One product, many patents: Imperfect intellectual property rights in the pharmaceutical industry

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Abstract

This paper identifies an underappreciated flexibility in pharmaceutical monopoly terms due to "imperfect" intellectual property rights, occurring when multiple patents cover a single product. I show these imperfections are widespread and provide the first causal evidence on the extent to which they allow innovators to endogenously alter their monopoly terms. Imperfect intellectual property rights substantially delay generic entry—with more novel drugs having longer monopoly extensions—yet these extensions translate to minimal increases in new drug development. Thus, existing imperfections may partially offset distortions inherent in a fixed-term patent system, but additional targeting is necessary to achieve innovation policy objectives.

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1 Introduction

Governments grant intellectual property (IP) rights as an inducement to innovation, yet a patent's fixed term of monopoly protection can distort innovation incentives (Nordhaus, 1969, 1972; Scherer, 1972). Indeed, prior work in the pharmaceutical industry has noted that diseases with long commercialization lags are less targeted for development, due to shorter effective monopoly terms post-launch (Budish et al., 2015).[1] Such work would suggest flexibility in IP regimes may offset distortions inherent in the fixed-term patent system. This paper identifies an existing, underappreciated flexibility in pharmaceutical monopoly terms due to "imperfect" intellectual property rights, occurring when multiple patents of uncertain scope and enforcement cover a single product. These imperfections are pervasive across high-technology sectors—such as software, semiconductors, information technology, and pharmaceuticals (Cohen et al., 2000; Grabowski et al., 2017; Grabowski and Kyle, 2007; Hemphill and Sampat, 2011, 2012; Noel and Schankerman, 2013)—but their causal impact on competition has yet to be quantified.

In a sample of novel drugs approved between 1985 and 2010, I show that imperfect intellectual property rights are widespread and provide the first causal evidence, in any industry, on the extent to which they allow innovators to endogenously alter their monopoly terms. Attaching drugs to patent applications and using an instrumental variables analysis, I find that these imperfections delay generic entry by an average of 3 years per drug (equal to 22 percent of mean monopoly term). In additional analyses, I show that more novel drugs receive longer monopoly extensions but these extensions translate to only minimal increases in new drug development. This research thus demonstrates that imperfections allow pharmaceutical IP rights to approach a first-best system where monopoly terms are proportionate to innovation size, but additional targeting may be necessary to achieve innovation policy objectives.

I define imperfect intellectual property rights as encompassing three possible characteristics: (1) Multiple patents may cover a single product and the (2) scope and (3) enforcement of each patent may be uncertain. These imperfections contribute to an indeterminate period of monopoly protection. In contrast, standard economic theory views intellectual property (IP) rights as "well-defined" and "enforceable" (Coase, 1960; Mas-Colell et al., 1995), meaning a single patent covers a product, that patent has a certain scope, and there is certain enforcement of monopoly rights while the patent is in effect. While the pharmaceutical industry is typically described as a "one-patent-one-product" industry due to the presence of a single, primary patent on the drug's molecule (Burk and Lemley, 2003), I document that this standard model does not hold.

The pharmaceutical industry offers a noteworthy setting for the study of imperfect intellectual property rights. First, the size of the industry alone—$485 billion in the United States in 2018—makes

[1] This is due to the lag between when a drug is first patented—at the time of discovery—and when it is commercialized. Under a fixed-term patent system, drugs that take longer to develop will have shorter remaining monopoly terms post-launch.

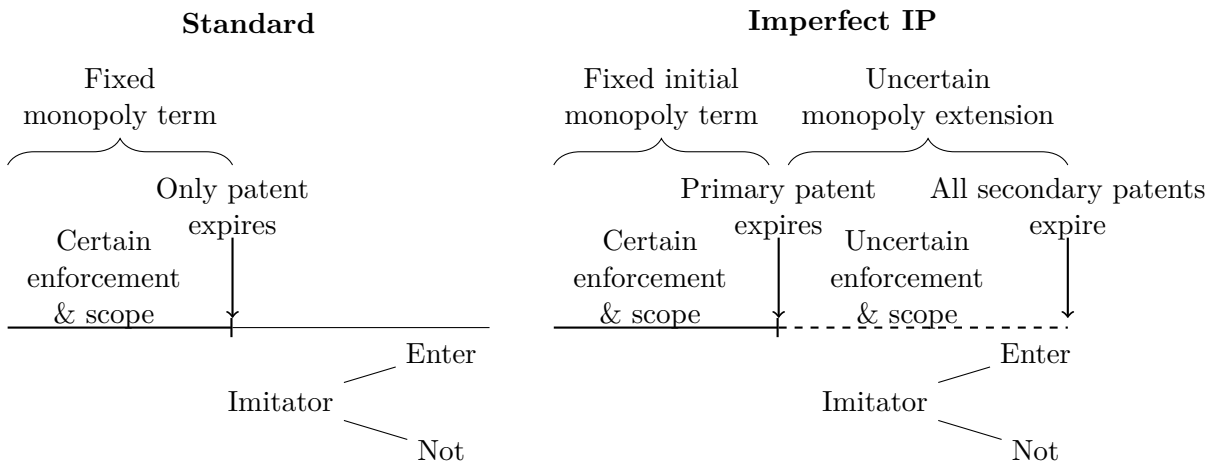
it an important market for analysis (IQVIA, 2019). Second, debate is ongoing on the strategic use of patenting for branded drug products—referred to as "life-cycle management" within the industry and as "evergreening" by critics. Branded manufacturers often obtain additional patents beyond a drug's initial patent for its molecule or active ingredient (the primary patent). These additional patents, called secondary patents, cover auxiliary features such as a drug's formulation (i.e., physical form and route of administration), manufacturing process, or use in treating a particular condition. One view holds that, given the high costs of pharmaceutical research and development (R&D), these additional patents are necessary to incentivize innovation (Gaudry, 2011; Voet, 2020); critics, however, argue that this practice serves only to extend a drug's monopoly life and maintain high drug prices (Angell, 2005; Tribble, 2019). Empirical evidence has shown that length of monopoly protection is an important determinant of innovation in the pharmaceutical sector (Budish et al., 2015), and thus, estimating the causal impact of imperfect intellectual property rights on monopoly life becomes a salient exercise.

Empirically, the pharmaceutical industry also offers advantages that simplify a study of imperfect intellectual property rights. First, there is a clear distinction between the primary and secondary patents, and the primary patent generally has certain enforcement. As such, the setting allows measurement of any extension in monopoly term beyond the initial (or primary) patent term. This may not be the case in other industries where a single product may not have an explicit primary patent. Further, the notion of a product (a given drug) is simpler than in other industries and there are limits to the possible scope of patents that can influence a drug's monopoly term. The Food and Drug Administration (FDA) requires relevant patents on a drug's substance, formulation, and approved uses to be listed in its Orange Book; these are the only patents that may extend a drug's period of monopoly protection. With these simplifications, my estimates of imperfect intellectual property and its impact on competition are likely conservative; the imperfections may be even larger in industries where the definition of a product is more complex and involves patents on numerous component products with nebulous scope (consider, e.g., a smartphone).

Figure 1 offers a visual depiction of the differences between the standard and imperfect models of intellectual property rights under the simplifications of the pharmaceutical sector. Under the standard model, there is a fixed period of protection while the only patent is in effect. After its expiration, competitors may choose to enter or not with an imitation product. Under the imperfect model, there is a fixed initial period of protection for the primary patent that is fully enforced and an uncertain monopoly extension afterwards, due to uncertain scope and enforcement of the secondary patents. This extension term becomes the empirical outcome of interest in the instrumental variables analysis.

As a motivating example, consider the antiretroviral drug Kaletra—used in the treatment of HIV and recently studied as a possible therapy for COVID-19 (Cao et al., 2020). Kaletra, a combination of the active ingredients lopinavir and ritonavir, is protected by 28 separate Orange Book patents

Figure 1: Standard vs. imperfect IP models



and 5 regulatory exclusivities—another form of IP protection granted to pharmaceuticals by the FDA, described in more detail in Section 2. The drug was launched in the U.S. in September 2002, and its primary patent expired in May 2014. Generic entry, however, did not occur until December 2016, after the expiration of several secondary patents and more than 2.5 years after the primary patent expiration. This paper aims to quantify the degree to which such extensions in a drug's monopoly life are attributable to secondary patent accumulation.

My empirical analysis combines several sources of data for the pharmaceutical industry, including information on each drug patent and exclusivity from the FDA, approval dates for branded drugs, and corresponding launch dates for each drug's first generic entrant. I focus on new chemical entities (NCEs) approved between 1985 and 2010. New chemical entities are those drugs with an entirely new active ingredient never before approved by the FDA (Thomas, 2017). For example, Prozac, launched in 1987 for the treatment of depression, is the first drug approved with active ingredient fluoxetine and an NCE; its product extensions with the same active ingredient—Prozac Weekly and Sarafem—are not. Focusing on NCEs means that my estimates will offer a lower bound on the extent to which IP imperfections lengthen monopoly life in that they do not include the effects of product extensions under new brand names.[2]

From these sources, I construct three novel analytic datasets. The first is a drug-level dataset of 431 NCEs, used in descriptive analyses. The second is a drug-month-level dataset following each NCE from branded launch through generic entry. Drugs are observed for 178 months on average (from branded launch through generic entry), yielding a total of 68,394 drug-month observations. I use this dataset to explore the mechanisms underlying how imperfect IP rights influence first generic entry timing. The third dataset is a drug-application-level dataset merging each NCE

[2]That is, a branded manufacturer may take out additional patents on its planned product extensions and launch these as the NCE's monopoly protection is set to expire. In recent work, Fowler (2019) confirms such launch timing of product extensions.

with its secondary patent applications (both granted and rejected) from the United States Patent and Trademark Office (USPTO).[3] The matched dataset, restricted to drugs that obtain secondary patent applications and have non-missing values of control variables, covers 267 NCEs and 6,572 drug-application observations and is used in the instrumental variables analysis.[4]

In the first part of the paper, I provide descriptive evidence on the presence of imperfect intellectual property rights and the duration of monopoly protection. First, I show that multiple IP rights cover a single product. In particular, the average drug is covered by 4 Orange Book patents and 3.2 regulatory exclusivities.[5] Second, I show that actual monopoly terms last beyond initial protection terms. On average, NCEs have an initial monopoly life—meaning time from branded drug launch to primary IP expiration—of 10.9 years. Average effective monopoly life—meaning time from branded drug launch to first generic entry—is 13.1 years. Of course, this 2.2-year extension in monopoly life cannot be considered a causal result of secondary patents, due to systematic differences in drugs that have more patents relative to those that do not and the endogenous nature of generic firms' decisions on which markets to enter. Third, I show that not all IP are enforced. The mean potential monopoly life—time from branded launch to the final secondary IP expiration—is 17.6 years. This is the monopoly term the average NCE would receive if all its secondary IP were fully enforced.

In the second part of the paper, I estimate the causal impact of an additional patent on a drug's monopoly term. Underlying endogeneity concerns stem from the interrelatedness of branded manufacturers' patenting decisions and generic manufacturers' entry decisions: Branded firms want to protect their most valuable drugs with additional patents; these are the same markets generic firms want to enter earlier, putting the drugs at risk of shorter monopoly terms. I employ an instrumental variables analysis using secondary patent applications for a drug; I evaluate the impact of whether a secondary application is granted on a drug's *extra* monopoly life (meaning time from primary IP expiry to generic entry). Looking at patent applications accounts for endogenous selection by branded firms into *applying* for a patent. Assuming that conditional on an application, whether a secondary patent is granted is not as good as random, it is necessary to find an instrument for whether the application is *granted*. For this purpose, I construct a measure of examiner leniency; such examiner designs have become increasingly popular in the economics literature across a variety of settings (e.g., Arnold et al., 2018; Farre-Mensa et al., 2020; Kling, 2006; Sampat and Williams, 2019). The relevance condition for a valid instrument is readily satisfied: A 10-percentage-point increase in an examiner's average grant rate is associated with a 5.7-percentage-point increase in the likelihood a secondary drug patent application is granted. The exclusion restriction requires that examiner leniency only affects extra monopoly life through the likelihood a patent application

[3] Technically, patent applications are never rejected by the USPTO but rather abandoned by the applicant. I use the term "rejected" throughout the paper to refer to these applications.

[4] Specifically, I include as controls a drug's market size and therapeutic area, discussed more fully in Section 5.

[5] I focus on patents listed in the FDA's Orange Book as these are the patents which generic firms must account for when they seek to enter a market. Number of total patents on a drug, including those not listed in the Orange Book, is much higher on average.

is granted, which is a reasonable assumption. The IV analysis indicates that a randomly granted secondary patent extends monopoly life by 10.6 months. Given that the average drug applying for secondary patents has 3.4 secondary Orange Book patents obtained prior to generic entry, this would suggest 36 months, or 3 years, of extra monopoly life per drug attributable to patent accumulation. Given a mean actual monopoly life of 13.4 years for these drugs, this suggests secondary IP rights account for 22 percent of a drug's monopoly term.

In the third part of the paper, I explore the mechanisms through which secondary IP influence first generic entry timing. I posit that secondary IP delay generic entry in two ways: by introducing a binding later IP expiration and by increasing uncertainty in the scope or enforceability of remaining IP rights. I then provide a series of descriptive evidence consistent with these mechanisms. Visual bunching evidence confirms that IP extensions are binding in their delay of generic entry: While 20 percent of branded drugs see their first generic entrant at primary IP expiry, another 8 percent see generic entry at exactly the time of a later secondary IP expiration. For those drugs with non-binding IP expirations—whose first generic enters either after all IP have expired or between IP expirations—I exploit variation in the number of secondary IP on a drug to disentangle the sources of delayed entry. I separate uncertainty in market profitability from uncertainty in IP scope/enforceability and find that the latter is an important factor.

Finally, I explore how these imperfections in intellectual property rights may influence our discussions of optimal IP policy and innovation incentives. I follow Krieger et al. (2022) to develop a measure of novelty for each drug in my sample based on its molecular structure and correlate novelty with resulting monopoly extensions. I find that more novel drugs receive longer monopoly extensions: A one-standard-deviation increase in novelty is associated with 6.1 months of additional monopoly extension. However, these monopoly extensions produce only a minimal increase in new drug development relative to the consumer welfare loss from monopoly pricing. Back-of-the-envelope calculations suggest a consumer welfare loss due to monopoly pricing of between $3.6 billion and $12.2 billion per new molecule approved, substantially larger than the costs of new drug development. This suggests that imperfections in IP institutions allow pharmaceutical IP rights to approach a first-best system where monopoly terms reflect innovation size, yet additional targeting may be necessary to meet innovation policy objectives and encourage new molecule development.

This paper contributes most directly to the literature on intellectual property protection and incentives for pharmaceutical innovation (Branstetter et al., 2016; Budish et al., 2015; Gaessler and Wagner, 2019; Gilchrist, 2016; Higgins et al., 2020; Mohapatra and Zhang, 2020). These papers evaluate how intellectual property duration affects outcomes such as new product introductions, R&D investment, or project continuation decisions but do not explore how firms can influence that IP duration. In particular, Budish et al. (2015) suggest that the fixed-term patent system reduces incentives for longer-term research due to the lag between discovery (when a drug is first patented) and commercialization. I add to this research by showing that an innovating firm may

extend its product's monopoly term beyond the initial fixed patent term by accumulating patents on the product. If firms with products requiring longer development times offset reductions in the initial term by acquiring more patents, then the distortions of the fixed-term system may be less than previously assumed. Conversely, if the products acquiring monopoly extensions are those that do not require greater development costs or time, then imperfect intellectual property rights may exacerbate the distortions of intellectual property design. My work thus offers an important nuance that intellectual property rights are less rigid than we typically assume and that these imperfections can alter our discussions on optimal patent policy and innovation.

