changes had a greater impact in ICT, as explained below. Importantly, we are not making any assumption about the direction of the effect of eBay on these firms. Instead, the idea is that – if eBay had the large, negative effects that many advocates for the return to the old standard claim – we expect to find some relative change among these two groups over the period considered.

Our analysis is divided into three parts. We start by considering evidence based on patent data. We then turn to R&D spending and venture capital investment. We conclude by looking at productivity.

Evidence from Patenting

If changes in the law of patent damages or eligibility led to a reduction in U.S. patent value, we should expect to see a reduction in the number (or growth rate) of new U.S. patent applications relative to the rest of the world. Figure 1 compares the number of annual applications filed at the USPTO and EPO between 1990 and 2016, using data from the World Intellectual Property Organization (WIPO). In this and all subsequent figures, the vertical line represents the 2006 eBay decision, and the gray shaded bar corresponds to the great recession years of 2008 and 2009.[16]

Figure 1: New Utility Patent Applications to USPTO and EPO



Although applications to both patent offices increased over this 26-year period, U.S. applications grew faster in both absolute and percentage terms. Moreover, there is no apparent decline is U.S. utility applications following the 2006 eBay decision, regardless of whether we use the EPO or the pre-eBay U.S. application growth rate as our baseline.

Figure 1 suggests that any decline in U.S. patent value caused by eBay and subsequent patent policy changes was not enough to prevent applicants from

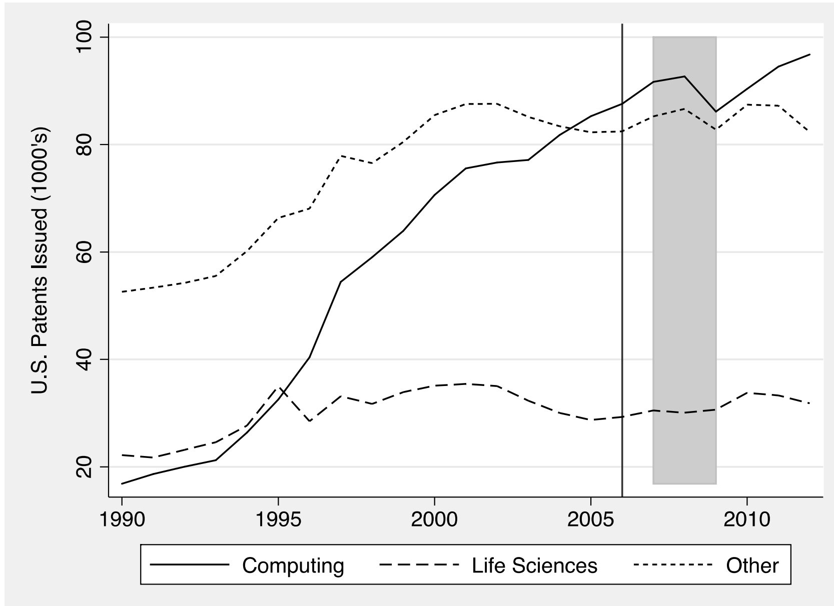
[16] According to the National Bureau of Economic Research, the recession began in December 2007 and lasted through June 2009.

continuing to seek them, and indeed, pursuing them with greater intensity than in other parts of the world. It is not clear what this trend means for innovation overall. First, as we have already suggested, patents do not measure total innovative output. Second, there may be other explanations for trends in the figure. For instance, the USPTO may have increased rejection rates over time, leading applicants to divide their ideas across more applications or file more request for continue examinations (RCEs). Nevertheless, Figure 1 is at odds with the hypothesis that recent changes in U.S. patent law are harming domestic innovation incentives. In fact, if we assume that reductions in patent value have a first order impact on incentives to patent, we would expect to find a reduction in US filings relative to Europe.

To understand what is driving the faster growth in US applications observed in Figure 1, we can look at their composition. Specifically, we use industry codes published by USPTO to divide new utility patent applicants into three broad groups: Computing (ICT), Life Sciences and Other (mainly Mechanical and Electrical).[17] Figure 2 plots the number of new applications in each industry group by year.

Figure 2: US Patents Issued by Industry

[17] The USPTO provides reports of U.S. utility patent grants by NAICS industry that we used to create this chart. We define "Computing" as NAICS 3341, 3342, 3344, 335- and 334-. We define "Life Sciences" as NAICS 3251, 3391, 325-, 3254, 326 and 3252. All other NAICS codes are in the "Other" category. The USPTO concordance is based on technology classification for issued patents (rather than patent applications) and is available through 2012. The concordance is applied at the individual patent level, and therefore does not necessarily reflect the NAICS category of the patent owner.



Note: Number of patents issued by the USPTO by application-year across Computing industries, Life sciences, and Other industries (residual group).

It is immediately apparent from Figure 2 that most of the increase in U.S. patent applications is associated with computer technologies (with a bit of an assist from the Other group). Changes in patent eligibility that made it easier to obtain software and business method patents – notably the 1998 State Street vs. Signature decision – almost certainly contributed to this pattern. At the same time, it may also reflect a response to real economic changes associated with ICT revolution, as suggested by Kortum and Lerner (1999). The dramatic increase in Computer patents, and the problems associated with them (Jaffe and Lerner 2004), are arguably key drivers of the legal changes we are seeking to evaluate.

