NBER WORKING PAPER SERIES

THE ROLE OF ASSETS IN PLACE: LOSS OF MARKET EXCLUSIVITY AND INVESTMENT

Matthew J. Higgins
Mathias J. Kronlund
Ji Min Park
Joshua Pollet

Working Paper 27588
http://www.nber.org/papers/w27588

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2020

We thank IMS Health Incorporated, now IQVIA, for their generous support and access to their data. The statements, findings, conclusions, views, and opinions contained and expressed herein are not necessarily those of IQVIA, IMS Health Incorporated or any of its affiliated or subsidiary entities. The statements, findings, conclusions, views, and opinions contained and expressed in this article are based in part on data obtained under license from the following IMS Health Incorporated or affiliate information service(s): IMS MIDAS. Higgins acknowledges support from the Sorenson Center for Discovery and Innovation. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

The Role of Assets In Place: Loss of Market Exclusivity and Investment
Matthew J. Higgins, Mathias J. Kronlund, Ji Min Park, and Joshua Pollet
NBER Working Paper No. 27588
July 2020
JEL No. D92,G31,G32,G35,L65,O30

ABSTRACT

We utilize a novel identification strategy to analyze the impact of assets in place on firms' decisions for future projects. We exploit the context in the pharmaceutical industry, where the loss of market exclusivity for a branded drug can be used to separate the impact of cash flows generated by a firm's current assets in place from the characteristics of its future investment opportunities. We first show that around the exclusivity losses in our sample of large drugs, the affected firms' profitability drops significantly. The timing of this profitability decrease was predetermined many years ago, and therefore, arguably independent of current investment opportunities. Nevertheless, we find that R&D spending drops by approximately 25% over two years following the loss of exclusivity of these pre-existing drugs. We also find that stock repurchases and cash balances decline significantly. Our findings do not support the predictions of traditional capital budgeting, but are more consistent with the pecking order theory. These results further point to a lack of long-term lifecycle management that could mitigate the effect of predictable negative shocks to cash flows.

Matthew J. Higgins
David Eccles School of Business
University of Utah
1731 E Campus Center Drive
Salt Lake City, UT 84112
and Max Planck Institute for Innovation and Competition
and also NBER
matt.higgins@eccles.utah.edu

Mathias J. Kronlund
Freeman School of Business
Tulane University
7 McAlister Dr
New Orleans, LA 70118
mkronlund@tulane.edu

Ji Min Park
Gies College of Business
University of Illinois at Urbana-Champaign
607 E Gregory Drive
Champaign, IL 61820
jpark358@illinois.edu

Joshua Pollet
Gies College of Business
University of Illinois at Urbana-Champaign
4039 BIF
515 E. Gregory Drive
Champaign, IL 61820
pollet@illinois.edu

1 Introduction

Many factors contribute to a firm's investment and financing decisions. The baseline model is provided by traditional capital budgeting. Firms invest to undertake positive net-present-value (NPV) projects with the funds for these investments being raised from either internal or external sources of financing without frictions (Modigliani and Miller (1958)). Alternatively, in the presence of asymmetric information, external financing is costly, and firms may optimally choose to forgo a positive-NPV project if the project cannot be financed using internal cash flows or pre-existing cash on the firm's balance sheet (Myers and Majluf (1984)).[1] Costly external finance leads to a pecking order theory for financing a firm's investment in which available cash is used before issuing equity to finance new projects.

It is typically challenging to distinguish between the relative contributions of these theories and to assess the role of financing frictions on firms' investments. This is because it is difficult to separate the impact from changes that affect cash flows available for investment (often generated from a firm's assets in place), from the changing valuations of a firm's current investment opportunities. In other words, whenever a firm's current profitability falls, the NPV of its investment opportunities tends to decline at the same time, thus reducing the benefits of such investment. In this context, even a model with frictionless investment would predict less investment in the face of lower cash flows.