The extent to which imperfect IP rights extend monopoly life is also important due to the trade-off inherent in intellectual property protection: A longer patent life encourages firms' ex-ante incentives to innovate but also increases the deadweight loss resulting from monopoly pricing (Nordhaus, 1969). Quantifying the causal impact of an additional patent on monopoly extension is thus a requisite first step in any evaluation of intellectual property policy. Within the pharmaceutical industry, related papers have explored the patenting propensity of branded pharmaceutical firms and corresponding patent challenges by generics (Grabowski et al., 2017; Grabowski and Kyle, 2007; Hemphill and Sampat, 2011, 2012). I build on this literature by estimating the causal impact of secondary patenting on monopoly life. To my knowledge, I provide the first such causal estimate of the extent to which additional patents extend innovators' monopoly protection in any industry.

My research on imperfect intellectual property rights relates to other work on non-standard intellectual property. Lemley and Shapiro (2005) provide an overview on the economics of "probabilistic patents"—including uncertainty in the commercial significance of a granted patent or in the scope and enforcement of the patent—and Bessen (2009) offers a theoretical treatment of contracting in the presence of imperfect IP rights. In their study of patent grant delays and cooperative licensing, Gans et al. (2008) detail the various types of uncertainty that exist in intellectual property rights. I offer a contribution by empirically documenting the extent and consequences of imperfect intellectual property rights at the product level in a key sector of the U.S. economy.[6]

The remainder of this paper proceeds as follows: Section 2 provides institutional details related to the pharmaceutical industry. Section 3 describes the data. Section 4 documents the existence of imperfect IP and of monopoly power beyond the initial patent term. Section 5 estimates a causal impact of secondary IP on monopoly term extension, and Section 6 explores the underlying mechanisms. Section 7 discusses implications for optimal IP policy and innovation. Section 8 concludes.

[6]My work relates to empirical studies in other sectors on cross-firm patent thickets (Galasso and Schankerman, 2010; Hall and Ziedonis, 2001; Noel and Schankerman, 2013; Ziedonis, 2004) and within-firm strategic patenting (Abrams et al., 2018; Cockburn and MacGarvie, 2011; Hegde et al., 2009; Kurakina, 2020; Noel and Schankerman, 2013; Righi and Simcoe, 2020). In the pharmaceutical sector, Frakes and Wasserman (2020) study how examiner time allocations relate to the granting of patents of weaker validity. The analyses of these papers occur at either the industry, firm, or patent level. By explicitly attaching patents to products, my paper considers imperfections at a different unit of analysis (the product level) and corresponding impacts to monopoly protection.

2 Background: The pharmaceutical industry

The Drug Price Competition and Patent Term Restoration Act of 1984, more commonly known as the Hatch-Waxman Act, established today's system of both drug regulation and intellectual property protection (Eisenberg, 2001). Meant to balance the competing interests of generic and "Big Pharma" manufacturers, the act was a "complex legislative compromise" that had dual goals of simultaneously fostering the generic drug industry while providing additional protections to branded drugs (Angell, 2005; Eisenberg, 2001, p. 121). This section briefly describes branded drug development and approval, the intellectual property protection available for small-molecule drugs, the generic entry process, and proposed reforms to pharmaceutical IP protection. For an overview of the pharmaceutical industry more generally, see Lakdawalla (2018).

2.1 Branded drug development and approval

Drug development begins with discovery of a new molecule. Once a molecule is designed, the firm will patent it (see more on drug patenting below), and the molecule begins preclinical, nonhuman testing. Successful drug candidates will then move through successive phases of clinical trials in human volunteers to establish safety and efficacy. Preclinical and clinical trials for a new molecule can take 10 years on average, upon the conclusion of which a manufacturer will submit a New Drug Application (NDA) to the FDA for approval, including the results of all phases of testing (PhRMA, 2015). Only after FDA approval can a manufacturer market a drug to consumers. While estimates vary, development of a brand new molecule is costly, ranging from $500 million to $2 billion per drug, depending on the therapy and manufacturer (Adams and Brantner, 2006).[7] As such, intellectual property protection is considered necessary to incentivize firms to undertake these high costs of development.

2.2 Intellectual property protection

The pharmaceutical industry is unique in that it receives intellectual property protection not only via patents granted by the USPTO but also via regulatory exclusivities by the FDA (Eisenberg, 2001). I describe here the two types of IP protection provided for pharmaceutical manufacturers.

2.2.1 Drug patents

Drug patents extend 20 years from the date of USPTO application and cover one of four characteristics: (1) the drug substance, or active ingredient; (2) its use for treating a certain indication; (3) its formulation, including both the physical form (e.g. liquid or capsule) and administration route (e.g. by mouth or injection); and (4) the manufacturing process to make the drug (Angell,

[7] Development costs for new drugs that make use of an already approved molecule are substantially reduced (according to Chong and Sullivan (2007), by about 40 percent). As existing molecules have already demonstrated safety in clinical trials, producers can typically obtain approvals for new uses of those drugs with fewer resources, i.e., time, money, and trial subjects (Hernandez et al., 2017).

2005). Once a molecule is developed, the branded firm will patent its active ingredient; this patent offers the strongest form of protection and is considered the primary patent. We think of primary patents as having certain enforcement. Secondary patents, covering one of the other three characteristics, are filed over the course of a drug's development and even after its launch. Multiple patents covering the same product can extend effective patent life, and Angell (2005) notes that even the pill colors and coatings can be patented. Hatch-Waxman also provides for a single USPTO patent term extension per new active ingredient of up to 14 years to account for time in which a drug is in development or under FDA review; branded manufacturers typically choose to apply this extension to the primary, or strongest, patent. Note that while patents last from 20 years after their initial filing, the *effective* patent term is typically smaller, due to the lag between when a patent is obtained (during the drug discovery/development process) and when a product is launched.

Hatch-Waxman requires branded manufacturers to list relevant patents (covering either the drug substance, formulation, or approved uses) in the FDA's Orange Book (Angell, 2005).[8] When a generic firm wants to enter a market, it must account for those patents listed in the Orange Book. As a drug substance patent is the first filed, it often expires before the secondary ones. The scope of secondary patents are described in the Orange Book under use codes or descriptions provided by manufacturers; the FDA relies on these descriptions rather than an actual reading of the patent claims when making generic approval determinations (Rai, 2012). As such, branded firms have previously employed a tactic of listing overly broad use codes in the Orange Book that exceed the actual scope of the patent (Rai, 2012). Under Hatch-Waxman, generic manufacturers, meanwhile, can file a "Paragraph IV certification" or challenge to a branded drug's remaining patents (described in more detail below).

2.2.2 FDA regulatory exclusivities

The Hatch-Waxman Act established a second pathway for IP protection for branded drugs—regulatory exclusivities from the FDA. They are granted once a drug is approved for marketing, and during periods of exclusivity, generic manufacturers cannot enter the market.[9] While patents are submitted to the USPTO for approval, exclusivities are submitted to the FDA. In applying for exclusivities, applicants may submit studies that were conducted by another entity—meaning manufacturers can rely on (1) clinical data or literature from other companies and/or (2) the FDA's prior safety and efficacy findings from an approved drug—thus lowering their burden of proof. Patent terms and exclusivity periods may or may not run concurrently, depending on the type of exclusivity (FDA, 2018).

[8] Unapproved uses and manufacturing processes should not be listed in the Orange Book.

[9] These exclusivities actually take two different forms: (1) data exclusivity and (2) marketing exclusivity. Data exclusivity covers a firm's clinical trial data on safety and efficacy. During periods of data exclusivity, generic manufacturers may not rely on the original firm's data to submit an abbreviated new drug application (ANDA, described in Section 2.3; however, generic firms are free to develop and submit their own full NDA. Marketing exclusivity prevents generic firms from submitting either application to the FDA irrespective of where the clinical trial data come from (Thomas, 2017). Effectively, exclusivities—whether data or market—forestall generic entry.

Numerous different exclusivities exist to protect branded drugs. New chemical entity (NCE) exclusivity is a 5-year protection starting from drug launch for a new active ingredient never before approved by the FDA (Thomas, 2017). Exclusivities may also be given to existing drug products. Changes to approved drugs result in a three-year clinical investigation exclusivity (CIE), including changes in dosage form or dosing regimen, administration route, strength, disease indication, and change from a prescription (Rx) to an over-the-counter (OTC) indication, among others (FDA, 1999; Thomas, 2017). Other exclusivities include those for orphan drugs, for approved medicines that undergo subsequent pediatric clinical trials, and for infectious disease products. Appendix Table 8 provides more detail on these key exclusivities; see Thomas (2017) for a description of all 16 FDA exclusivities that currently exist.

2.3 Generic entry

The Hatch-Waxman Act also provided a pathway for generic entry—the Abbreviated New Drug Application (ANDA)—which lowered the burden of evidence required for generic drug approval. Prior to the act, generic manufacturers were required to submit full NDAs proving safety and efficacy of their drugs. An ANDA allows the generic manufacturer to rely on clinical trial data of the original manufacturer and instead show only bioequivalence to the original branded drug. Note that generic drugs contain the same active ingredient, in the same dosage form, same strength, and route of administration as the original drug. The time and costs of generic development are nontrivial. Copying a branded drug and conducting bioequivalence studies can take a few years, and the ANDA approval process requires both factory inspections by the FDA and laboratory tests of the generic product. Thus, although substantially lower than the costs required for branded drug development, there are still sizeable sunk costs of entry for a generic manufacturer, estimated to be between $250,000 and $20 million per ANDA (Scott Morton, 1999).

A generic firm may submit an ANDA to the FDA four years after NCE launch, although actual entry cannot occur until at least one year later, after the NCE exclusivity has expired. At the time of application, a generic firm must account for a drug's patents listed in the Orange Book and all remaining exclusivities. That is, the generic entrant must specify its intended market entry date and show that, by that date, any unexpired IP on a drug will either be invalid or that the generic can enter without infringing upon those remaining IP. The FDA may then tentatively approve a generic application, with official approval coming only after the scope/enforceability of remaining IP has been fully determined.

Hatch-Waxman created a specific process by which such determinations occur. Specifically, generic firms may submit a Paragraph-IV challenge of a branded drug's remaining patents on the grounds of either non-infringement or invalidity.[10] When a generic manufacturer files an ANDA with a Paragraph-IV certification, the branded firm can either (1) do nothing or (2) sue (within 45 days)

[10]Under non-infringement, generic firms seek approval for the generic with a narrower labeling that excludes on-patent uses.

the generic manufacturer for patent infringement. If the branded firm does nothing, then the FDA may approve the generic drug.

If the branded manufacturer sues, then there is an automatic stay on FDA approval to allow for ensuing litigation or a settlement. If the courts decide in favor of the branded firm, then the patent challenge fails and the FDA will not approve generic entry. For the generic firm that chooses to submit an ANDA while patents remain on a drug, they thus risk potentially large litigation expenses (and the previously incurred development expenses) without guarantee of approval. Whenever a first court ruling decides in favor of the generic (that either all or some remaining secondary patents are unenforceable), the stay ends and the FDA will officially approve generic entry. Generic entry can occur immediately if all remaining patents are deemed unenforceable. If there is partial enforcement, i.e., at least one remaining secondary patent is fully enforced while others are deemed unenforceable, then generic entry can occur at the point at which those fully enforced patents expire. The first generic firm to win a patent challenge receives 180 days of generic exclusivity, during which time the branded firm and generic challenger constitute a duopoly. After the 180 days, other generic manufacturers may submit ANDAs and enter the market. (Branstetter et al., 2016). Thus, a trade-off exists for the first generic entrant for a drug: Earlier entry gives it the opportunity to earn duopoly profits but comes with greater uncertainty about IP enforceability, raising potential litigation costs.

Scholars disagree on the impact of additional IP to generic entry. One view holds that secondary patents and exclusivities would have little effect in forestalling generic entry since generic manufacturers theoretically can enter after the primary IP expiration (i.e., the latter expiration of either the active ingredient patent or NCE exclusivity). For instance, if a brand new molecule is initially approved by the FDA for the treatment of depression and then subsequently obtains secondary IP for the treatment of bipolar disorder, a generic manufacturer theoretically could enter the market for depression at the primary IP expiration. Indeed, in line with this view, the pharmaceutical industry is often described as a "one-patent-one-product" industry (Burk and Lemley, 2003). Yet other scholars note that strategic patenting practices by branded manufacturers still create a considerable barrier to generic manufacturers for entry for any use, as they must navigate an "infringement minefield" of all potential infringement cases that could result (Furrow, 2008; Tribble, 2019). That is, there is considerable uncertainty in the scope and enforceability of secondary IP that must be resolved. I settle this debate by providing systematic evidence on when generic entry occurs relative to a drug's primary and secondary IP expirations and estimating the causal impact of secondary IP to monopoly term.

2.4 Proposed reforms to pharmaceutical IP

Various legislative proposals have suggested reforms to IP policy in the pharmaceutical industry to limit the extent to which IP imperfections extend a drug's monopoly life. These include reducing exclusivity periods and restricting CIE to drugs showing significant clinical benefit relative to

existing therapies (Thomas, 2017). Other proposals similarly suggest raising the threshold for patentability, as is the case in other countries. India, for example, requires higher standards for nonobviousness, and any patent applications that claim improvements over existing drugs must show evidence of clinical benefit; Brazil and Argentina have similar requirements for secondary patents (Amin and Kesselheim, 2012; Sampat and Shadlen, 2017).[11] A first step to evaluating any such change to IP policy is to quantify the impact of secondary intellectual property protections for pharmaceuticals on resulting monopoly terms and generic entry.

3 Data

This project draws from several data sources. The main source of information on drug approvals, patents, and exclusivities is the FDA. Historical FDA Orange Books list all relevant patents and exclusivities and their expiration dates for each small molecule drug in the US.[12] I supplement these data with information from the Drugs@FDA database, including approval dates for branded and generic drugs (FDA, 2019). Due to inconsistencies in the FDA data in generic approval dates, I manually review news articles and press releases from generic manufacturers to confirm precise launch dates for all drugs in my sample. This is important for a study on monopoly protection as the FDA data provide tentative approval dates, meaning when a generic is approved pending the outcomes of any ongoing patent litigation. Consequently, the actual final approval and corresponding launch dates may differ dramatically from the tentative date. For my analysis, I use generic launch dates rather than approval dates to obtain a fully complete measure of a branded drug's monopoly life, as the launch date may lag behind the approval date. More details on each granted patent as well as all patent applications (both granted and rejected) come from the USPTO.[13] I determine drug market size using the Medical Expenditure Panel Survey's (MEPS) Prescribed Medicines Files and therapeutic area using the World Health Organization's Anatomical Therapeutic Chemical (ATC) classification system (AHRQ, 2020; WHO, 2019).[14]

From these sources, I create three novel analytic datasets. The first is a drug-level dataset of 431 new chemical entities (NCEs) approved between 1985 and 2010.[15] Focusing on NCEs means that my estimates will offer a lower bound on the extent to which secondary patenting lengthens monopoly life (by excluding the effects of product extensions under new brand names). Key variables include

[11] Sampat and Shadlen (2017) find little effect of India's and Brazil's policies to limit secondary grant rates and greater impact of Argentina's policies. They focus on the granting of these patents; I estimate the impact of granted secondary patents on monopoly terms in the U.S.

[12] I obtained these data from Heidi Williams's website; the data are described in Durvasula et al. (2023).