Importantly for us, there does appear to be some slowing in the growth of computer patents after eBay. Such a slowdown would be consistent with the idea that legal and policy changes reduced incentives to seek Computer patents. However, the timing of this slowdown coincides with the financial crisis, and Figure 1 shows a resurgence in the growth rate of total U.S. patent applications between 2012 and 2016.[18]

[18] Figure 2 omits the bulk of the broad resurgence in applications between 2012 and 2016 because it is based on grants rather than applications, and there is significant truncation of later application-

In the Appendix, we show that the results in Figure 2 are not sensitive to the way we classify patents. In particular, Appendix Figure A.1 shows very similar patterns based on the alternative technology classification scheme of Hall et al (2001), and it also shows that the increase in US patenting relative to European patenting between 1990 and 2010 is largely associated with Computing.[19] Table A.1 provides estimates from a simple regression model showing that, if anything, US patenting has grown faster than European patenting after the eBay decision .[20]

Since patenting is not equivalent to innovation, we now turn to alternative measures to see whether they provide any evidence that post-eBay U.S. patent policy produced a measurable impact.[21]

Research and Development

We gathered data on R&D investments from two sources. The National Science Foundation Science and Engineering Indicators is the best source of total U.S. R&D spending by private businesses. However, these data do not allow for more detailed examination of R&D spending at the firm or industry level.[22] So, we also collected

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year cohorts due to pendency lags. Nevertheless, consistent with Figure 2, we observe some positive pick-up in Computer patents post-2010.

[19] For US patents, the classification method of Hall et al. (2001) treats "Computer" classes identically to our approach, while Life Sciences is defined as the sum of Drugs and Medical plus organic chemistry. For European data, we start from data aggregated at CPC-level and we then manually map the 4-digit CPC to the three aggregate groups, following the same logic as Hall et al. (2001). As with the rest of the paper, these data are available online.

[20] In the first column of Table A.1, we regress the log of patents by region (US vs. Europe), year, and major technology (Computer, Life Sciences, and others) on region by technology FE, year FE, and the interaction between US and a post dummy, which is equal to 1 after 2006. The sample considered includes years 1999 through 2013. We find that US patenting increased by 25% post-2006 relative to Europe. In the second column, we augment the previous specification with technology linear trends and we find consistent results.

[21] Another advantage of R&D data relative to patent data is that patenting may be slower to respond than R&D spending, making it harder to detect any effect on patenting on a relatively short time window.

[22] After 2008, the NSF redesigned their R&D survey instrument, and the more recent data do provide additional industry-level statistics. However, this change in survey design makes it very hard to compare data at industry level across the two periods.

firm-level data from Compustat, which provides information from the financial statements of publicly listed firms.

It is important to point out that the Compustat data are not comprehensive, because they do not capture private firms (which represent a growing share of the economy) and because some public firms do not report their R&D spending. However, prior studies have found that a relatively small number of large public firms concentrated in certain industries perform the vast majority of all reported R&D investment. Therefore, we believe that these data may provide important insights on R&D investment during the period of interest.

Figure 3: Privately Funded R&D of U.S. Companies

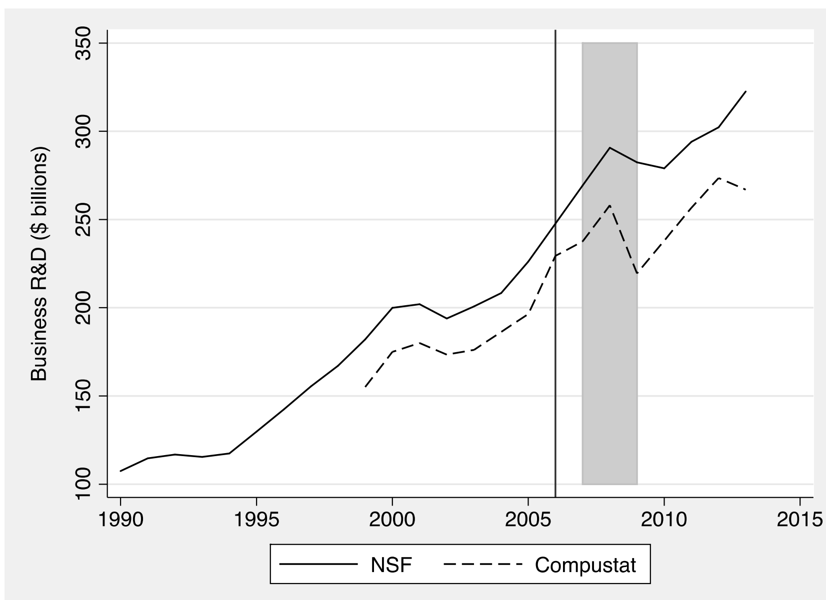
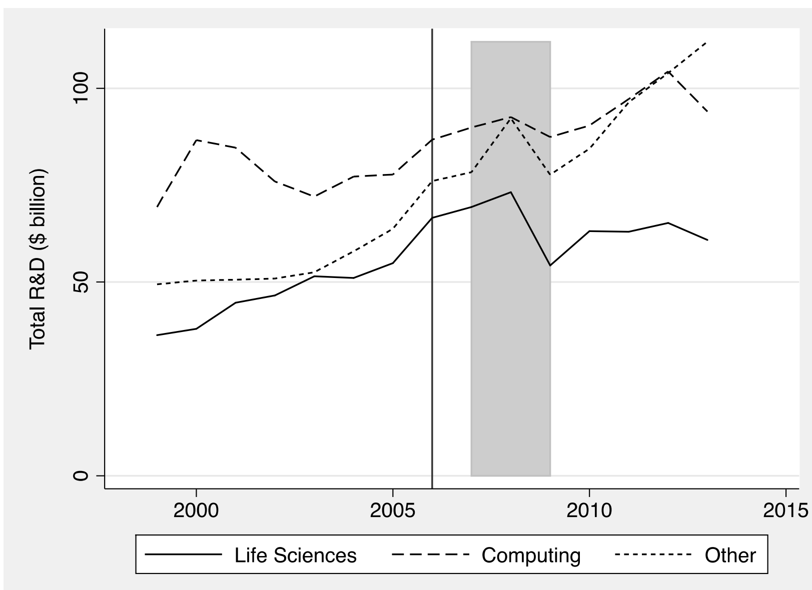