The expiration of pharmaceutical patents protecting a branded drug or the resulting loss of market exclusivity represents a unique situation that can distinguish between these two theories. Immediately following the loss of market exclusivity, other firms may directly compete by providing a bioequivalent generic version of the original drug that does not require clinical testing as part of the approval process created by the Food and Drug Administration

[1] There is another factor that may affect external financing decisions. For instance, market timing predicts that firms issue and repurchase equity to take advantage of mispricing (Baker, Ruback, and Wurgler (2007); Stein (1996)). However, this market timing theory does not make precise predictions about the relation between the timing of investment or R&D and profitability patterns.

(FDA).[2] This form of competition from generic entry dramatically reduces revenue for the affected branded drug, and consequently, the profitability of the branded firm (e.g., Reiffen and Ward (2005); Branstetter, Chatterjee, and Higgins (2016)).

Crucially, it is implausible for the timing of the change in cash flow associated with the loss of market exclusivity to contain information about future investment opportunities for the affected firm. The timing is pre-determined based on the drug's patents that were granted many years prior, and the fact that a drug losses exclusivity on a specific date has no bearing on the future profitability of *other* drugs in the affected firm's development pipeline.[3] This implies that there is a predictable change in the cash flow from assets in place, which is caused by the loss of market exclusivity, and that this change is plausibly exogenous to current investment opportunities to develop new drugs by the firm.[4] The impact of these losses of market exclusivity is often also economically large; thus, we expect that they may cause measurable effects on investment if firms indeed act as if they are constrained.

To study the effects of these loss-of-market-exclusivity events, we follow the methodology in Gormley and Matsa (2011) to construct cohorts of peer firms. Treated firms in each *cohort* consists of firms that experience a loss of market exclusivity in that quarter, and these firms are then compared to peer control firms that did not suffer such a loss. We compare these groups of firms over eight quarters before and after the loss by employing a difference-in-differences approach.

Our results indicate that quarterly firm revenues decrease by more than three percentage

[2]To be more precise, this is accurate for chemical-based drugs as opposed to biologic-based drugs. For the purposes of this paper, our focus will be on the loss of market exclusivity (i.e., patent protection) and subsequent generic entry surrounding chemical-based drugs. The current regulatory environment faced by pharmaceutical companies in the U.S. and the delineation between chemical- and biologic-based drugs will be discussed in Section 2.1.

[3]As a consequence of external technology markets, including licensing, merger and acquisitions, the patent holder at expiration is often not responsible for the original patent application or the underlying research.

[4]Drugs are often protected by multiple patents, and patent protection can be extended under particular circumstances. Furthermore, some patents are subject to"Paragraph IV" legal challenges by generic manufactures. These challenges can occur anytime between the end of the regulatory data exclusivity period and the end of patent protection. For a more complete discussion, see Voet (2016). In our empirical analysis, we examine corporate decisions over sufficiently long time windows before and after the expected date of patent expiration that any residual uncertainty is unlikely to have an appreciable impact on the timing patterns that we find.

points, as scaled by lagged total assets, following the loss of market exclusivity for a branded drug. Because the average firm in our sample has quarterly drug revenue scaled by lagged assets of approximately 17 percent, this decrease is approximately 20 percent of the baseline revenue. We find even larger effects when we further exclude any events where the branded drugs are relatively less economically important (i.e., those that generate less than 1 percent of a firm's revenue before the loss of exclusivity) and thus focus on the relatively more significant events. We observe similar patterns of decreases in firm profitability and cash flows, especially around these larger events.

Since new investment and research and development (R&D) are critically important for firms in the pharmaceutical industry, we expect these corporate decisions to reflect the rational assessment of investment opportunities and any trade-off imposed by external financing. According to Acemoglu and Linn (2004) and Dubois, Mouzon, Scott-Morton, and Seabright (2015), pharmaceutical companies do respond to the predictable changes in demand induced by demographics. The industry as a whole develops more drugs for categories that are predicted to have an increase in patients. Additionally, Ellison and Ellison (2011) show that pharmaceutical companies use advertising expenditures in a sophisticated manner to strategically deter entry. Based on these findings, it certainly appears as if firms in this industry are sophisticated actors that implement corporate decisions using a logical evaluation of the available investment opportunities.