[13] Specifically, I use the following USPTO datasets: PatentsView, Patent Examination Research Dataset, Patent Assignment Dataset, Patent Claims Research Dataset, and Historical Patent Data Files. These can be obtained from https://www.uspto.gov/ip-policy/economic-research/research-datasets.

[14] Since the MEPS data begin in 1996, I calculate a drug's market size as its average for all years for which it is present in the data; this method thus includes drugs approved prior to 1996. I manually clean the MEPS data to match on branded names with the drugs in my sample.

[15] These 431 NCEs are those that have a generic entrant as of the time of data collection. Empirically, the restriction to NCEs with a generic entrant is necessary so that I have a measure of each drug's actual monopoly life. NCEs which are not included in the sample are those approved by 2010 that have not yet experienced generic competition.

branded approval date, generic launch date, and the start and expiry of each intellectual property right. One challenge is determining which of a drug's IP is primary and which are secondary. I consider a drug's molecule patent to be the one receiving a USPTO patent term extension and in the case of no such extension, the earliest patent filed. I take the primary IP expiry to then be the latter of either the molecule patent or NCE exclusivity expiry. All subsequent patents and exclusivities are secondary.

The second is a drug-month-level dataset of these NCEs from branded launch through the month of first generic entry. Drugs are observed for 178 months on average, yielding a total of 68,394 drug-month observations. This dataset tracks the periods during which each patent or exclusivity is in effect, and I use it to explore the mechanisms behind how imperfect IP influence first generic entry timing.

The third dataset is a drug-application-level dataset merging each NCE with its secondary patent applications, both granted and rejected. Attaching patent applications to products is not a straightforward task and existing work on patent applications generally employs industry-, firm-, or patent-level analyses. I thus offer a methodological contribution that could potentially be applied to future work in other sectors. Construction of this dataset requires restricting the universe of all USPTO patent applications to the set of drug applications and determining which of these applications correspond to each NCE. I attach a patent application to a drug if its brief summary or claim text includes its active ingredient and if its assignee is one of the assignees for the drug's granted patents listed in the Orange Book. Because of the high degree of M&A activity in the pharmaceutical industry, I hand collect data on nearly 500 M&A events involving large pharmaceutical firms and match drugs and assignees to their parent firms as of today; this ensures patent applications are correctly attached to a drug even when the drug manufacturer changes over time. I also include parent and child applications of Orange Book patents. I restrict to drugs that apply for secondary patents and have non-missing values of control variables. The matched dataset includes 267 NCEs and 6,572 drug-application observations.[16] I use this final dataset in the OLS and IV application-level analyses of the impact of secondary patents on extra monopoly life. More details on the construction of this dataset are available in Appendix A.2, and summary statistics on the number of applications and grant rates per drug are in Appendix A.3.

3.1 Definitions

I list below definitions for key terms used throughout the paper.

Primary versus secondary IP:

- *Primary IP*: Either the drug's molecule patent or NCE exclusivity (whichever has a later

[16] The reduction in sample size from 431 to 267 NCEs is primarily due to the restrictions to drugs with secondary patent applications and to drugs with non-missing market size. Due to the survey nature of the MEPS data, drugs with low market sizes or received in hospital settings will have missing values for market size.

expiration date). Typically the strongest IP on a drug, with certain enforcement
- *Secondary IP*: All of a drug's other patents/exclusivities obtained after the primary IP, covering auxiliary features and uses

Measures of monopoly duration:

- *Initial monopoly term*: Time from branded launch to primary IP expiry
- *Potential monopoly term*: Time from branded launch to final IP expiry
- *Actual/effective monopoly term*: Time from branded launch to generic entry
- *Extra monopoly life/monopoly extension*: Time from primary IP expiry to generic entry (dependent variable in Section 5 analyses)

4 Existence of imperfect IP

I present in this section a series of descriptive statistics invalidating the standard "one-patent-one-product" model that is often ascribed to the pharmaceutical sector. I show that firms obtain multiple IP rights per drug product, that not all IP rights are enforced, and that monopoly terms across drugs vary, lasting beyond the initial term indicated by the primary IP.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Number of Orange Book patents	4	4	0	28
Number of FDA exclusivities	3.2	2.5	1	16
Initial monopoly term (years)	10.9	4.2	0.3	23.1
Potential monopoly term (years)	17.6	6.9	3	45.8
Actual monopoly term (years)	13.1	4.6	0.6	32.7

Total number of drugs is 431. All monopoly terms are relative to branded launch.

Table 1 provides summary statistics on IP accumulation and monopoly life. The first key takeaway from this table is that multiple IP may cover a single drug. The average drug is protected by 4 Orange Book patents and 3.2 FDA exclusivities, with substantial cross-drug heterogeneity in that IP acquisition.[17] For example, HIV treatment Kaletra, discussed previously, is covered by a maximum 28 Orange Book patents, and Gleevec (imatinib), an oral chemotherapy medication used for leukemia, is covered by a maximum 16 FDA exclusivities.

The bottom three rows of Table 1 look at different measures of IP duration. If drugs were restricted to solely their primary (or initial) IP, they would experience an average monopoly life of 10.9 years on the market.[18] (Note that this measure restricts to time on the market post-launch—from branded

[17] The patent numbers focus on patents specifically listed in the Orange Book; these patents cover a drug's substance, formulation, or approved uses and are the ones generic firms must account for when they seek to enter a market. A branded firm may also take out other patents that are not listed in the Orange Book, such as patents on manufacturing process. Appendix Table 9 provides detail on per-drug patent applications, including total number granted and rejected.

[18] All drugs in the sample are new chemical entities (NCEs) and thus receive a 5-year NCE exclusivity. The

launch to primary IP expiry—and does not include time when the drug may have been protected by a primary patent but still in development). The fourth row gives statistics on potential monopoly term—time from branded launch to final IP expiry. This represents the monopoly life a branded firm would experience if all secondary IP were fully enforced, 17.6 years on average. Comparing this row to the final row indicates that for at least some drugs, not all IP are enforced. That is, when generic entry occurs, additional patents or exclusivities may still be in place but are deemed unenforceable in terms of preventing generic entry. We infer this because mean actual effective monopoly life—time from branded launch to generic entry—is 13.1 years, or 4.5 years shorter than the mean potential term. Note that this actual monopoly term, or time to generic entry, is 2.2 years longer than the initial monopoly term. Subsequent analyses will evaluate the extent to which such extensions in monopoly life represent a causal impact of secondary IP rights.

Figure 2: Distributions of initial and actual monopoly terms

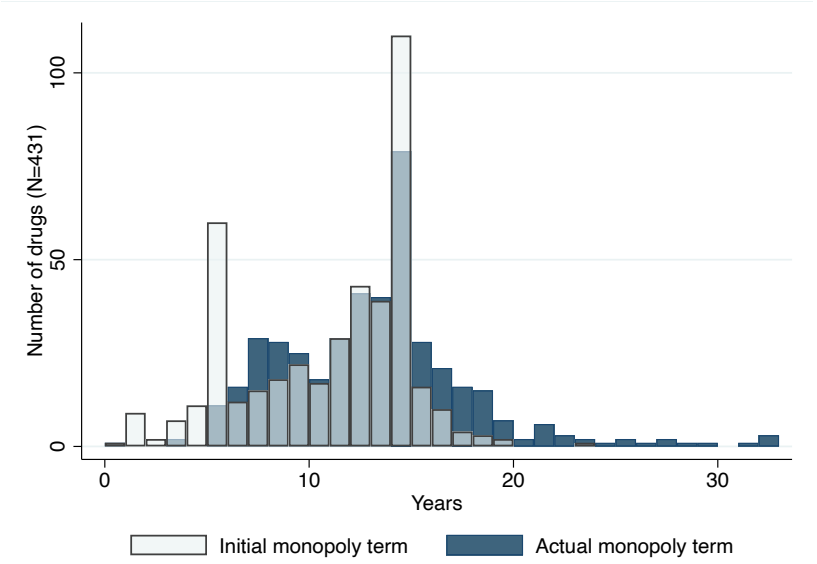


Figure 2 compares the distributions of initial and actual monopoly terms.[19] Two noteworthy facts emerge from this figure. First, there is substantial heterogeneity across drugs in both time to primary IP expiry and in time to generic entry. Second, the distribution of monopoly life shifts right once secondary IP is included, i.e. the distribution of time to generic entry is to the right of that of time to primary IP expiry. This figure suggests that considering only the fixed initial term of the primary IP may result in an incomplete measure, or underestimate, of a product's monopoly

minimum initial monopoly term in Table 1 (0.3 years) is below 5 years because in a handful of cases, the branded manufacturer discontinued its original product and transferred the remaining exclusivity period to another product with the same active ingredient. In other cases, a branded manufacturer licensed rights to its drug to a different manufacturer who then received the remaining exclusivity.

[19]Two spikes are present in the distribution of initial monopoly terms, one at 5 years and one at 14 years. The first spike at 5 years represents those drugs for which the 5-year NCE exclusivity is the primary IP. The second spike at 14 years results from a limit on the USPTO patent term extension to 14 years past the drug's launch date.

term. Future research on optimal IP design and innovation should incorporate this potential for products to experience monopoly extensions.

The section confirms that intellectual property rights in the pharmaceutical industry are imperfect: multiple IP cover a single drug, not all of those IP are enforced, and drugs experience varying terms of monopoly protection that can last beyond the initial term. The next section estimates the causal effect of imperfect IP rights on monopoly extension, and Section 6 explores the channels through which those rights influence generic entry timing.

5 Causal impacts to monopoly term

5.1 Naive analysis: Comparing drugs by number of secondary patents

Estimating a causal impact of secondary IP on monopoly life is difficult due to endogeneity concerns stemming from both the branded firm's decision to patent and the generic firm's decision to enter a market. The naive analysis would simply compare drugs with secondary IP to those without and observe resulting monopoly terms. If intellectual property rights were as good as randomly assigned, this would be enough to estimate a causal effect of secondary IP. Two main endogeneity concerns make such an analysis problematic. First, there is the potential for omitted variable bias: Characteristics of a drug that are unobservable to the researcher may influence both the branded firm's decision to patent and the generic firm's decision to enter (and hence, the monopoly life of a drug). Stated differently, there is selection into patenting in that drugs with secondary IP are systematically different from those without. Second, there is a reverse causality concern: The branded firm may anticipate the end of its monopoly life and as a result, attempt to obtain more intellectual property to forestall entry.

Intuitively, branded firms want to protect their most valuable or promising drugs with additional IP, and these are exactly the drugs that generics want to copy (which would shorten a drug's effective monopoly life). By not accounting for this selection into patenting or unobserved attractiveness to generic entry, then the estimated coefficient on a simple regression of monopoly life on number of secondary IP would be biased. I present the naive analysis in Table 2. For comparison with subsequent analyses, I focus specifically on secondary patents.[20]

I regress a drug's *extra* monopoly life in months (meaning time between primary IP expiry and generic entry) on its number of secondary Orange Book patents obtained prior to generic entry; I restrict to Orange Book patents as these are the ones which generic firms must account for when they seek to enter a market. Column (1) shows this basic regression; the coefficient of interest is insignificant. A first solution to improve the naive analysis would be to add controls to proxy for a drug's unobserved characteristics. Column (2) adds fixed effects for branded drug approval year,

[20] Appendix Table 10 gives the naive analysis using number of all secondary IP (both Orange Book patents and FDA exclusivities) as the main explanatory variable.

Column (3) adds fixed effects for therapeutic area, and Column (4) adds a control for market size. Scott Morton (1999) shows that therapeutic area and market size are important for generic entry decisions; their inclusion helps control for attractiveness to a generic firm.[21] Moving left to right across the table we see that the addition of these controls does help explain the total variation in extra monopoly life and that their inclusion further raises the coefficient on the number of secondary patents. Finally, as expected, drugs with larger markets have shorter extra monopoly terms and controlling for this raises the estimated coefficient on number of secondary patents. Looking at the specification in Column (4), with both sets of fixed effects and the control for market size, suggests that each secondary Orange Book patent is associated with an additional 1.7 months of monopoly life.

Table 2: Secondary patents and extra monopoly life: Drug-level analysis

	(1)	(2)	(3)	(4)
# secondary patents	0.452	0.406	0.642	1.705**
	(0.810)	(0.866)	(0.882)	(0.824)
ln(market size)				-8.706***
				(1.921)
Observations	324	324	324	324
Adj. R^2	-0.002	0.084	0.162	0.211
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes

Dependent variable in all regressions is extra monopoly life in months (i.e., from a drug's primary IP expiry to generic entry). Analysis at the drug level. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

5.2 Comparing granted versus rejected secondary patent applications

Even with the inclusion of these controls, it is plausible that observed differences in monopoly life across drugs may still reflect selection of which drugs are patented rather than a causal effect of secondary patents on delaying generic entry. Thus, a next step would be to compare monopoly terms for drugs in accepted versus rejected secondary patent applications. If conditional on being included in an application, whether a patent is granted is as good as random, then such an analysis would imply a causal effect. I match drugs to their patent applications and carry out a drug-application-level analysis.[22] The regression specification is as follows, with d indexing drugs and j indexing applications:

$$Extra_d = \beta \mathbb{1}\{Granted\}_{dj} + \delta_{approval\ year_d} + \delta_{therapeutic\ area_d} + ln(market\ size_d) + \epsilon_{dj} \quad (1)$$

[21] Requiring drugs with non-missing market size reduces the sample size because the MEPS survey data do not capture (1) drugs with low market sizes and (2) drugs that are received in hospital settings, e.g., chemotherapy drugs.

[22] Appendix A.2 describes this matching process in detail.

The dependent variable is again a drug's extra monopoly life and the main explanatory variable is an indicator for whether or not each secondary patent application for that drug is granted. Because the treatment (whether a patent is granted or not) is at the application level, I follow Abadie et al. (2023) and use robust standard errors.

Table 3 presents the OLS results of the application-level analysis, with Columns (1) through (4) adding the same controls as before. The increase in the coefficient on $\mathbb{1}_{Granted}$ relative to the estimates of the naive analysis confirms a selection into patent applications. Moving across specifications from left to right, the increase in the adjusted R-squared indicates that there is substantial heterogeneity across drugs and these controls soak up variation in the model. The preferred specification in Column (4) suggests that each secondary Orange Book patent application granted is associated with 6.3 months of additional monopoly life.