Figure 3 plots the NSF estimates of total R&D spending from 1990 through 2013 along with the cumulative R&D reported by U.S. public companies in the Compustat database from 1999 through 2013.[23] There are three main take-aways. First, Compustat captures the majority of U.S. business R&D spending – 87 percent, on

[23] The NSF series is for all R&D conducted in the domestic Unites States by public and private firms with five or more employees. We end the analysis in 2013 because that is the last year of data currently available. Although additional years of Compustat data are available, the years 1999 through 2013 produce a sample that is symmetric around the 2006 eBay decision, and as noted below, are unlikely to reflect the impact of later court decisions.

average, for years in this figure. Second, both time-series exhibit a sharp drop in R&D spending in 2009, coinciding with the Great Recession. This drop is larger in the Compustat data, but the recovery begins sooner and is more dramatic for that series. Finally, there is no sudden change in the R&D investment growth trend around 2006. Overall spending accelerated during the boom years between 2006 and 2009 and fell during the recession. Even after the end of the recession, we see R&D spending going back to the same trend it was experiencing before the eBay decision. Overall, the R&D time-series data provide no evidence that changes in patent-law led to any dramatic changes in R&D spending.

Figure 4: U.S. Privately Funded R&D by Industry Sector



With the Compustat data, we can also examine industry-level trends in R&D investment before and after eBay. Figure 4 uses S&P industry sector codes to group companies into three broad sectors, as above, corresponding to Computers, Life Sciences and Other industries.[24] Interestingly, for the public companies in these data, between 1999 and 2013 total R&D spending grew faster outside of the

[24] For this analysis, we define "sectors" using S&P industry codes. Specifically, we classify firms with an industry code between 180 and 190 (inclusive), 220 to 239 or 247 as "Computing." We classify firms with S&P industry code 147, 160 to 169, or 280 to 300 as "Life Sciences." All remining firms are assigned to the "Other" category.

Computer and Life Science sectors. Computer-related R&D fell in the years following the Internet bubble, and then grew steadily. For this industry, the progress was more-or-less parallel to growth in Life Sciences R&D, although the latter sector experienced the recession more sharply. To us, the broad industry-level R&D trends suggest that large changes in aggregate R&D spending are driven by changes in "demand" (specifically, the macro-economic environment) and shocks to financial conditions, rather than changes in patent policy that occurred in 2006.

As a last effort to find a connection between changes in patent law and R&D spending, we estimate a series of firm-level difference-in-difference regressions using the Compustat data. Our basic specification will be

$$\ln(RD_{it}) = \alpha_i + \lambda_t + \beta_1 \text{PostEbayICT}_{it} + \beta_2 \ln(\text{Assets}_{it}) + \varepsilon_{it}$$

where the outcome (RD_{it}) is annual R&D expenditures; α_i are a set of firm fixed effects that capture time-invariant unobserved factors that drive R&D spending; λ_t are a set of year effects that capture changes in the overall economic environment, including (importantly) the great recession; and the main explanatory variable is PostEbayICT_{it}, an indicator that equals one for firms in the ICT sector after 2006. By taking the natural log of the outcome, we can interpret β_1 as the percentage change in computer-related R&D relative to the "control" industries following the eBay decision. Our sample includes all firms that report R&D expenditures for every year they appear in the Compustat data, and we include the log of total assets as a time-varying control for firm size.[25]

The basic idea behind this regression is that if changes in patent-law (including but not limited to the eBay decision) disproportionately impact the ICT sector, and if there is a strong link between patent strength and R&D investment, then we should observe a decline in R&D spending for ICT firms relative to firms in other sectors.

[25] This firms in our sample account for 92 percent of all Compustat R&D spending.

That is, a strong link between patents and R&D would lead to estimates of β_1 less than zero.