How should firm decisions regarding investment opportunities be affected by a substantial and predictable decrease in revenue and profitability generated by assets in place? If traditional capital budgeting largely explains firm decisions, then investment and R&D expenditures should only depend on whether current projects have an NPV that is greater than zero. Expenditures supporting investment opportunities should be unrelated to the timing of the loss of market exclusivity. Moreover, the timing for raising external financing should be positively related to the timing of these expenditures on investment opportunities. By

contrast, if external financing is costly, then revenues and profitability from assets in place should be positively associated with higher expenditures on investment opportunities.

Our evidence indicates that R&D decreases significantly during the eight quarters following the loss of market exclusivity. During these eight quarters, quarterly R&D expenses, normalized by lagged assets, decrease by about 0.6 percentage points (relative to a sample mean of 2.36%) for the affected firms, when compared to peer firms that do not experience a loss of market exclusivity at the same time. In other words, R&D is around 25 percent lower for the affected firms following the loss of market exclusivity. The estimated impact on capital expenditures is also negative, but this effect is economically smaller and not statistically significant.

Next, we examine the impact of this predictable decrease in cash flow due to the loss of market exclusivity on the financing and cash policies. First, consistent with almost any theory in which internal pre-existing cash balances are deployed to support the firm when it suffers a shock to cash flows, we find that cash balances significantly decrease. We also find that payout decreases, although this effect is driven merely due to a sharp cutback of buybacks. By contrast, we find some evidence that dividends increase after these events, although this effect is mostly driven by events that involve smaller and thus less-economically important drugs.

We also examine the effect on firms' other financial policies. Buybacks (measured as quarterly share repurchases scaled by lagged assets) decrease substantially following the loss of market exclusivity.[5] The decrease is approximately 0.5 percentage points relative to the mean of 0.68 percent. The total payout ratio, i.e., the sum of repurchases and dividends, also declines significantly. This pattern is consistent with the pecking order theory in which the firm adjusts cash and payout policy to finance investment before issuing new securities. However, the pattern linking the loss of market exclusivity and external finance is more nuanced. We also find some evidence that debt issuances increase and equity issuances

[5]Our measure of share repurchases scaled by assets is defined as zero if the net of stock repurchases minus sales is negative.

decrease for firms that are more financially constrained. On the other hand, firms that are likely to be less financially constrained (measured as the largest firms in the sample), do not exhibit any patterns regarding security issuance following the loss of market exclusivity. The decline in investment is also lower for these relatively less constrained firms.

The paper presents several tests to ensure the robustness of the results. We first show that there are no pre-trends in investment or financial policies before the loss events. To further ensure that the negative effect on revenues and cash flows is not somehow spuriously driven by our methodology for collecting patent information, we also consider the expiration of "non-critical" patents as a "placebo" robustness test. We define non-critical patents as those that expire but that are not followed by generic entry. We find that the expiration of non-critical patents is not associated with a statistically significant impact on firm revenues, and consequently, also is not associated with cuts to investment. We similarly separately study the impact of the loss of exclusivity for economically less important drugs—defined as those that represent less than 1% of firm revenues before the loss—and find little measured impact on any of our outcome variables.

These results provide important evidence of how generic entry impacts future innovation (e.g., Branstetter, Chatterjee, and Higgins (2014); Murphy (2017)). Crucially, this evidence is broadly consistent with the view that revenue from existing branded products are used to support subsequent innovation. However, our evidence does not allow us to assess whether this subsequent innovation would be socially optimal (Branstetter et al. (2016)). Importantly, our findings also suggest that firms in practice are failing to effectively plan across their pipeline and product lifecycles.[6]

Overall, these results point to assets in place as having a vital role in firm decisions. First, expenditures on investment opportunities, as measured by investment and R&D, are strongly related to the loss of market exclusivity for branded drugs, particularly those that generate

[6]This does not mean they are not trying (e.g., Amoresano (2007); Prajapati and Dureja (2012)). However, these efforts do not appear to be sufficiently effective. For example, Pfizer's efforts to develop a follow-on or next-generation drug for their global blockbuster, Lipitor, ultimately failed.

a large share of the firm's revenue. Second, the timing of these expenditures on investment opportunities is not strongly related to raising funds from equity. Critically, these findings contradict the main predictions of traditional capital budgeting explanations. Instead, this evidence suggests that costly external financing affects firms' decisions in a manner that is more consistent with the pecking order theory.