Table 3: Secondary patents and extra monopoly life for drugs in granted versus rejected applications: Application-level analysis

	(1)	(2)	(3)	(4)
$\mathbb{1}_{Granted}$	4.887***	7.343***	6.258***	6.295***
	(1.852)	(1.708)	(1.633)	(1.633)
ln(market size)				-1.498***
				(0.393)
Observations	6,572	6,572	6,572	6,572
Adj. R^2	0.027	0.135	0.277	0.278
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes

Dependent variable in all regressions is extra monopoly life in months (i.e., from a drug's primary IP expiry to generic entry). Analysis at the drug-application level; number of drugs is 267. All regressions include patent application/examiner art unit fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

5.3 Exploiting variation in examiner leniency

Comparing granted and rejected patent applications above controlled for selection into obtaining a patent *application*. It is plausible that there still remains a selection issue into whether or not a patent is *granted*. This may be the case, e.g., if branded firms devote more resources to revising a secondary patent application for certain drugs that are more valuable or more at risk of earlier generic entry. Assuming that conditional on being included in an application, whether a secondary patent is granted is *not* as good as random, the natural solution is to find an instrument for which patent applications are granted patents. I follow previous research and use the "leniency" of the assigned patent examiner as an instrument (Farre-Mensa et al., 2020; Sampat and Williams, 2019). Prior work confirms that patent examiners have considerable discretion in whether or not to grant a patent (Cockburn et al., 2003; Lemley and Sampat, 2012; Sampat and Lemley, 2010) and that

the assignment of patent applications is random conditional on application year and technology area (Sampat and Williams, 2019).[23] This type of analysis thus exploits both the variation in cross-examiner leniency and the quasi-random assignment of patent applications to examiners.[24]

I construct a measure of examiner leniency—the share of applications granted by an examiner—using a separate first-stage sample of drug-related applications that are *not* attached to the NCEs in my analytic sample.[25,26] Three criteria must be satisfied for a valid instrument: the relevance condition, exclusion restriction, and monotonicity assumption. The relevance condition requires that this measure of examiner leniency is relevant to explaining whether a patent application is granted. Table 4 gives first-stage results regressing whether a patent application is granted on the leniency measure; the table demonstrates the relevance condition is satisfied. Across specifications, the 0.57 point estimate suggests that a 10-percentage-point increase in an examiner's average grant rate is associated with a 5.7-percentage-point increase in the likelihood a secondary patent application is granted. The F-statistic of these regressions is on the order of 500, substantially above the threshold for weak instruments. The exclusion restriction requires that examiner leniency only affects extra monopoly life through the likelihood a drug's secondary patent application is granted, which is a reasonable assumption. Finally, the monotonicity assumption requires that patents granted by a stricter examiner would also be granted by a more lenient examiner, and vice versa.

Table 4: First-stage results

	(1)	(2)	(3)	(4)
leniency	0.577***	0.571***	0.567***	0.567***
	(0.0256)	(0.0254)	(0.0253)	(0.0253)
ln(market size)				0.00221
				(0.00344)
Observations	6,572	6,572	6,572	6,572
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes
F-statistic	506.9	503.4	501.3	501.4

Dependent variable in all regressions is an indicator for whether a patent application is granted. Analysis at the drug-application level; number of drugs is 267. All regressions include patent application/examiner art unit fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

Table 5 presents the IV results. The estimates in all four specifications are substantially larger than the OLS estimates, suggesting that, as expected, selection into whether a patent is granted indeed

[23] All regressions control for technology area with the inclusion of patent application/examiner art unit fixed effects.

[24] Righi and Simcoe (2019) raise the concern of technological specialization by patent examiners within art units. Appendix A.5 repeats the subsequent analyses adding technology class-subclass fixed effects. Coefficient estimates remain similar.

[25] Appendix A.2 provides details on the first-stage sample construction.

[26] Appendix A.6 repeats the subsequent analyses using leave-out examiner leniency as the instrument instead. Qualitative implications remain the same, with larger estimated coefficients on $\mathbb{1}_{Granted}$ using leave-out leniency.

biases the OLS estimates downward. The preferred specification in Column (4) indicates that the average effect of a randomly granted secondary patent on monopoly extension is 10.6 months. To convert this patent-level effect into a drug-level one, it is necessary to scale the coefficient estimate by the average number of secondary patents per drug. The typical drug in my sample applying for secondary patents has 3.4 of them obtained prior to generic entry. Multiplying the IV estimate of 10.6 months by 3.4 secondary patents per drug would suggest 36 months, or 3 years, of extra monopoly life per drug attributable to secondary patent acquisition.

Table 5: Secondary patents and extra monopoly life using variation in examiner leniency: IV analysis

	(1)	(2)	(3)	(4)
$\mathbb{1}_{Granted}$	10.437*	10.311**	10.682**	10.622**
	(5.395)	(5.044)	(4.542)	(4.543)
ln(market size)				-1.506***
				(0.395)
Observations	6,572	6,572	6,572	6,572
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes

Dependent variable in all regressions is extra monopoly life in months (i.e., from a drug's primary IP expiry to generic entry). Examiner leniency instruments for whether a secondary patent application is granted or not. Analysis at the drug-application level; number of drugs is 267. All regressions include patent application/examiner art unit fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

There are two key points to note in interpreting this estimate. First, it provides an estimate of the average *net* effect of secondary patents on monopoly life, irrespective of any patent application order or timing issues. This is due to the dependent variable being a drug-level measure of extra monopoly life, from primary IP expiration to generic entry. Consider the simple case of two drugs A and B. Drug A has 4 years of extra monopoly life and 4 granted patents, all filed on the same date and expiring on the same date. Each patent contributes an average of one year extra monopoly life to the drug, for a total of 4 years. Drug B also has 4 years of extra monopoly life and 4 granted patents, but they are obtained sequentially, each filed one year after the previous. As the regression specification involves a drug-level outcome, we again obtain an average contribution of one year extra monopoly life per patent, for a total of 4 years. As such, my estimate captures the average net effect of secondary patents on monopoly life, including both patent scope and length contributions.

Second, it is important to keep in mind that the IV estimate is not giving the average treatment effect but rather a local average treatment effect (LATE)—the effect of an additional patent granted on extra monopoly life for those drugs where changing examiner leniency would change whether the patent application was granted. It does not apply to those applications that would always

be granted irrespective of examiner leniency or never granted. That is, we can consider the 10.6 months as an average treatment effect specifically for those patents that are granted by a more lenient examiner but not by a stricter one. If we think that such patents are less likely to be enforced later by the courts (and hence less likely to contribute to delays in generic entry), then the LATE will underestimate the average effect of a secondary patent and this 3-year per-drug extension in monopoly life will be a conservative estimate of the extent to which secondary patents delay generic entry.

6 Mechanisms: Uncertainty in IP scope and enforceability

The prior section estimated the causal effect of secondary patents on monopoly extension. This section discusses the mechanisms through which imperfect IP delay generic entry. Looking at the timing of the first generic entrant, three patterns are apparent from the data: (1) a binding primary IP expiry for some drugs, (2) a binding secondary IP expiry for others, and (3) first generic entry after or between expirations for the remaining. The patterns suggest that there is some uncertainty in either a market's profitability or in the enforceability of a drug's secondary IP that leads to delayed (or non-binding) generic entry. I disentangle these sources of delay to show that uncertainty in IP scope/enforceability is an important mechanism behind delayed generic entry.

6.1 Binding primary and secondary IP expirations

I first explore the extent to which IP rights—both primary and secondary—are binding in blocking generic entry. Figure 3 displays the timing of generic entry in months for each drug relative to its IP expirations.[27] Panel (a) gives generic entry relative to the primary IP expiration, i.e., a drug's *extra* monopoly life relative to the standard model. The spike at 0 months shows that a drug's primary IP is binding for 86 out of 431 drugs, or 20 percent of the sample.[28] But looking at a drug's primary IP does not give a complete picture. Panel (b) thus considers generic entry relative to the branded drug's most recent (primary or secondary) IP expiration prior to generic entry. This panel confirms that with secondary IP included, the spike at month 0 rises dramatically, with another 34 drugs, or 8 percent of the sample, experiencing generic entry at exactly when a secondary IP

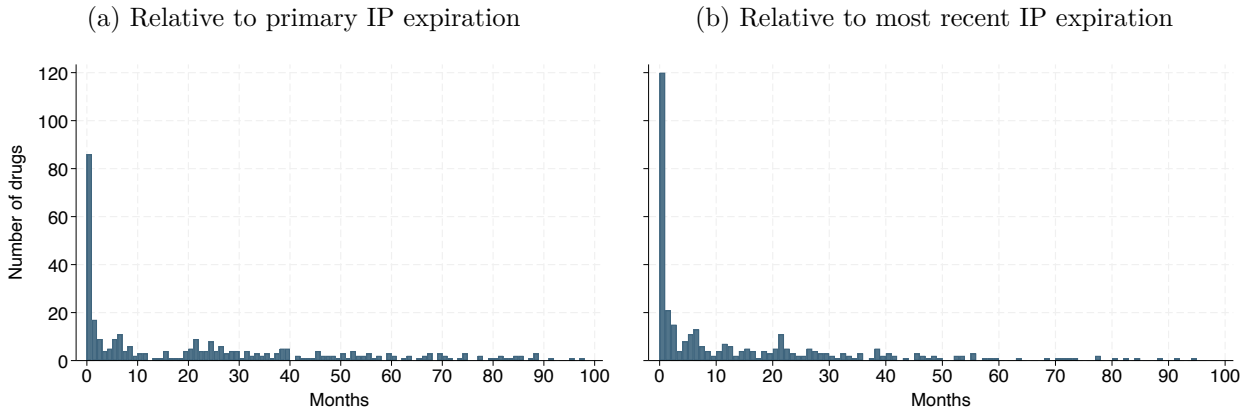
[27] For visual purposes, I limit the display of this and subsequent figures to those drugs with first generic entry timing within 100 months following the relevant IP expiration. Appendix A.8 gives the same figures without limiting the display, i.e., including the few drugs with generic entry occurring after the 100-month windows. Any sample sizes and proportions given include drugs with entry outside these windows.

[28] Note that some drugs (15 percent) see generic entry prior to primary IP expiration. These drugs may be (1) entrants that have chosen to enter at risk of infringement, (2) entrants winning a Paragraph IV challenge or obtaining a settlement agreement with the branded manufacturer, or (3) authorized generics. Authorized generics are marketed by either a separate company that has received permission by the branded firm to enter early in exchange for a portion of its profits or by the branded manufacturer itself—i.e., the branded manufacturer may choose to launch its own generic to preempt future outside generic competition. For simplicity, I exclude these drugs from Figure 3 and subsequent bunching analyses of this section; they are included in the rest of the paper's analyses. The fact that primary IP rights are not enforced for 15 percent of drugs indicates that imperfections in the pharmaceutical sector are even greater than suggested by the simplified depiction of the imperfect model in Figure 1 or common wisdom (which considers primary IP on a drug's molecule to have certain enforcement).

expires. Thus, binding secondary IP rights are important, accounting for two-fifths as much binding entry as primary IP. To provide additional detail on generic entry timing, Appendix A.7 repeats the analysis of Figure 3 separated by whether or not a drug has any secondary IP.

Two questions emerge from this figure: First, which secondary IP matter? Is it the first secondary IP that is binding, or do later secondary IP similarly block entry? Second, we see that for many drugs, IP expirations are non-binding—for these drugs, the first generic enters either after the drug's final IP expiration or between expirations. Delayed or non-binding generic entry can be due to uncertainty in a market's profitability or uncertainty about the enforceability and scope of remaining IP rights. Uncertainty in market conditions leads the generic manufacturer to actively delay entry until some signal is received that reduces or resolves the uncertainty (as in real options theory). Uncertainty in IP enforceability delays entry (even if the generic manufacturer wants to enter) until the uncertainty is resolved via established legal institutions. How do we separate these different sources of delay? I address each of these questions in turn.

Figure 3: Timing of generic entry (in months)



Restricted to NCEs with generic entry at or after primary IP expiration, i.e. 366 drugs out of total sample of 431. Panel (a) gives timing of generic entry relative to primary expiration while panel (b) gives timing relative to most recent (primary or secondary) IP expiration prior to generic entry.

To answer the first question as to which secondary IP is binding, I estimate a linear probability model of first generic entry and include as explanatory variables indicators for the month of primary and secondary IP expirations and the periods between those expirations. I use the drug-month-level dataset tracking drugs from branded launch through initial generic entry. There are 431 drugs observed for 178 months on average, for 68,394 drug-month observations total. I estimate the following regression:

$$\mathbb{1}\{Entry\}_{it} = X_{it}\beta + \delta_i + \varepsilon_{it} \tag{2}$$

The outcome of interest $\mathbb{1}\{Entry\}_{it}$ is a binary variable indicating whether or not first generic entry for drug i occurs in month t following branded launch. X_{it} is a vector of indicators for month of primary IP expiration, time between primary and first secondary IP expirations, month of first

secondary IP expiration, time between first and second secondary IP expirations, and so forth. For fourth and subsequent secondary IP, I collapse the periods during which they are in effect into a single indicator and their expirations into another. A final indicator specifies when all IP has expired. Note that as multiple patents or exclusivities may expire in the same month (or even on the same day), I form these indicators based not on individual patents and exclusivities but rather on periods of IP protection. That is, multiple secondary patents may expire in the "month of first secondary IP expiration." With the inclusion of these indicators, the excluded reference period is the time after branded launch and before the primary IP expires. I include drug fixed effects and robust standard errors clustered at the drug level.

Figure 4: Linear probability model of first generic entry

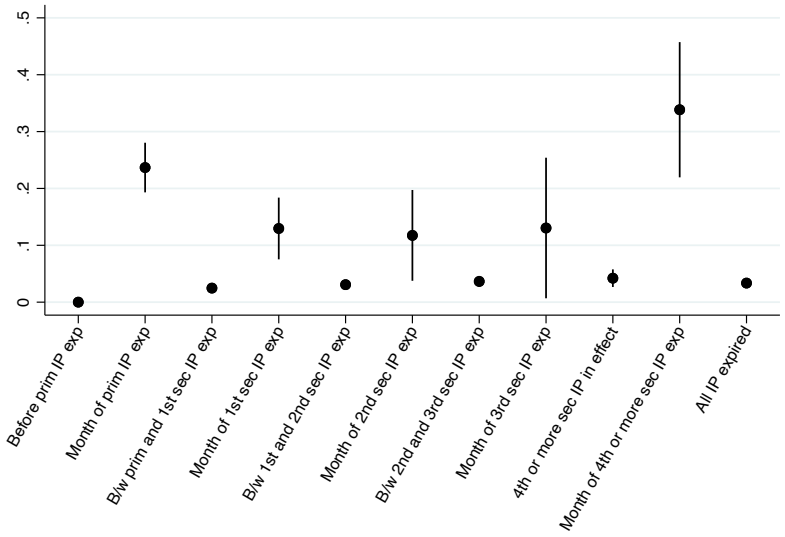


Figure plots β coefficients from linear probability model; all are significant at the 1-percent level except coefficient on indicator for "month of third secondary IP expiration," which is significant at the 5-percent level. Reference period is time before the primary IP expires.

Figure 4 plots the coefficients of the linear probability model. Generic entry is 23.7 percentage points higher in the month of a drug's primary IP expiration than in the months prior. After primary IP expiry, the relative probability of generic entry then drops dramatically (to merely 2.5 percentage points higher) until the first secondary IP expiry, at which point it rises again (to 13.0 percentage points higher). This non-monotonic pattern continues with subsequent secondary IP, suggesting the binding nature of these IP in delaying generic entry.

A key takeaway from this figure is that not only does the first secondary IP matter but later secondary IP also introduce binding entry points. It is important to note that this figure plots relative entry in a *given* month. As the periods between two IP expirations for a drug may last for many months, when we consider total entry, there is more non-binding entry (occurring between or after all expirations) than binding entry (occurring exactly when an IP expires). Appendix Figure

12 shows the raw proportions of cumulative entry occurring in each period of IP protection. I next turn to answering the second question of disentangling the sources of non-binding entry.[29]

6.2 Decomposition of the sources of non-binding entry

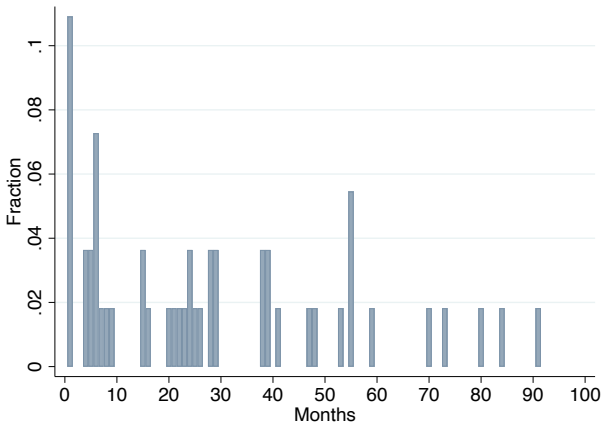
Non-binding entry may be due to a generic firm actively waiting (a) to learn more information that resolves some uncertainty about a market's profitability or (b) for a legal resolution that resolves uncertainty in the scope or enforceability of remaining IP rights on a drug. Consider first the case of market learning. The generic firm may delay entry in markets offering less revenue or where there is concern about new treatments in development that would make the drug in question obsolete. Here, the generic firm may delay undertaking the costs of bioequivalence trials and its application to the FDA until receiving some positive signal on market profitability. Next consider the case of uncertainty in the enforceability of remaining IP rights. In this case, a generic entrant may seek to enter the market prior to the expiration of all secondary patents by filing a patent challenge (described in Section 2.3). The generic firm will submit an application to the FDA specifying that remaining patents are either invalid or that the generic can enter the market without infringing upon those patents. The uncertainty in IP enforceability is then resolved via litigation in the courts, with final FDA approval for the generic occurring only following a court decision in its favor or a settlement agreement between the branded and generic manufacturers.