The assumption that the eBay decision had a disproportionate impact on ICT firms is consistent with Seaman's (2016) findings on post-eBay patent injunctions in software and pharmaceuticals, as described above. Prior research also shows that patent assertion by Non-Practicing Entities (NPEs) is concentrated in the ICT sector, and that NPEs are unlikely to obtain injunctive relief (Allison, et al. 2018). Finally, because ICT patents often cover a particular component within a larger system, whereas patents in other industries (e.g. pharmaceuticals) may be more "fundamental" to the final product, we expect the balance of hardships factor to favor injunctive relief outside the ICT sector.

While we believe that the assumption of disproportionate impact on ICT is a reasonable one, and consistent with most of the discussion on the law change, different experts may disagree on the definition of a control group. For instance, one could argue that some areas of Life Science were also strongly affected by the law change. Because our Compustat data end in 2013, the impact of the *Mayo* and *Myriad* decisions on the analysis should be minimal. Nevertheless, to guard against this problem, we will conduct our analysis using Life Sciences and "Other" industries as separate control groups. Our analyses will therefore use three different control samples, where in each case the treatment is defined as the ICT-sector and the control group changes column-by-column. In the first column we compare ICT to all non-ICT firms. In the second column the control group contains only life-science companies, and in the third column the control group contains only companies that are in neither ICT nor life-science industries. Comparing the coefficients across the different specifications should assuage concerns that the choice of control group is driving the results.

It is important to note that we do not interpret these estimates as the causal effect of eBay on R&D investment. In particular, our analysis may also partially capture unobserved changes in the business environment that interact with the effect of the new rules. However, if eBay led to a significant decline in the expected returns to U.S. R&D investment, we should be able to detect some changes across the different groups in our model.

We estimate these models in two different specifications: ordinary least squares regression with a logged outcome, and an exponential (or Poisson) model of R&D in levels. The results of our regression analysis are presented in Table 1.

Table 1: Post-eBay Changes in R&D, Diff-in-Diff Models

Specification		OLS			Poisson	
Control Group	*All Firms*	*Life Science*	*Other*	*All Firms*	*Life Science*	*Other*
PostEbayICT	-0.02	0.00	-0.04	-0.03	0.00	-0.04
	[0.03]	[0.04]	[0.03]	[0.08]	[0.10]	[0.09]
log(Assets)	0.52	0.53	0.51	0.62	0.66	0.62
	[0.01]	[0.02]	[0.02]	[0.06]	[0.03]	[0.06]
Observations	29,256	16,154	24,361	28,818	15,940	23,961
R-squared	0.39	0.41	0.40			

Notes: The variable PostEbayICT is a dummy which is equal to one for companies in the treated group (ICT) after the eBay decision. In columns one and four, the control group is composed by non-ICT firms in Compustat. In columns two and four, the control group is constituted by firms in life-science. In columns three and four, the control group is instead the set of firms that are not in ICT and life-science. Robust standard errors (clustered on firm) in brackets.

Across all of the regression models, we can never reject the null hypothesis that there was no change in ICT-sector R&D spending relative to other industries after 2006. Compared to all other firms, post-2006 R&D investment in the computer sector declined by 2%, with a standard error of 3%. Comparing estimates in the second and third columns, it appears that the small relative decline in computer-related R&D is driven by firms outside the life sciences sector, as suggested by Figure 4. Estimates based on the Poisson specification are very similar, but exhibit less precision. In the Appendix, we show that the results in Table 1 are robust to small changes in the sample and specification.[26] Overall, the results in Table 1 imply that if one wishes to maintain that eBay had a large negative impact on U.S. R&D investment incentives, it is important to think about what else happened around the same time period to increase R&D incentives by a similar amount.

Before moving on, it is interesting to compare the coefficient on the PostEbayICT "policy" variable in Table 1 to the coefficient on log(Assets). Because these regressions include firm fixed-effects, the latter coefficient measures the association between firm-growth and R&D. It is well known that growing firms increase their R&D spending, and our estimates suggest that after controlling for time-invariant factors, a 10 percent increase in assets is associated with a 5 percent increase in R&D spending. What is notable about these estimates is that they are large and *precise*. Comparing the magnitude and precision of the two coefficients in Table 1 suggest that even hotly debated changes in patent policy can have a minor impact on individual firms' R&D investment decisions compared to other firm-level factors that drive growth.

Venture Capital Investment

Although R&D investment remains highly concentrated among large firms, there is other evidence that innovation is becoming more distributed (Foster, Grim and Zolas 2016; Ozcan and Greenstein 2013). Perhaps our previous analyses have missed the impact of patent-policy changes on smaller innovators. To rule out this hypothesis, we gathered data on venture capital spending from the Price Waterhouse MoneyTree survey. These data allow us to look at aggregate VC spending by sector and deal-type, but not individual investments.[27]