The paper is organized in the following manner. Section 2 describes the loss of market exclusivity events analyzed in this paper and explains how this information is linked to data about firms' investment and financing decisions. Section 3 provides preliminary evidence about the source of identification. Section 4 documents the substantial negative impact of the loss of market exclusivity on firm revenue and profitability. This section also analyzes the relation between the loss of market exclusivity and the fundamental decisions of the firm: investments in capital expenditures and R&D, payout, cash, and external financing. We conclude in Section 5.

2 Data

2.1 Regulatory environment

The current regulatory environment faced by pharmaceutical companies in the United States can be traced to the passage of the Drug Price Competition and Patent Term Restoration Act in 1984, informally known as the "Hatch-Waxman" Act. The Act provided a delicate balance between expedited FDA approval for generic entry and extensions to pharmaceutical patents in order to compensate innovators for lost time while waiting for FDA approval (Grabowski and Kyle (2007)).[7] When a pharmaceutical company submits a New Drug Application (NDA) to the FDA for approval they are required, by law, to identify all relevant patented

[7]There are limits to this. Pharmaceutical firms cannot receive a patent extension of more than five years, nor are they entitled to patent extensions that provide them with a patent life (post-approval) that is effectively greater than 14 years.

technologies necessary to create the drug; these patents are subsequently listed in the FDA Orange Book.[8]

Upon approval, the FDA will grant each new drug regulatory protection lasting for five years (also known as data exclusivity) which runs concurrently with patent protection.[9] During this data exclusivity period, regardless of the status of the underlying patent(s), no generic entry may occur. At the conclusion of data exclusivity, branded products are protected only by their patents; this period running from the cessation of data exclusivity to the expiration of the patent(s) is commonly referred to as "market exclusivity" (see Appendix Figure 1).

Prior to the passage of Hatch-Waxman, generic manufacturers seeking to enter the market had to demonstrate the safety and efficacy of their products by putting them through clinical trials (Mossinghoff (1999)). While Hatch-Waxman did not lessen the burden of the clinical trials process for branded pharmaceutical companies seeking approval for new drugs, it virtually eliminated the requirement for separate clinical trials for generic manufacturers. This was made possible since generic manufacturers could simply demonstrate "bioequivalence" with branded products by showing that the active ingredient in their product diffused into the human bloodstream in a manner similar to the original product.

Hatch-Waxman provides four pathways (or "Paragraphs") a generic firm may follow in order to gain entry into a market. The process starts with the filing of an Abbreviated New Drug Application by a generic manufacturer with one of the four Paragraph certifications. A Paragraph I certification is one for which the originator firm has not filed patent information for its branded product. Paragraph II certification relates to when the branded product's patent has already expired (i.e., the end of market exclusivity), and Paragraph III certifica-

[8]Importantly, outside of the requirement to list relevant patents, there is no regulatory screening of which patents firms ultimately choose to list in the Orange Book. This has led to criticism of gaming in terms of when patents get listed (Bulow (2004)) and the relevance of the patents themselves (Hemphill and Sampat (2011); Hemphill and Sampat (2012)). The implication of this regulatory anomaly is that not every patent attached to a branded drug will allow for generic entry upon expiration. We use this anomaly as a basis for one of our placebo tests.