To disentangle non-binding entry due to market learning versus uncertainty in IP scope or enforceability, I exploit variation across drugs in their number of secondary IP and narrow in on exactly the set of drugs with non-binding generic entry; Figure 5 presents their generic entry timing. Panel (a) depicts drugs without secondary IP. These drugs have no secondary IP to forestall generic entry, meaning that any delay for these drugs must reflect learning in market conditions. For drugs with secondary IP, I further divide the sample into those where the generic enters after all secondary IP have expired and those with intermediate entry between IP expirations. Panel (b) looks at this first group. For these drugs, IP enforceability is again no longer an issue and market profitability is the only source of uncertainty. We would expect these drugs to have similar entry patterns as those in panel (a). Indeed, the entry patterns look visually similar. Out of the drugs in panel (a) without secondary IP and delayed entry, 31 percent enter by 10 months after their primary IP expiration, 47 percent by 25 months, and 71 percent by 50 months. For the drugs in panel (b) with secondary IP and delayed entry after all secondary IP have expired, the comparable statistics are similar, albeit entry is a bit slower: 17 percent by 10 months post-final secondary IP expiration, 40 percent by 25 months, and 62 percent by 50 months. To further assess their similarity, I apply the non-parametric Kolmogorov-Smirnov test of the equality of two distributions; with a p-value of 0.399, the test fails to reject the null hypothesis that these two entry distributions are the same.

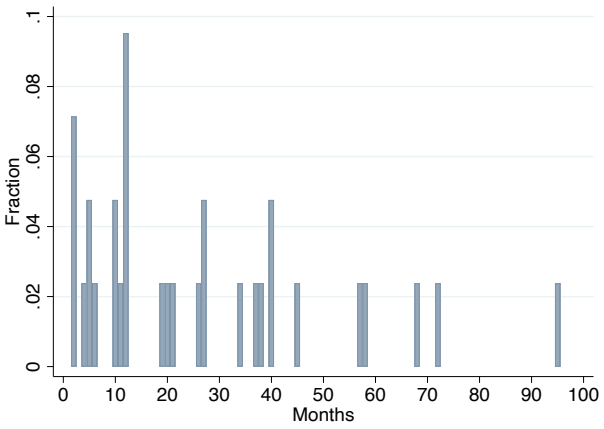
[29] Recall that by IP, I am referring to both patents and regulatory exclusivities. For the interested reader, I provide some additional facts: Out of the 366 drugs with generic entry at or after primary expiration, 72 percent enter following a patent expiration; 27 percent enter following an exclusivity expiration; and 0.8 percent, following the expiration of both (i.e., at least one patent and exclusivity expire in the same month).

Figure 5: Timing of *delayed* generic entry (in months)

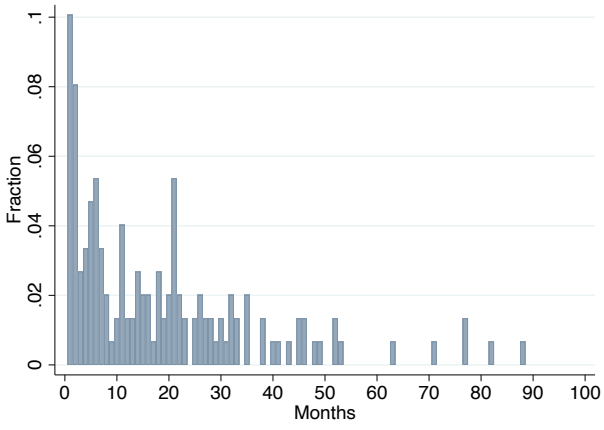
(a) Drugs without secondary IP; relative to primary IP expiration



(b) Drugs with secondary IP & all have expired; relative to final IP expiration



(c) Drugs with secondary IP & at least one still unexpired; relative to most recent IP expiration



Restricted to NCEs with non-binding IP expirations, i.e., delayed generic entry. Panel (a) gives timing of delayed generic entry relative to primary expiration for drugs without secondary IP; number of drugs is 55. Panel (b) gives delayed timing relative to final IP expiration for drugs with secondary IP and all secondary IP expired; number of drugs is 42. Panel (c) gives delayed timing relative to most recent (primary or secondary) IP expiration prior to generic entry for drugs with at least one secondary IP still unexpired; number of drugs is 149.

Panel (c) looks at entry timing for generics with secondary IP that enter while at least one secondary IP still remains on a drug; entry is graphed relative to the most recent (primary or secondary) IP expiration. For these drugs, uncertainty in IP scope/enforceability is an important contributor, with intermediate entry occurring once the nonenforcement of remaining IP is determined. Consider the counterargument: There is no uncertainty about which secondary patents are enforced (i.e., there is certain unenforcement of these patents) and the only source of uncertainty is in market profitability. If this were the case, we would expect the entry timing distribution for this group to match those in panels (a) and (b). But this is not what we see—the entry distribution looks remarkably different. In fact, entry is faster relative to the final *enforced* expiration: 40 percent enter by 10 months post-expiration; 70 percent by 25 months; and 92 percent by 50 months. This makes sense if we consider the different types of drugs in these samples. Drugs that have delayed entry after all IP expired are likely to be drugs less attractive to generic entry, e.g., that may be in lower revenue markets or at risk of becoming obsolete pending results of clinical trials on other drugs in development. Rather than a situation where the generic firm is waiting to enter as soon as the binding IP expires, entry occurs only once a positive signal has been received on market profitability—e.g., a medical study that suggests a new use for an older off-patent drug.

In contrast, a generic with intermediate entry between IP expirations—between a final enforced expiration and a later unenforced one—is likely a more attractive drug, e.g., in a higher revenue market, and the generic must wait for a determination on the remaining secondary IP scope and enforceability. Under such a situation, we would expect faster entry for these drugs relative to the final enforced expiration, occurring as soon as nonenforcement of remaining IP is established. To confirm, I again apply the Kolmogorov-Smirnov test to assess the equality of the distribution in panel (c) with those in panels (a) and (b). These tests reject the hypotheses that the generic entry distribution for drugs with secondary IP still remaining is the same as that of drugs with no secondary IP (with a p-value of 0.000) or that of drugs with all secondary IP expired (p-value of 0.000). I also conduct a Cox regression of entry timing in which I compare the hazard or probability of generic entry for drugs with secondary IP still unexpired to those with all IP expired.[30] The regression indicates that the probability a drug sees its first generic entrant in any given month after its final *enforced* IP expiration (conditional on not having had a generic entrant prior) is twice as likely for drugs with at least one IP still unexpired than for those with all IP expired.[31]

To confirm the sources of delay as being either market learning or uncertainty in IP enforceability,

[30] Specifically, I run the following regression: $h_{it} = h_0(t)\exp\big(\beta \mathbb{1}\{IP\ unexpired\}_{it}\big)$, where the hazard rate h_{it} is the conditional probability a drug sees its first generic entrant in month $t+\delta$ post-final enforced IP expiration given that it has not had a generic entrant through month t; $h_0(t)$ gives the baseline hazard, i.e. the probability of generic entry for any drug t months post-final enforced IP expiration; and $\mathbb{1}\{IP\ unexpired\}_{it}$ is an indicator for having at least one secondary IP still unexpired. I include robust standard errors clustered at the drug level. The sample includes 191 drugs and 6,379 drug-month observations.

[31] The unexponentiated coefficient on $\mathbb{1}\{IP\ unexpired\}_{it}$ is 0.940, significant at the 1-percent level. The exponentiated coefficient, or hazard ratio, is 2.556—indicating a hazard (probability of generic entry) more than 2.5 times as large for drugs with secondary IP still unexpired as those with all IP expired.

Table 6: Relationship between number of secondary IP and Paragraph IV challenges

	N	Challenged (%)
Drugs without secondary IP	82	20.7
Binding primary IP	27	40.7
Non-binding	55	10.9
Drugs with secondary IP	284	63.4
Binding primary IP	59	88.1
Binding secondary IP	34	64.7
All expired, non-binding	42	16.7
At least one unexpired, non-binding	149	66.4
Total	366	53.8

Restricted to NCEs with generic entry at or after primary IP expiration.

I incorporate data on Paragraph IV patent challenges and market size.[32] Table 6 subsets drugs according to the presence of secondary IP, and whether or not the IP is binding, and looks at the proportion of each drug category experiencing a Paragraph IV patent challenge. As expected, drugs without secondary IP are challenged less frequently (21 percent) than drugs with secondary IP (63 percent). Of those drugs without secondary IP and with non-binding entry, only 11 percent are challenged, validating the hypothesis that delayed entry here is due mainly to market conditions rather than uncertainty in IP enforceability. Looking at drugs with secondary IP, those with binding IP are heavily challenged (88 percent of those with binding primary IP and 65 percent of those with binding secondary IP). The same trend does not hold for drugs with non-binding entry after all IP have expired; only 17 percent experience a patent challenge. This supports the hypothesis that non-binding entry for these drugs is more likely due to market profitability. Those drugs with non-binding IP and at least one still unexpired at the time of generic entry, however, are challenged at a similar rate to those with binding IP, at 66 percent. As discussed above, the non-binding entry occurs due to generic entry once a legal resolution determines remaining IP rights to be unenforceable; thus, uncertainty about IP enforceability is an important mechanism behind the delay.

Table 7 again subsets drugs according to presence of secondary IP and whether or not the IP is binding; this table compares the shares in each drug category falling within each quartile of overall market size. A number of facts emerge from this table. First, drugs of lower market size are less protected by secondary IP; drugs without secondary IP are more frequently of the lowest market size quartile (38 percent) relative to drugs with secondary IP (22 percent). Second, focusing on those drugs without secondary IP, the share falling within the lowest market size quartile differs drastically depending on whether the drug's primary IP is binding (19 percent) or not (49 percent).

[32]Data on Paragraph IV challenges were obtained from ParagraphFour.com.

Combined with the evidence above, this supports the view that for these drugs without secondary IP and with non-binding entry, learning about market conditions is the primary source of delay. Third, a similar trend holds for those drugs with secondary IP and non-binding entry after all IP have expired: Fifty-eight percent fall within the lowest market size quartile and none are in the highest quartile. As discussed above, for these drugs, IP enforcement is no longer an issue and thus the delayed, or non-binding, entry must be due to market conditions. In contrast, those drugs with non-binding entry and at least one IP still unexpired are more evenly distributed across market size quartiles, suggesting market profitability is not a driving factor behind their delayed entry.

Table 7: Relationship between number of secondary IP and market size

	N	Q1 (%)	Q2 (%)	Q3 (%)	Q4 (%)
Drugs without secondary IP	60	38.3	25	13.3	23.3
Binding primary IP	21	19	38.1	9.5	33.3
Non-binding entry	39	48.7	17.9	15.4	17.9
Drugs with secondary IP	213	21.6	24.9	28.2	25.4
Binding primary IP	50	10	16	20	54
Binding secondary IP	23	17.4	30.4	26.1	26.1
All expired, non-binding entry	24	58.3	33.3	8.3	0
At least one unexpired, non-binding entry	116	19.8	25.9	36.2	18.1
Total	273	25.3	24.9	24.9	24.9

Restricted to NCEs with generic entry at or after primary IP expiration and non-missing market size measure. Market size quartiles are defined over all drugs, with each row then giving the proportion of that drug category, e.g., drugs without secondary IP & with binding primary IP, falling within each quartile.

Taken together, this evidence can be summarized as follows: Secondary IP are important for influencing first generic entry timing and they work in two ways. First, secondary IP rights introduce later binding expirations—secondary IP account for two-fifths as many binding expirations (8 percent) as primary IP (20 percent). Second, they also influence generic entry by increasing uncertainty in the scope or enforceability of the remaining IP on a drug. Roughly 35 percent of drugs in the sample see their first generic competitor enter between two IP expirations—between a final enforced expiration and a later unenforced one. Comparing the distribution of generic entry timing for these drugs relative to those whose first generic enters after all IP have expired suggests that market profitability alone is not driving delayed entry for these drugs. Rather, uncertainty in IP scope/enforceability must also be a crucial factor.[33]

[33]Considering the results of the Cox regression—which shows a hazard 2.5 times as large for this group as for those with all IP expired—if we suppose that certain unenforcement is the case for $\frac{1}{3.5} = \frac{2}{7}$ of this group (and hence uncertainty in market profitability the contributing factor behind their delayed entry), that would suggest for $\frac{5}{7} \times 35 = 25$ percent of the sample, uncertainty in IP scope/enforceability is the limiting factor.

7 Discussion: Implications for IP policy and innovation

7.1 Relationship between drug novelty and monopoly terms

A question that naturally arises from the above analyses is whether the imperfections in our intellectual property system lead to resulting monopoly terms that more closely match those of a first-best system—where terms are differentiated according to innovation size or measures of quality—or if these imperfections exacerbate distortions to innovation incentives in the fixed-term patent system. To explore this, I follow Krieger et al. (2022) and develop for each drug in my sample a measure of novelty, comparing its molecular structure to the structures of all previously approved drugs. This measure is based on the idea that structurally similar molecules typically have similar functional properties (Johnson and Maggiora, 1990). The measure ranges from 0 to 1, where 0 indicates the drug has complete overlap in its chemical fragments with at least one previously approved drug and 1 indicates the drug has no common fragments with any approved drugs. That is, higher levels of the measure correspond to more novel drugs at their time of launch. Appendix A.10 provides additional detail on the construction of this measure.

Figure 6: Relationship between drug novelty and monopoly extension

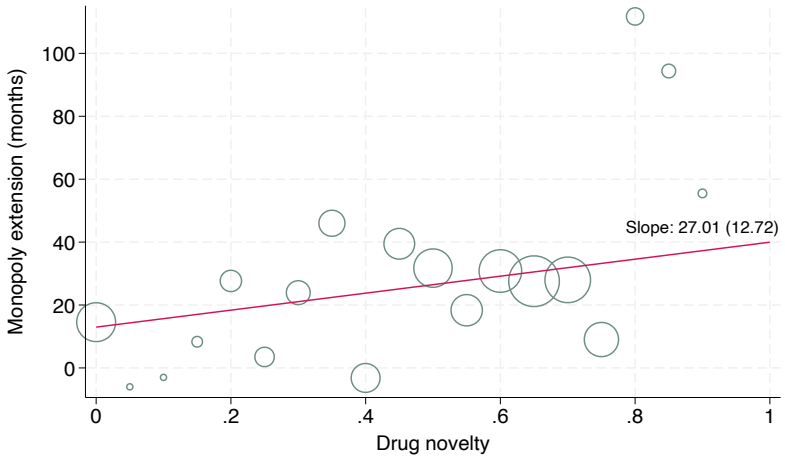


Figure plots relationship between drug novelty and monopoly extension. Open circles represent binned averages of the data, with circle dimension proportionate to the number of observations in each equally spaced bin. Line of best fit comes from a regression of monopoly extension on drug novelty, with estimated coefficient and robust standard error reported in the figure. Number of drugs is 429.