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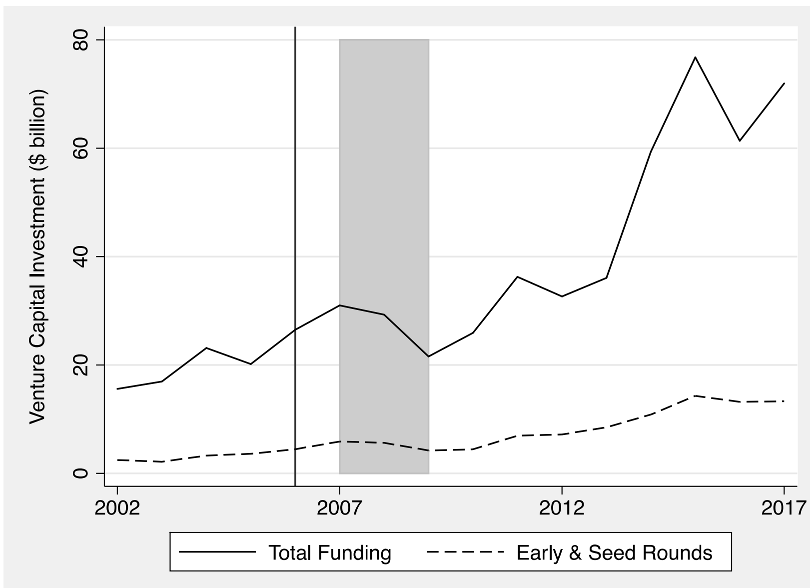
[26] Appendix Table A.2 shows that the results in Table 1 are not sensitive to changing the sample period. For instance, ending the sample in 2011, 2012, or 2013 yields qualitatively identical results. In an unreported regression, we also find that using a shorter pre-period, for instance post 2003, does not change the results. Appendix Table A.3 reports very similar results based on an alternative specification that uses R&D/ Assets as the outcome variable, while dropping log(Assets) as a control.

[27] The Money Tree survey data are available for download at https://www.pwc.com/us/en/industries/technology/moneytree/explorer.html#/. We define the

Figure 5 shows that Venture Capital Investment followed an upward trend from 2002 through 2012, at which point there was a dramatic increase in total VC funding, coming mainly in later rounds. There is no apparent change in either early or later stage VC funding in the years immediately after the eBay decision, although there is a drop in later round funding in 2009 and 2010, coinciding with the recession.

Figure 5: U.S. Venture Capital Investment

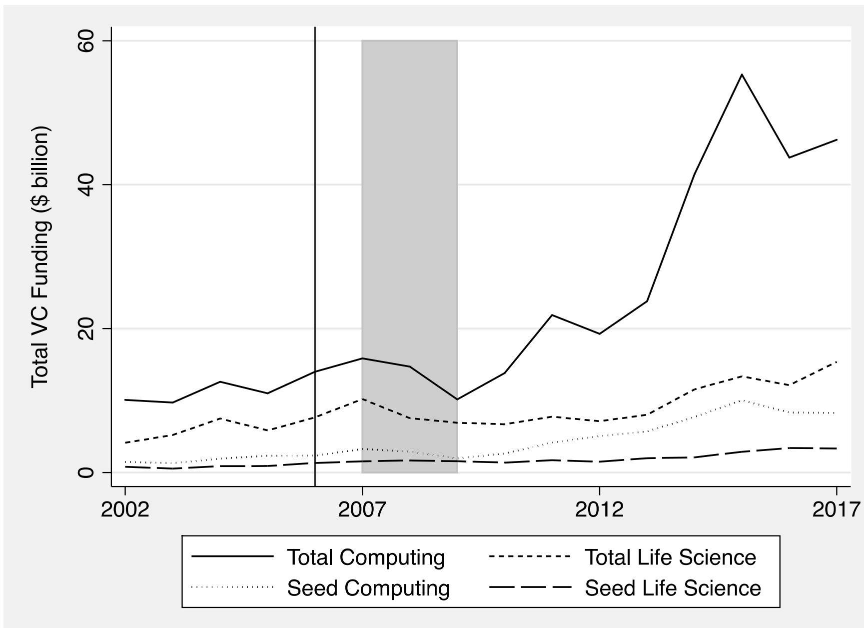


To provide additional insight into possible links from patent policy to VC investment, we can examine investments for the computing and life science sectors. Figure 6 plots Total VC investments and Seed stage investments for both sectors. The graph clearly illustrates that the large surge in investment around 2012 is associated with later rounds in the computing industries. Late stage life science investments also increase around this period, but not by the same amount. There is also an increase in early-stage computer-related VC investing (relative to early-stage

"Computing" sector as the following PWC survey categories: Computer Hardware & Services; Electronics; Internet; Mobile & Telecommunications; and Software. We define the "Life Science" sector as Healthcare (which includes Pharmaceuticals and Biotechnology); Agriculture; and Food & Beverages.

life science investing) starting around 2009. While computer-related investment is higher than life sciences investment throughout this time period, it is notable that there is no sharp decline in Life Sciences VC investing following the AMP and Myriad decisions.

Figure 6: Venture Capital Investment by Stage and Sector



Overall, we take the main message of Figures 5 and 6 to be a shift in VC investment *towards* industries most influenced by the post-eBay changes in patent policy. It is important to highlight that we cannot say whether VC investments might not have been higher absent the changes. However, to the extent that the observed changes reflect other factors that were more significant than patent-policy, this result is consistent with the idea that intellectual property is less important for driving investments in innovation than those other factors. Moreover, as we emphasized above, economic theory also provides reasons to suspect that a more flexible patent remedies regime could lead to more innovation – particularly in settings like the IT sector where rights are fragmented and innovation is highly cumulative.