Figure 6 plots the relationship between drug novelty and monopoly extension for my sample. More novel drugs receive longer monopoly extensions, with this relationship both economically and statistically significant. A one-standard-deviation increase in novelty is associated with 6.1 months of monopoly extension.[34] That is, firms with more novel drugs are able to endogenously obtain longer monopoly extensions for their drugs. However, if more novel drugs have substantially longer

[34]Mean drug novelty is 0.506, with a standard deviation of 0.225.

commercialization lags (i.e., longer development times), then these monopoly extensions may not necessarily translate to longer actual monopoly terms.

To explore this, I repeat the analysis of Figure 6, plotting instead the relationship between drug novelty and actual monopoly term. Figure 7 shows that more novel drugs still have longer actual monopoly terms than less novel ones. In fact, this relationship is more positive than the prior—a one-standard-deviation increase in drug novelty is associated with 9.8 additional months of actual monopoly term—indicating that commericalization lags are not longer for more novel drugs. These analyses suggest that imperfections in IP institutions do allow pharmaceutical IP rights to approach a first-best system where monopoly terms are proportionate to innovation size.

Figure 7: Relationship between drug novelty and actual monopoly term

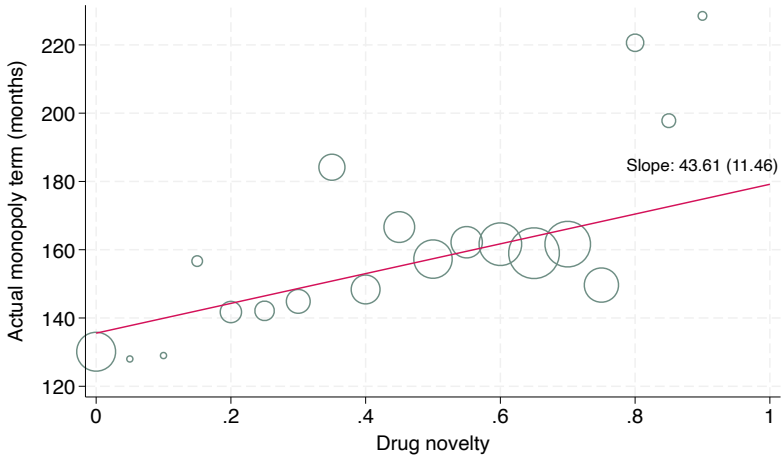


Figure plots relationship between drug novelty and actual monopoly term. Open circles represent binned averages of the data, with circle dimension proportionate to the number of observations in each equally spaced bin. Line of best fit comes from a regression of actual monopoly term on drug novelty, with estimated coefficient and robust standard error reported in the figure. Number of drugs is 429.

7.2 Monopoly pricing and innovation impacts

Natural follow-on areas of inquiry include how these monopoly extensions impact consumer welfare, in terms of both monopoly pricing and new molecule development. A lot of attention has been paid recently to rising US prescription drug prices (Hernandez et al., 2019; Talmadge, 2020). To understand how these monopoly extensions affect commonly used drugs, I correlate drug market size with measures of monopoly term in Appendix A.11. Consistent with prior work (e.g., Grabowski et al., 2017; Hemphill and Sampat, 2012), I find that while potential monopoly term increases sharply with market size, monopoly extensions are smallest for the highest-selling drugs—reflecting the imperfections in pharmaceutical IP rights: While branded manufacturers may seek to extend the monopoly terms of their "blockbuster" drugs with additional IP, these IP are challenged by generic manufacturers and often not enforced.

Despite the fact that monopoly extensions are shorter for the highest-selling drugs, I find in a back-of-the-envelope calculation outlined in Appendix A.12.1 that these extensions still have sizeable impacts to monopoly pricing. Taking the conservative approach that these extensions impact only low- and medium-selling drugs, I determine that the 3-year delay in generic entry leads to an average consumer welfare loss of $148.3 million per drug due to monopoly pricing.[35,36] This amounts to $52.6 billion total over the 355 drugs in my analytic sample that apply for secondary patents. Of course, the consumer welfare loss estimated here is a transfer from consumers to producers under monopoly pricing, and the potential for monopoly extension influences firms' ex-ante incentives to innovate.

While I leave a complete welfare analysis to future research, existing evidence indicates that the patent-term extension I observe here should have had a sizable impact on pharmaceutical innovation. In a second back-of-the-envelope calculation detailed in Appendix A.12.2, I determine that the 3-year extension in monopoly life should have increased pharmaceutical R&D investment (as measured by clinical trials) from 21 to 69 percent relative to a counterfactual where innovating firms are restricted to solely the fixed term of their initial molecule patent. This increase in R&D investment translates to an increase in the number of approved NCEs of between 1.4 and 4.8 percent (i.e., between 5 and 17 new drugs) during my sample period.

Note that some observers argue that the ability of branded firms to make minor tweaks to existing drugs in dosage or formulation disproportionately extends their effective patent terms relative to the R&D costs of these improvements.[37] Others point out that, given the high costs of drug development, these extensions are necessary to incentivize a drug's initial development. Connecting my two back-of-the-envelope calculations suggests a consumer welfare loss due to monopoly pricing of between $3.1 billion and $10.5 billion per new drug approved.[38] Given estimates of the cost of new drug development range between $500 million to $2 billion (Adams and Brantner, 2006), this would suggest not enough innovative drugs are being produced to justify the monopoly extensions drugs receive from imperfect intellectual property rights.

8 Conclusion

Despite the standard "one-patent-one-product" model in intellectual property rights discourse, a common practice by innovators is to acquire numerous patents on different features of the same product to extend its monopoly life. In this paper, I systematically document the presence of im-

[35] Per Schuhmacher et al. (2022), low-selling drugs have annual revenues of <$0.1 billion and medium-selling drugs have annual revenues of $0.1–0.499 billion. I exclude blockbusters (>$1 billion) and high-selling drugs ($0.5–0.999 billion) in my calculations of mean annual revenues per drug.

[36] Note that the term "consumer" refers to all "downstream" entities, i.e., patients, drug retailers, and insurance companies.

[37] This relates to the antitrust issue of "product hopping" whereby a manufacturer will cease production of prior dosages or formulations and switch consumers to the newer one at higher monopoly prices.

[38] These figures are obtained by dividing the total consumer welfare loss of $52.6 billion by the upper and lower bounds of the number of approved NCEs.

perfect intellectual property rights in the pharmaceutical industry, an industry often characterized by the standard model (Burk and Lemley, 2003). I show that the standard model does not hold: Multiple patents may cover a single product, with the scope and enforceability of each patent potentially uncertain, contributing to indeterminate periods of monopoly protection. In a sample of novel drugs, I find that nearly all drugs are covered by multiple intellectual property rights and that actual monopoly terms often last well beyond the fixed term of a drug's initial molecule patent. I then offer, to my knowledge, the first causal estimate in any industry on the extent to which additional patents extend monopoly life. By exploiting the quasi-random assignment of patent applications to examiners and variation in cross-examiner leniency, I determine that the average drug receives 3 years of additional monopoly life due to imperfect intellectual property rights, equivalent to 22 percent of mean monopoly term. I posit two mechanisms by which the accumulation of intellectual property rights on a single drug may delay generic entry: by introducing a binding later IP expiration and by increasing uncertainty in the scope and enforceability of remaining IP rights. Consistent with these mechanisms, I provide empirical evidence of non-monotonic generic entry patterns relative to IP expirations and a series of analyses illustrating that uncertainty in IP scope/enforceability is an important factor behind delayed generic entry.

The paper's analysis demonstrates that the strategic use of patents by innovating firms can substantially increase entry barriers into a market and lengthen monopoly durations. The results are in line with prior research on secondary patenting by branded manufacturers and patent challenges by generics. For instance, my finding that uncertainty in IP enforceability is an important mechanism for delaying generic entry complements work by Hemphill and Sampat (2011, 2012), who note that patent challenges may serve to limit evergreening behavior by branded firms, and research by Grabowski et al. (2017), who find both increased patenting activity and more challenges for the most popular new drugs. In recent work, Kyle et al. (2021) note that primary drug patents are the key patents impacting generic competition in India. My results are complementary to theirs. I show that in addition to primary patents, secondary Orange Book patents play a significant role in delaying competition in the U.S. drug market.

The results of this paper have important implications for consumer welfare, innovation incentives, and the design of intellectual property rights both broadly across sectors and within the pharmaceutical industry in particular. I find that more novel drugs receive longer monopoly extensions. That is, these imperfections allow pharmaceutical IP rights to approach a first-best system where monopoly terms are proportionate to innovation size. However, the extensions translate to only minimal increases in new molecules, relative to the substantial consumer welfare loss due to extended monopoly pricing. Thus, these imperfections in our patent system mean that firms can at least partially offset distortions of a fixed-term system by accumulating patents on a single product; yet at the same time, additional targeting may be necessary to achieve innovation policy objectives. Overall, this paper highlights that intellectual property rights are less rigid than we typically assume and these imperfections matter for discussions on optimal patent policy and innovation.

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A Appendix

A.1 FDA regulatory exclusivities

Table 8 provides term lengths for several key exclusivities; see Thomas (2017) for a description of all 16 FDA exclusivities that currently exist.

Table 8: Key FDA exclusivities by type and term length

Exclusivity type	Term length
New chemical entity (NCE)	5 years
Clinical investigation exclusivity (CIE)	3 years
–New dosage form or dosing regimen	
–New administration	
–New strength	
–New indication	
–Switch from Rx to OTC	
Orphan drug exclusivity (ODE)	7 years
Pediatric (PED)	6 months
Qualified infectious disease products (QIDP)	5 years

A.2 Data construction

I describe here the construction of the drug-application-level dataset. Granted drug patents are listed in historical FDA Orange Books. I merge these granted patents to their application, examiner, and assignee (i.e., patent owner/drug manufacturer) information using the USPTO Patent Assignment and Examination Research Datasets. Note that drugs may have additional granted patents beyond what is listed in the Orange Book, however generic manufacturers must only account for Orange Book-listed patents when they attempt entry. Hence, this set of patents is the relevant subset of granted patents to be used in estimating the effect of an additional patent on monopoly life.

Attaching rejected patent applications to drugs is a more complex process. I begin with the universe of patent applications from the USPTO PatentsView and Historical Patent Data Files.[39] I then restrict to those applications belonging to either one of three NBER technology subcategories (drugs, organic compounds, and surgery/medical instruments) or one of several CPC classifications (A61P, A61K, A61K6, A61K8, Y10S514, and C07). I merge these applications with their patent application text available from PatentsView and the USPTO Patent Claims Research Dataset.[40] Using the complete list of all active ingredients for the 431 NCEs in my analytic sample, I attach applications to individual drugs by first restricting to those applications with a brief summary or

[39] PatentsView includes applications from 2005 on; the Historical Patent Data Files include applications from 2001 to 2014.

[40] PatentsView includes brief summary and claim text for applications from 2005 on; the Patent Claims Research Dataset includes claims for applications from 2001 to 2014.

claim including at least one of the drug's active ingredients. Because an active ingredient may be mentioned by another company who does not manufacturer the drug in question, I obtain the list of all assignees for each NCE's granted patents in the Orange Book and then further restrict applications for each NCE to the subset with at least one of the same assignees. To account for assignee changes due to M&A activity, I hand collect data on nearly 500 M&A events involving large pharmaceutical firms and match drugs and assignees to their parent firms as of today; this ensures patent applications are correctly attached to a drug even when the drug manufacturer changes over time. This process of relying on application text and assignee name captures 79% of all Orange Book patents, suggesting it is a fairly accurate and complete method for attaching patent applications to drugs and may be useful for future research. Because of instances in the data where a patent application for a given drug does not include the active ingredient name, I also include parent and child applications of Orange Book patents.

One limitation of the USPTO data is that rejected patent applications are only available if filed on or after November 29, 2000. Granted patent applications are available before and after this date. One approach to addressing this limitation would be to restrict to patent applications filed on or after November 29, 2000. However, such an approach would produce an overestimate of the effect of an incremental patent on monopoly duration (by excluding from the analysis some granted patents). Thus, for each drug, I include all granted secondary patents in the Orange Book regardless of filing date and rejected secondary patent applications on or after November 29, 2000, provided they were filed in advance of generic entry. I rely on an assumption that the unobserved rejected patent applications are "missing at random" and have characteristics similar to the observed rejected applications. Restricting to those drugs with non-missing market size and at least one secondary patent application, the resulting drug-application-level dataset has 273 drugs and 7,110 applications.

To instrument for whether a given patent application is granted or not, I construct a time-invariant measure of examiner leniency using a separate first-stage sample. The first-stage sample includes all applications from the NBER subcategories for drugs or organic compounds that are NOT attached to any NCE in my sample and for which examiner information is available. The measure of examiner leniency used in the main text is the share of applications granted over time by an examiner in this first-stage sample. In the analytic sample, I then exclude applications where the examiner is missing (leading to 271 drugs/6,820 applications) or where the examiner is only present in the USPTO data in years up to 2000, as these examiners will be attached solely to granted patent applications and will artificially have leniency measures of 1 (leading to 268 drugs/6,614 applications). I also exclude exclude applications where the examiner does not have a leniency measure, due to not reviewing any applications in the first-stage stample (leading to 268 drugs/6,601 applications). Excluding applications that are singleton observations within a given examiner art unit (as these are dropped with the inclusion of art unit fixed effects) results in a final sample for the IV analysis of 267 drugs and 6,572 applications.

A.3 Summary statistics on per-drug patent applications

Table 9 provides summary statistics on the number of patent applications per drug and their grant rates. On average, each drug has 98 patent applications, of which a mean of 61 are granted and 37 abandoned. Of those granted, a mean of 4 patents per drug are listed in the Orange Book. These means, however, mask substantial variation across drugs, with the number of applications per drug ranging from a minimum of 1 to a maximum of 771.

Table 9: Summary statistics on per-drug patent applications

Variable	Mean	Std. Dev.	Min	Max
Number of applications	98.3	110.8	1	771
Number of granted applications	61.4	74.1	1	487
Number of granted Orange Book patents	4.4	4	1	28
Number of granted non-Orange Book patents	57	73.2	0	483
Number of abandoned applications	37	43	0	393

Restricted to drugs with at least one patent application. Total number of drugs is 395.

A.4 Naive analysis: Comparing drugs by number of secondary IP

Table 10 repeats the analysis of Table 2 using the number of all secondary IP as the main explanatory variable. The coefficient in the preferred specification here (0.87) is lower relative to that on *# secondary patents* (1.7) in Table 2 and insignificant, suggesting that manufacturers may obtain more exclusivities for patents at risk of shorter monopoly terms, but on average, they are not associated with monopoly extension.

Table 10: Secondary IP and extra monopoly life: Drug-level analysis

	(1)	(2)	(3)	(4)
# secondary IP	-0.0638	-0.243	-0.0606	0.867
	(0.531)	(0.574)	(0.597)	(0.595)
ln(market size)				-8.572***
				(1.965)
Observations	324	324	324	324
Adj. R^2	-0.003	0.084	0.160	0.204
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes

Dependent variable in all regressions is extra monopoly life in months (i.e., from a drug's primary IP expiry to generic entry). Analysis at the drug level. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

A.5 Inclusion of class-subclass fixed effects

Tables 11–13 repeat the analyses of Tables 3–5 including technology class-subclass fixed effects.

Table 11: Secondary patents and extra monopoly life for drugs in granted versus rejected applications: Application-level analysis including class-subclass fixed effects

	(1)	(2)	(3)	(4)
$\mathbb{1}_{Granted}$	5.059***	6.596***	5.863***	5.865***
	(1.882)	(1.787)	(1.716)	(1.712)
ln(market size) e				-1.434***
				(0.450)
Observations	6,203	6,203	6,203	6,203
Adj. R^2	0.204	0.280	0.381	0.382
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes

Dependent variable in all regressions is extra monopoly life in months (i.e., from a drug's primary IP expiry to generic entry). Analysis at the drug-application level; number of drugs is 259. All regressions include patent application/examiner art unit fixed effects and technology class-subclass fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

Table 12: First-stage results including class-subclass fixed effects

	(1)	(2)	(3)	(4)
leniency	0.556***	0.552***	0.552***	0.552***
	(0.0290)	(0.0289)	(0.0288)	(0.0288)
ln(market size)				9.14e-05
				(0.00362)
Observations	6,203	6,203	6,203	6,203
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes
F-statistic	368.2	365.4	366.7	366.6

Dependent variable in all regressions is an indicator for whether a patent application is granted. Analysis at the drug-application level; number of drugs is 259. All regressions include patent application/examiner art unit fixed effects and technology class-subclass fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

Table 13: Secondary patents and extra monopoly life using variation in examiner leniency: IV analysis including class-subclass fixed effects

	(1)	(2)	(3)	(4)
$\mathbb{1}_{Granted}$	14.069**	13.622**	9.864*	9.875*
	(6.254)	(5.969)	(5.466)	(5.466)
ln(market size)				-1.435***
				(0.451)
Observations	6,203	6,203	6,203	6,203
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes

Dependent variable in all regressions is extra monopoly life in months (i.e., from a drug's primary IP expiry to generic entry). Examiner leniency instruments for whether a secondary patent application is granted or not. Analysis at the drug-application level; number of drugs is 259. All regressions include patent application/examiner art unit fixed effects and technology class-subclass fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

A.6 Leave-out examiner leniency as instrument

Tables 14–15 repeat the analyses of Tables 4–5 using a leave-out measure of examiner leniency as the instrument. Rather than determining examiner leniency from the separate first-stage sample, I calculate it using the analytic sample as the share of all other applications granted by the examiner excluding the application in question.

Table 14: First-stage results (leave-out examiner leniency)

	(1)	(2)	(3)	(4)
leave-out leniency	0.431***	0.426***	0.419***	0.420***
	(0.0231)	(0.0229)	(0.0228)	(0.0228)
ln(market size)				0.00203
				(0.00354)
Observations	6,450	6,450	6,450	6,450
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes
F-statistic	347.7	346.4	339.2	339.2

Dependent variable in all regressions is an indicator for whether a patent application is granted. Analysis at the drug-application level; number of drugs is 266. All regressions include patent application/examiner art unit fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

Table 15: Secondary patents and extra monopoly life using variation in leave-out examiner leniency: IV analysis

	(1)	(2)	(3)	(4)
$\mathbb{1}_{Granted}$	20.595***	22.416***	19.007***	18.704***
	(6.697)	(6.357)	(5.831)	(5.821)
ln(market size)				-1.466***
				(0.404)
Observations	6,450	6,450	6,450	6,450
Approval year FE		yes	yes	yes
Therapeutic area FE			yes	yes

Dependent variable in all regressions is extra monopoly life in months (i.e., from a drug's primary IP expiry to generic entry). Leave-out examiner leniency instruments for whether a secondary patent application is granted or not. Analysis at the drug-application level; number of drugs is 266. All regressions include patent application/examiner art unit fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

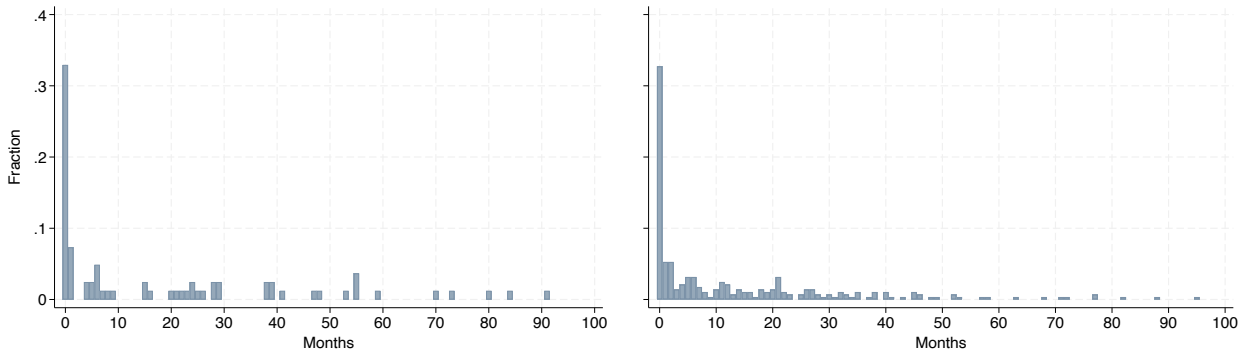
A.7 Timing of generic entry, by number of secondary IP

Figure 8 repeats the analyses of Figure 3 on timing of generic entry but separated by whether or not a drug has any secondary IP.

Figure 8: Timing of generic entry (in months)

(a) Drugs without secondary IP; relative to primary IP expiration

(b) Drugs with secondary IP; relative to most recent IP expiration



Restricted to NCEs with generic entry at or after primary IP expiration. Panel (a) gives timing of generic entry relative to primary expiration for drugs without secondary IP; number of drugs is 82. Panel (b) gives timing relative to most recent (primary or secondary) IP expiration prior to generic entry for drugs with secondary IP; number of drugs is 284.

Panel (a) of Figure 8 shows the generic entry timing for drugs without secondary IP relative to primary IP expiration. We see, as would be expected, that primary IP is binding for a much larger portion of these drugs (33 percent) relative to the entire sample (20 percent in Figure 3). Panel (b) restricts to drugs with secondary IP and depicts generic entry timing relative to the branded drug's most recent (primary or secondary) IP expiration prior to entry. For this set of drugs, intellectual property protection is binding in blocking generic entry for 33 percent (or 93 out of 284 drugs). Separating this binding IP expiry by type, for 21 percent the primary IP is binding and for the other 12 percent, secondary IP is binding.

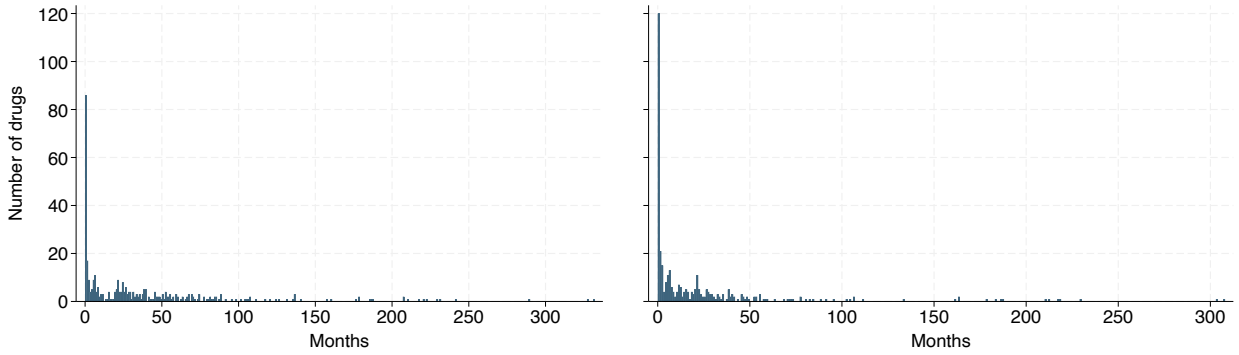
A.8 Complete distributions of generic entry timing

Figures 9–11 display the full windows of generic entry timing for Figure 3, Appendix Figure 8, and Figure 5, i.e., including drugs with generic entry occurring after 100 months since the relevant IP expiration.

Figure 9: Timing of generic entry (in months)

(a) Relative to primary IP expiration

(b) Relative to most recent IP expiration

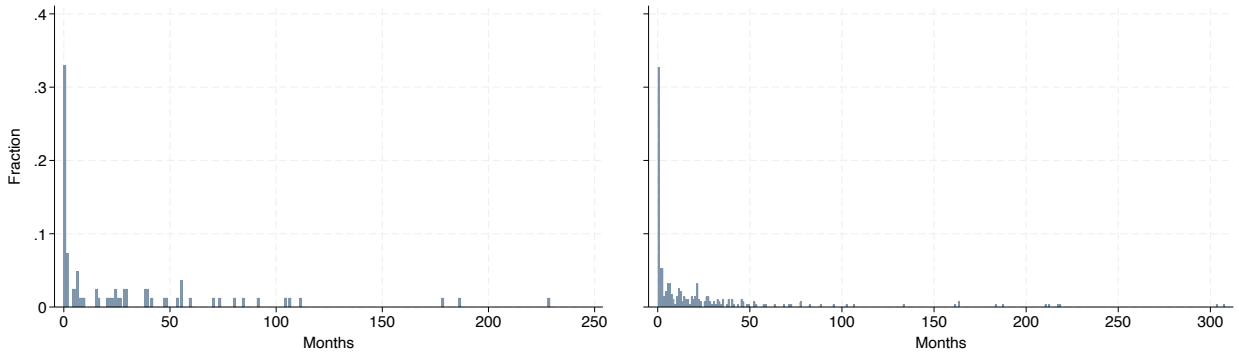


Restricted to NCEs with generic entry at or after primary IP expiration, i.e. 366 drugs out of total sample of 431. Panel (a) gives timing of generic entry relative to primary expiration while panel (b) gives timing relative to most recent (primary or secondary) IP expiration prior to generic entry.

Figure 10: Timing of generic entry (in months)

(a) Drugs without secondary IP; relative to primary IP expiration

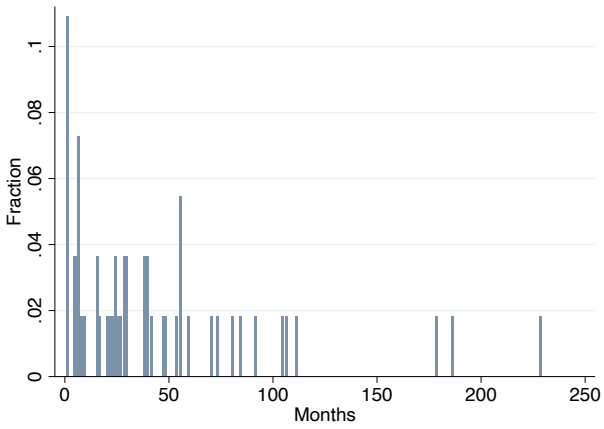
(b) Drugs with secondary IP; relative to most recent IP expiration



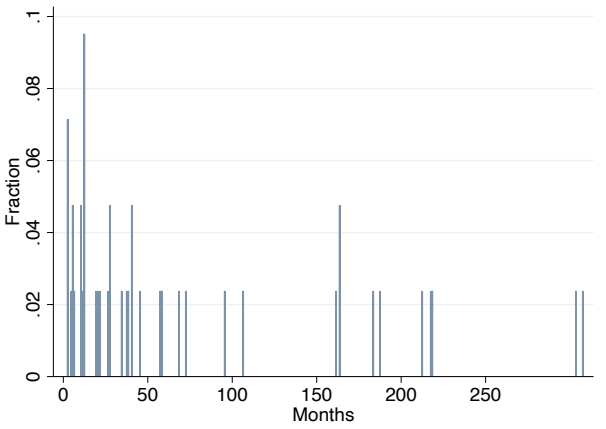
Restricted to NCEs with generic entry at or after primary IP expiration. Panel (a) gives timing of generic entry relative to primary expiration for drugs without secondary IP; number of drugs is 82. Panel (b) gives timing relative to most recent (primary or secondary) IP expiration prior to generic entry for drugs with secondary IP; number of drugs is 284.

Figure 11: Timing of *delayed* generic entry (in months)

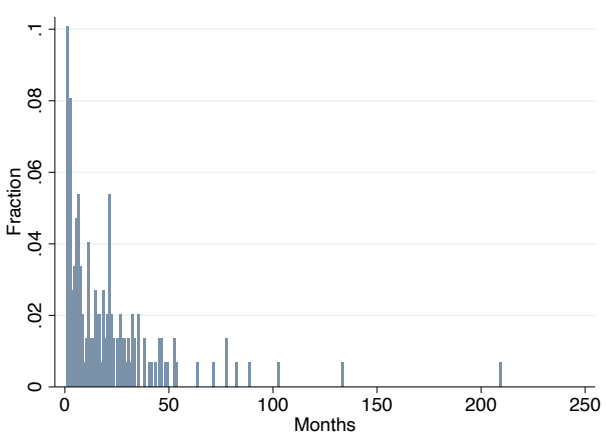
(a) Drugs without secondary IP; relative to primary IP expiration



(b) Drugs with secondary IP & all have expired; relative to final IP expiration



(c) Drugs with secondary IP & at least one still unexpired; relative to most recent IP expiration



Restricted to NCEs with non-binding IP expirations, i.e., delayed generic entry. Panel (a) gives timing of delayed generic entry relative to primary expiration for drugs without secondary IP; number of drugs is 55. Panel (b) gives delayed timing relative to final IP expiration for drugs with secondary IP and all secondary IP expired; number of drugs is 42. Panel (c) gives delayed timing relative to most recent (primary or secondary) IP expiration prior to generic entry for drugs with at least one secondary IP still unexpired; number of drugs is 149.

A.9 Cumulative entry relative to IP expirations

Figure 12 shows the raw proportions of first generic entry occurring in each period of IP protection. The figure confirms binding IP expirations for some drugs and uncertainty in market profitability and/or IP enforceability delaying entry for others.

The leftmost bar shows that some drugs (15 percent) see generic entry prior to primary IP expiration. These drugs may be (1) entrants that have chosen to enter at risk of infringement, (2) entrants winning a Paragraph IV challenge or obtaining a settlement agreement with the branded manufacturer, or (3) authorized generics. Authorized generics may be marketed by either a separate company that has received permission by the branded firm to enter early in exchange for a portion of its profits or by the branded manufacturer itself. That is, the branded manufacturer may choose to launch its own generic to preempt future outside generic competition.

The dark blue bars confirm that 20 percent of the sample has a binding primary IP and another 8 percent total has a binding secondary IP. The rightmost bar shows that 22 percent of drugs see their first generic entrant after all IP have expired, meaning that for these drugs, uncertainty in market conditions is the only limiting factor. The remaining drugs see intermediate entry occurring between two IP expirations; for these drugs, either market conditions or IP enforceability may be the source of delay. In sum, total non-binding entry (occurring between or after all expirations) is larger than binding entry.