Productivity

Most economists agree that the ultimate measure of innovation is productivity, which measures the total economic value created for a given level of resources used in production. Macroeconomists equate productivity growth with technological change, and over long periods of time changes in the productivity growth rate can have dramatic consequences for individual economic wellbeing.

U.S. productivity growth has been sluggish in recent years compared to late 1990s, and there is a robust ongoing debate among economists about the causes of this slowdown (Syverson, 2017). It is possible that critics of eBay attribute the broad U.S. productivity-growth slowdown to changes in patent policy. In our view, that inference would be misplaced for several reasons. First, it is too soon: the historical evidence suggests that it takes decades for significant inventions to have an impact on aggregate productivity (e.g. David 1990, Solow 1987). Because patent policy impacts the early stages of the innovation process, any impacts of post-eBay patent policy are not likely to have influenced the productivity statistics.[28] Second, if patent policy were the mechanism driving the productivity slowdown, we should see it in the R&D and patent data. But we do not.

Nevertheless, as a final step in our analysis, we examine industry-level links between patenting and productivity. Our approach compares industries that do and do not use patents, before and after 2006. If patents are a significant driver of innovation in patenting industries, and if the eBay decision harmed incentives to innovate in those industries, then we expect to find slower productivity growth in those industries after 2006. As with our previous analysis, we might fail to measure the impact of the patent-policy changes because of unmeasured changes in industries over time that lead to faster relative productivity growth in patenting industries. However, this statement is just another way of saying that unmeasured factors were equally important to changes in patent policy.

[28] This argument also holds for more prominent recent developments, such as the smartphone.

Our productivity data come from the NBER-CES manufacturing industry productivity database. Although the NBER data contain productivity information for 473 NAICS 6-digit industries, after merging them to the USPTO industry-level patent statistics, we are left with a balanced panel of seventeen NAICS 3 and 4-digit manufacturing industries from 2000 through 2011.[29] We use a four-factor productivity index that accounts for capital, production and non-production workers, and materials.

Figure 7: Total Factor Productivity

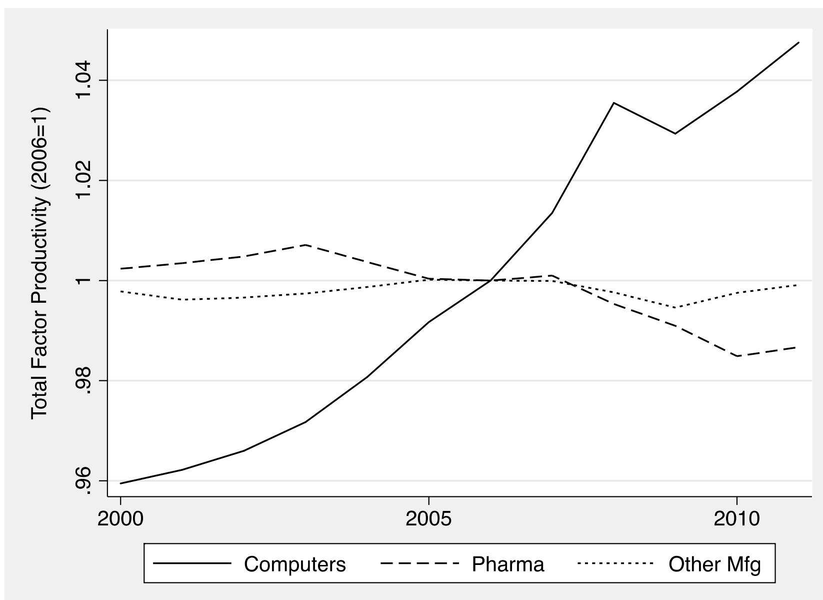


Figure 7 plots the TFP index for Computers (NAICS 334), Pharmaceuticals (NAICS 3254) and other manufacturing industries. Each index is normalized to equal one in 2006, the year of the eBay decision. The figure shows that computer-related manufacturing industries experienced faster TFP growth both before and after the eBay decision than Pharmaceuticals or the other manufacturing sectors in our data. This is a common feature of many productivity time-series and is partly due to rapid

[29] We use output weights to aggregate the productivity measures to the 3 and 4 digit level, as described in Bartelsman & Gray (1996).

quality improvements associated with Moore's law (as well as the difficulties of accounting for them).

To check for a systematic relationship between patenting and post-eBay productivity trends, we use a difference-in-difference regression based on the following specification:

$$TFP_{it} = \alpha_i + \lambda_t + \beta_1 * \ln(Patents_i) * PostEbay_t + \varepsilon_{it}$$

where TFP_{it} is the log of four-factor TFP for industry I in year t; α_i are a set of industry fixed effects; λ_t are a set of year effects that capture common economy-wide productivity trends; $\ln(Patents_i)$ measures the patent-intensity of industry i; and $PostEbay_t$ is an indicator variable that equals one for 2006 and all subsequent years. The main effects of patent-intensity and the eBay decision are absorbed by the industry and year fixed effects respectively.[30] The coefficient β_1 measures changes in the TFP growth rate for patent-intensive industries relative to less patent-intensive industries following the 2006 eBay decision.

To address the differential pre-eBay trends observed in Figure 7, we consider two robustness checks. First, we estimate a model where each industry has its own liner productivity trend. Specifically, we interact each industry fixed effect with a time trend ($\alpha_i * t$). In that specification, β_1 captures any deviation from trend following the eBay decision for more patent-intensive sectors. Our second robustness test drops all observations from the "Computer and electronic product manufacturing" sector (NAICS 334), where hedonic adjustments play a particularly important role in productivity measurement. The results are presented in Table 2.

Table 2: Post-eBay Productivity Growth

[30] Because TFP is already normalized to 100 in 2007 for all industries, we could obtain identical estimates from a model without industry fixed effects. We include them for ease of interpretation and consistency with our prior specification.

Outcome	(1) Four Factor TFP	(2) Four Factor TFP	(3) Four Factor TFP	(4) Four Factor TFP
PostEbay*ln(Patents)	0.0028* [0.0013]	0.0011** [0.0004]	0.0015** [0.0004]	0.0008** [0.0001]
Observations	204	204	192	192
R-squared	0.3026	0.9307	0.4064	0.7789
Year Effects	Y	Y	Y	Y
Industry Effects	Y	Y	Y	Y
Linear Industry Trends	N	Y	N	Y

Note: Estimates based on the equation presented above over a sample of industry-year observations, where the outcome is a measure of four-factor TFP at industry-year level. The sample of column (3) differs because it drops the Computer-manufacturing sector. Robust standard errors clustered at industry-level are in brackets. **1% significance, *5% significance.

Results in the first column show that total factor productivity growth accelerated after 2006 for more patent-intensive industries. This is inconsistent with the idea that changes in patent-policy during that period acted as a drag on innovation. In column 2, we add industry-specific trends to the model. Although this reduces the size of β_1, the coefficient remains positive and statistically significant. Columns 3 and 4 are based on the same specification as columns 1 and 2, respectively, while dropping observations from the computer-manufacturing sector from the estimation sample. In both cases, we continue to find that TFP growth increased for more patent-intensive industries following the 2006 eBay decision.

We do not wish to make too much of these models. Productivity is notoriously difficult to measure, and changes slowly in response to a wide variety of factors. However, this is precisely the reason to avoid thinking that broader changes in productivity over the last decade are necessarily linked to changes in patent policy. Our analysis simply shows that if there is any statistically discernable link between the eBay decision and subsequent short-run productivity growth, the data suggest a *positive* correlation between innovation and recent changes in U.S. patent policy.

IV. Conclusions

The eBay decision marked a turning point in U.S. patent policy in the minds of many observers, but we find no evidence that it had a dramatic impact – positive or negative – on American Innovative performance. In particular, we observed that applications to the USPTO continued to climb following eBay, in both absolute terms and relative to the European Patent Office. There was no clear decline in private domestic R&D investment, and a regression analysis detected no change in the post-2006 R&D expenditures by U.S. public firms in sectors that were more likely to be affected by the eBay decision. We found no evidence that the eBay decision influenced VC investment. And if anything, we observe a small increase in total-factor productivity growth for more patent-intensive industries after 2006.

In some ways, our empirical findings (or lack thereof) are not very surprising. Economic theory provides no clear prediction about the impacts of eBay or post-eBay patent policy on innovation. Indeed, one general theme of the theoretical literature is that stronger patents – and specifically injunctions – can be harmful to innovation in some cases. The eBay decision merely provides courts with the flexibility to choose monetary damages as an alternative in settings where the "balance of hardships" dictates that approach.

Nevertheless, some observers continue to make strong claims about the detrimental effects of the eBay decision, and policy-makers continue to debate the availability of injunctive relief for patent infringement. As we have emphasized throughout the paper, measuring the impact of patent policy on innovation is difficult. In the absence of a natural experiment, we cannot categorically rule out the hypothesis that eBay has a modest impact – either positive or negative – on American innovation. Given our results, however, future claims of a substantial "eBay effect" should be accompanied by an explanation of the countervailing factors that cause all evidence of that effect to be missing from the aggregate innovation statistics.

In conclusion, we see two major avenues for future research on this topic. First, the academic and policy debate over recent changes in U.S. patent policy would greatly benefit from more efforts to estimate causal impacts of these interventions. Finding a credible instrument or control group will be challenging given the unitary nature of the U.S. patent system, but the increasing availability of firm-level data should help. Secondly, there is relatively little research examining the impact of patent policy changes on markets for technology. For example, we would like to know whether and how eBay influenced the prevalence and terms of licensing agreements among non-competing parties. Because patent license agreements are typically confidential, the key challenge for this line of inquiry is likely to be data availability.

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Online Appendix

Table A.1: US and EPO Aggregate Patenting Trends

VARIABLES	(1)	(2)
	Log Number of Patents (1000's)	
US * PostEbay	0.2542*	0.2542*
	[0.1049]	[0.1022]
Observations	90	90
R-squared	0.923	0.929
Year FE	Y	Y
Technology by Region FE	Y	Y
Linear Industry Trend	N	Y

This table reports a regression of log patent counts at the region (US vs. Europe), technology (Computer, Life Sciences, Others), year level on the interaction between a dummy for the US region and post-2006, controlling for region by technology FE, and year FE. In the second column, we repeat this same analysis, but we add also technology linear trends. The sample includes years 1999-2013. Robust standard errors in brackets. **1% significance, *5% significance.