Figure 12: Cumulative entry relative to IP expirations

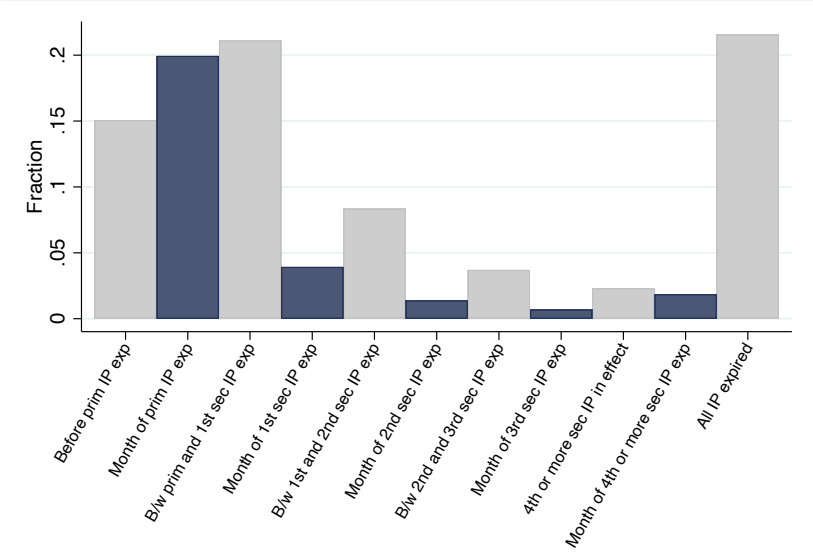


Figure gives proportion of sample experiencing generic entry in each period of IP protection. Number of drugs is 431.

A.10 Measuring drug novelty

This section provides additional details on the construction of a drug novelty measure based on molecular structures, as developed in Krieger et al. (2022); their paper offers a complete description of the measure. Its rationale comes from the fact that structurally similar molecules will typically have similar functional properties (Johnson and Maggiora, 1990). I follow Krieger et al.'s methodology, although my novelty measure has some differences to theirs.

I compare my sample of NCEs to all prior approved drugs, whereas Krieger et al. compare drug candidates to all prior candidates. Due to data availability, I also use a different data source to obtain drugs' molecular structures. I make use of PubChem, an open chemistry database at the National Institutes of Health (Kim et al., 2023). I obtain for each FDA-approved drug its PubChem compound identifier, which identifies unique chemical structures. I match each chemical structure to its parent compound, which PubChem defines as the "important" part of a molecule, and for each parent compound, I obtain its 2-dimensional chemical structure (a structure data file, or SDF).

I use these chemical structures to calculate Tanimoto distances for each NCE in my sample relative to all prior approved drugs. The Tanimoto distance between two chemical structures A and B is given by:

$$T_{A,B} \equiv \frac{|A \cap B|}{|A \cup B|} = \frac{|A \cap B|}{|A| + |B| - |A \cap B|} \tag{3}$$

These distances are obtained from ChemMine Tools (Backman et al., 2011). A Tanimoto distance of 0 occurs if A and B have no common fragments while a distance of 1 occurs when they have the exact same fragments.

For each NCE d in my sample, its novelty measure is then given by 1 minus its maximum pairwise similarity to all prior approved drugs $s \in S_d$, where S_d is the set of drugs receiving FDA approval before NCE d does:

$$Novelty_d \equiv 1 - \max_{s \in S_d} T_{d,s} \tag{4}$$

As such, this measure ranges from 0 to 1, where 0 indicates an NCE has complete overlap in its chemical fragments with at least one previously approved drug and 1 indicates the drug has no common fragments with any approved drugs. That is higher levels of the novelty measure correspond to more novel drugs at their time of launch.

A.11 Relationship between drug market size and monopoly terms

Figures 13–15 depict the relationship between drug market size and different measures of monopoly term. Figure 13 suggests that pharmaceutical firms obtain more IP on drugs with larger market sizes. Looking at drugs in the top quartile of the market size distribution, they have potential monopoly terms that are 53 months (or nearly 4.5 years) longer than drugs in the bottom quartile.[41] That is, firms disproportionately seek to extend the monopoly terms of their "blockbuster" drugs via imperfect intellectual property rights.

Figure 13: Relationship between drug market size and potential monopoly term

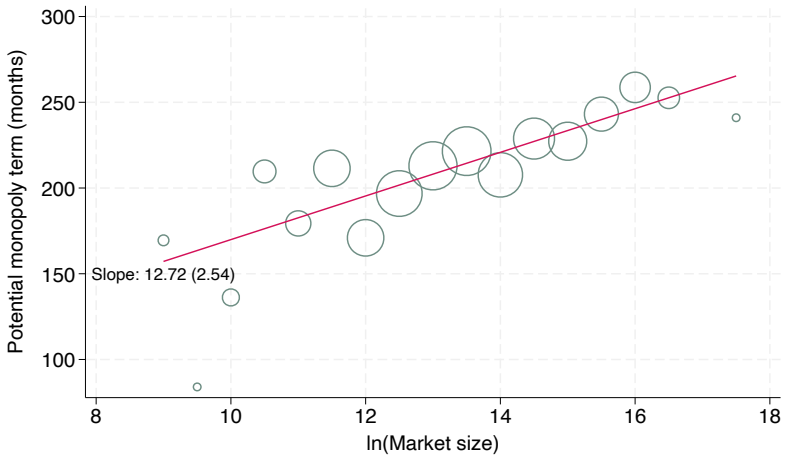


Figure plots relationship between drug market size and potential monopoly term. Open circles represent binned averages of the data, with circle dimension proportionate to the number of observations in each equally spaced bin. Line of best fit comes from a regression of potential monopoly term on the log of market size, with estimated coefficient and robust standard error reported in the figure. Number of drugs is 324.

Despite seeking longer monopoly terms via additional IP for their blockbuster drugs, not all of these IP are enforced. Figure 14 shows that blockbuster drugs receive shorter monopoly extensions than small-market drugs, and when it comes to actual monopoly term, Figure 15 demonstrates no significant relationship across drug market sizes. These results are consistent with prior research on secondary patenting and generic challenges, including those of Hemphill and Sampat (2012), who find that potential monopoly term increases sharply with sales but see no relationship between sales and actual monopoly term, as well as those of Grabowski et al. (2017), who find both increased patenting activity and more challenges for the most popular new drugs. That is, while firms may disproportionately seek to extend the monopoly terms of their best-selling drugs via additional IP rights, these rights are challenged by generic manufacturers and are not always enforced—leading to no real relationship between market size and actual monopoly term.

[41] This estimate comes from a regression of potential monopoly term on indicators for market size quartiles, where the bottom quartile is the reference group. Estimated coefficient is statistically significant at the 1-percent level under robust standard errors.

Figure 14: Relationship between drug market size and monopoly extension

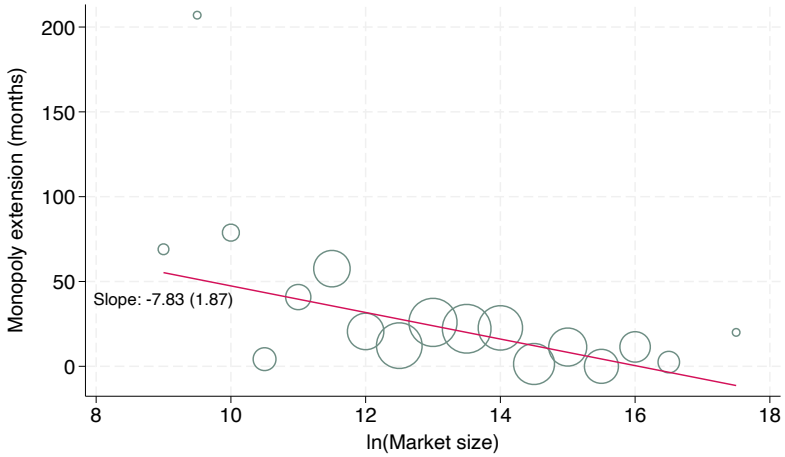


Figure plots relationship between drug market size and monopoly extension. Open circles represent binned averages of the data, with circle dimension proportionate to the number of observations in each equally spaced bin. Line of best fit comes from a regression of monopoly extension on the log of market size, with estimated coefficient and robust standard error reported in the figure. Number of drugs is 324.

Figure 15: Relationship between drug market size and actual monopoly term

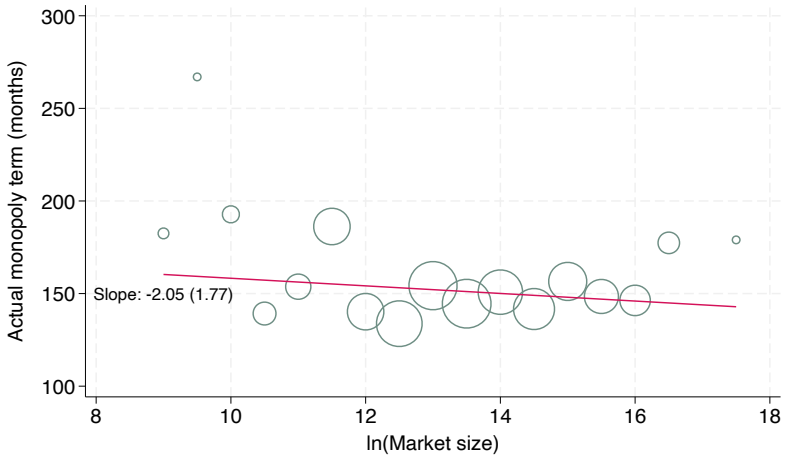


Figure plots relationship between drug market size and actual monopoly term. Open circles represent binned averages of the data, with circle dimension proportionate to the number of observations in each equally spaced bin. Line of best fit comes from a regression of actual monopoly term on the log of market size, with estimated coefficient and robust standard error reported in the figure. Number of drugs is 324.

A.12 Back-of-the-envelope calculations

A.12.1 Consumer welfare loss from monopoly pricing

There are two ways by which the introduction of a generic may expand consumer surplus: first, by lowering costs for those who were already purchasing the branded drug and switch to the generic, and second, by expanding the market for a drug. I consider solely the first channel as I calculate the consumer welfare loss from the 3-year per-drug delay in generic entry attributable to secondary patenting. I determine the difference in total dollars spent by consumers who were taking the average branded drug and would have switched to a generic version if it were available earlier. Key inputs into this calculation are thus mean per-drug revenues for branded versus generic versions of a molecule and the percent of consumers who switch from branded to generic. As noted by Branstetter et al. (2016), the term "consumer" in the pharmaceutical setting captures not just patients, but all "downstream" entities, including drug retailers and insurance companies.

To determine per-drug revenues under monopoly pricing, I rely on Figure 1 of Schuhmacher et al. (2022), which gives the number of new drugs launched and their total sales from 2011–2020. Given the analyses of Appendix A.11 that these monopoly extensions are less likely to occur for more popular drugs, I exclude both blockbusters (with mean annual sales since entering the market of >$1 billion) and high-selling drugs ($0.5–0.999 billion) in my calculations of per-drug revenues. Considering only low-selling (<$0.1 billion) and medium-selling ($0.1–0.499 billion) drugs, I obtain a per-drug annual revenue of $143.2 million for branded drugs under monopoly pricing.[42]

To determine per-drug revenues for generic molecules, I use estimates by Berndt and Aitken (2011), who find that generic prices fall to 78 percent of their initial value by six months post-generic entry, to 50 percent by one year post-generic entry, and to 23 percent by two years. I make the simplifying assumptions that the first generic entrant launches its product at the same price as the branded version and that these price declines occur at exactly six months, one year, and two years post-generic entry. These assumptions will contribute to an underestimate of the welfare loss to consumers, as generic price at launch may be lower than the branded price and gradual price declines will have likely occurred in advance of these specific endpoints.

If all consumers taking the branded version switched to the generic once it were available, they would spend $143.2 million $\times \frac{6}{12} = \$71.6$ million in the first six months post-generic entry, $143.2 million $\times \frac{6}{12} \times 0.78 = \$55.8$ million in the next six months, $143.2 million $\times \frac{12}{12} \times 0.5 = \$71.6$ million from year one to year two post-generic entry, and $143.2 million $\times \frac{12}{12} \times 0.23 = \$32.9$ million from year two to year three. This equals a total of $231.9 million spent per drug in the 3 years after generic entry, if all consumers used the generic version. In contrast, if all consumers used the branded version, they would spend $143.2 $\times \frac{36}{12} = \$429.6$ million. This amounts to a difference of $429.6 million −

[42] Calculation is as follows: $82.1 billion total revenues for medium-selling drugs + $4.7 billion for low-selling drugs)/(51 medium-selling drugs + 50 low-selling drugs)/6 years average commercialization period over 2011–2020 = $143.2 million annual per-drug branded revenues.

$231.9 million = $197.7 million per drug attributable to monopoly pricing over 3 years.

The final input to determine is the degree of consumer switching from branded to generic versions of a drug upon generic availability. Berndt and Aitken (2011) find a generic efficiency rate, meaning share of generic prescriptions for molecules where a generic version is available, of 92 percent and an overall generic share (including molecules without an available generic) of 75 percent as of 2009. Morton and Kyle (2011) note that aggressive formulary management by pharmacy benefit managers and mandatory substitution laws result in a branded product often losing 75 percent or more of its market share very quickly upon generic entry. Using this figure, I arrive at a final welfare loss to consumers of $197.7 million $\times$ 0.75 = $148.3 million per drug resulting from the 3-year extension in monopoly pricing. Given there are 355 drugs in my analytic sample that apply for secondary patents, this equates to a total welfare loss of $52.6 billion. This calculation represents a lower bound on the welfare loss consumers experience from delayed generic entry not only due to the choice of assumptions above but also in that it ignores any market expansion that may occur with generic entry. Note that this consumer welfare loss does not contribute to any changes in total social welfare but instead represents a transfer from consumers to producers under monopoly pricing.

A.12.2 Impacts to innovation

I carry out a second back-of-the-envelope calculation to determine how the 3-year patent extension may have influenced new drug development during my sample period. I begin with Budish et al.'s (2015) elasticity of R&D investment with respect to an additional year of patent life. They find a semi-elasticity ranging between 7 and 23 percent, where R&D investment refers to clinical trials. Applying their estimate to my results implies that the average 3-year extension in monopoly term should have increased number of clinical trials by between 21 to 69 percent relative to a counterfactual where innovating firms are restricted to solely the fixed term of their initial molecule patent.

Of course, not all clinical trials result in new molecules actually approved by the FDA. To translate this elasticity into one of how approved NCEs vary with the observed patent extension, I require estimates of the proportion of clinical trials that are successful (i.e., resulting in an approved drug) and the proportion of total approved drugs that are NCEs. My elasticity of interest $\frac{\partial \text{ (NCEs)}}{\partial \text{ (patent term)}}$ can thus be calculated as follows:

$$\frac{\partial \text{ (NCEs)}}{\partial \text{ (patent term)}} = \frac{\partial \text{ (clinical trials)}}{\partial \text{ (patent term)}} \times \frac{\partial \text{ (total approved drugs)}}{\partial \text{ (clinical trials)}} \times \frac{\partial \text{ (NCEs)}}{\partial \text{ (total approved drugs)}} \quad (5)$$

The first term on the right-hand side of Equation 5 is the Budish et al. elasticity. For the second term, I rely on a comprehensive study by Wong et al. (2019) of drug development success rates across therapeutic indications. They find that 13.8 percent of all Phase 1 clinical trials lead to an

approved drug. Finally, my data shows that roughly 50 percent of all drugs approved by the FDA between 1985 and 2010 were NCEs, providing an estimate for the third term.

As a lower bound, I estimate a $21 \times 0.138 \times 0.5 = 1.4\%$ increase in NCEs during my sample period attributable to the average 3-year patent extension, equivalent to $355 \times 0.014 \approx 5$ NCEs out of the total sample of 355. As an upper bound, I estimate a $69 \times 0.138 \times 0.5 = 4.8\%$ increase, equal to $355 \times 0.048 \approx 17$ NCEs. While I leave a complete welfare analysis to future research, combining the two back-of-the-envelope calculations suggests a consumer welfare loss of $3.1 billion to $10.5 billion from monopoly pricing for each NCE gained.