Table A.2: Table 1 PostEbayICT Coefficients for Alternative Samples

	Control Group		
Last Year in Sample	*All Firms*	*Life Science*	*Others*
2011	-0.04	-0.02	-0.05
	[0.03]	[0.04]	[0.03]
2012	-0.03	-0.01	-0.04
	[0.03]	[0.04]	[0.03]
2013	-0.02	0.00	-0.04
	[0.03]	[0.04]	[0.03]

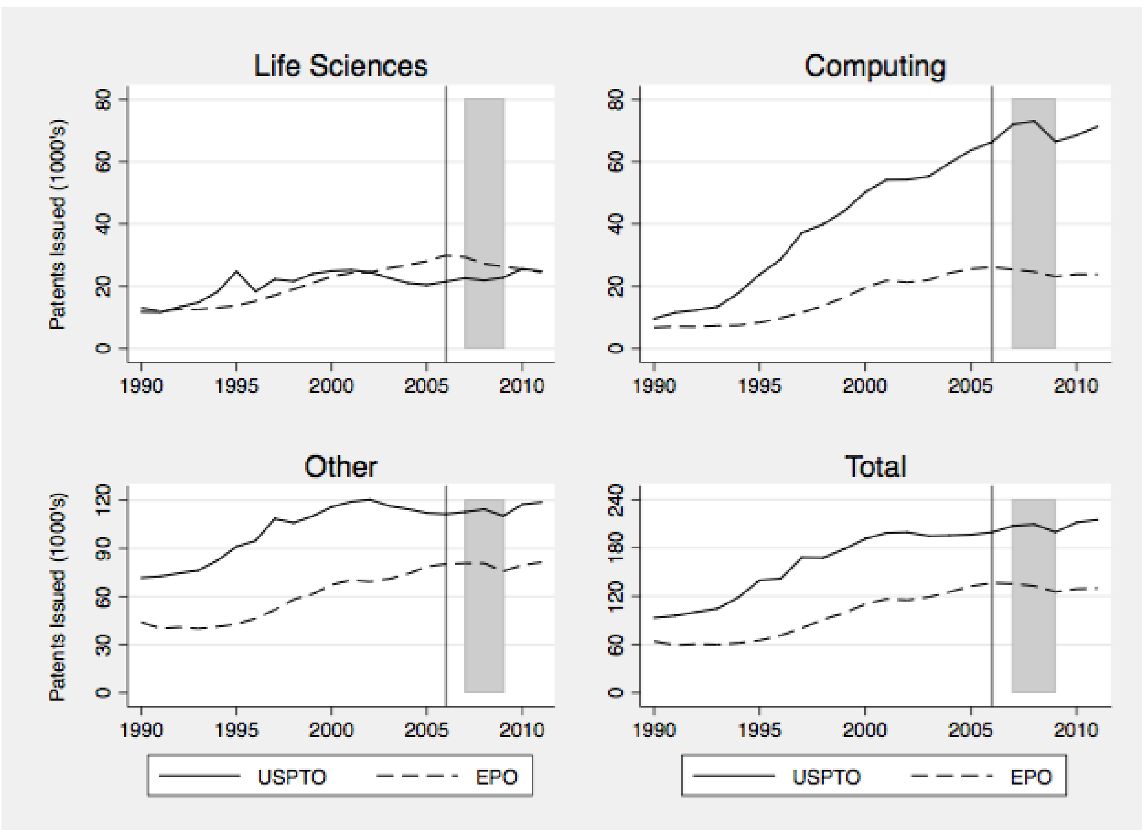
This Table replicates the key coefficient from Table 1 of the paper using samples that end in different years. All models are based on the OLS specification using log(R&D) as the outcome variable. Everything else is identical to Table 1.

Table A.3: Table 1 Using R&D/Assets as Outcome

	(1)	(2)	(3)	(4)	(5)	(6)
Specification		OLS			Poisson	
Control group	*All Firms*	*Life Science*	*Other*	*All Firms*	*Life Science*	*Other*
PostEbayICT	0.03	-0.07	0.08	0.21	0.03	0.42
	[0.06]	[0.11]	[0.06]	[0.27]	[0.29]	[0.29]
Observations	29,251	16,152	24,357	28,811	15,937	23,956
R-squared	0.001	0.002	0.001			

This Table replicates Table 1, with the difference that the main outcome of interest is R&D/Asset. The variable postEbayICT is a dummy, which is equal to one for companies in the treated group (ICT) after the eBay decision. In columns one and four, the control group is composed by non-ICT firms in Compustat. In columns two and four, the control group is constituted by firms in life-science. In columns three and four, the control group is instead the set of firms that are not in ICT and life science. Robust standard errors (clustered on firm) in brackets.

Figure A.1 Patenting by technology between US and Europe



This Figure reports patenting by major technology class (Life Sciences, Computing, and Other) for both Europe and the U.S. Variable definitions are provided in the text. Note that the Y-axis scale differs across panels.