[9]Orphan drugs receive seven years of data exclusivity, reformulations receive three years of data exclusivity, and pediatric indications receive an additional six months of data exclusivity.

tion relates to cases when the generic manufacturer notes that the patent on the branded product will expire on a specific date and that it seeks to enter only after patent expiry or end of market exclusivity. The fourth certification, Paragraph IV, argues that the generic manufacturer does not infringe on a branded product's patents or that those patents are invalid. More importantly, however, a Paragraph IV certification can be acted on by the FDA after the conclusion of data exclusivity anytime during the market exclusivity window (see Appendix Figure 1).[10] These certifications result in litigation, and in the case that the challengers are successful, this would bring generics to the market earlier than otherwise would be the case (Higgins and Graham (2009); Grabowski and Kyle (2007); Panattoni (2011); Palermo et al. (2019)).

It is critical to note that the preceding discussion relates only to chemical-based or small-molecule drugs. Generic versions of biologic-based drugs (often referred to as biosimilars) are governed by the Biologics Products Competition and Innovation Act, which was passed in 2009. However, due to a delay in the enabling regulations, the first biosimilar was not introduced in the U.S. until 2015. As we discuss below, this will be outside of our sample period. As such, for the purposes of this paper, our focus will be on the loss of market exclusivity and subsequent generic entry surrounding chemical-based or small-molecule drugs.

2.2 Sample of branded drugs

Our sample consists of loss-of-exclusivity events between 1999 and 2016. We begin our sample construction by first collecting revenue information on branded drugs in the U.S. market. Our main source for this data is the IMS MIDAS (now IQVIA) database. This is a quite comprehensive database of quarterly drug sales, and our data covers the years 1998–2010. We use several additional resources to build out our list and to ensure that our data covers

[10]Paragraph I and II certifications are rarely used. Paragraph III certifications are the most common filing by generic firms because they will be anticipating the expiration of underlying patents (Federal Trade Commission (2002)). Paragraph IV challenges have increased over time, especially since 2003; however, this mode of entry is still probabilistic as it depends on a litigation outcome (Berndt, Danzon, and Kruse (2007); Palermo, Higgins, and Ceccagnoli (2019)). For reasons we discuss below, we will focus on generic entry via Paragraph III certifications.

as many of the highest-revenue drugs as possible. These additional data sources consist of lists from two pharmaceutical magazines, Drug Topics and Medical Advertising News, which publish lists of either Top-100 or Top-200 branded drugs by sales, and the online website drugs.com. In general, these high-revenue drugs or 'blockbusters' tend to persist over time.

Next, we hand-collect the expiration dates for all the patents attached to these drugs from the FDA Orange Book. This dataset contains detailed information on approved drugs, including the name of applicants, active ingredients, availability of generic counterparts, and the dates of each patent's expiration. Firms will frequently get regulatory extensions for their patents, for example, due to the time spent in the FDA approval process. In order to ensure that the patent expiration dates that we identify include any granted extensions, we augment our data using the extended patent information as published by the United States Patent and Trademark Office.

We next take these patent expiration dates, including their extensions, and look for introductions of generic drugs entering within six months of a patent expiration. This merge between patent expiration dates that are followed by generic entry forms our main set of loss of market exclusivity events. We use the IMS MIDAS to measure revenue during specifically in the quarter preceding patent expiration. The branded drug's revenue before expiration is used to determine if the patent's expiration is likely to have a meaningful impact on the firm. Even if a drug has substantial sales, it can still be a small portion of overall revenues for the largest pharmaceutical firms. Because our IMS data starts in 1998, this data requirement narrows the list of drugs to those with patents that expire after this date.

Merging the patent expiration dates and generic entry dates has two purposes. First, we seek to eliminate generic entry that is *not* associated with loss of market exclusivity (i.e., those that are not Paragraph III generic entry). In these cases, the entry may be unanticipated, or at least probabilistic (Lemley and Shapiro (2005)). For example, as discussed in the prior section, a firm's monopoly position can be lost before the loss of market exclusivity if a branded firm loses an early generic "Paragraph I" challenge (Palermo et al. (2019)).

By contrast, if a generic enters because of the loss of market exclusivity (i.e., Paragraph III generic entry), then that event can be fully anticipated.

Second, we also exclude patent expirations that are *not* followed by generic entry. One plausible explanation why this may occur, as noted previously, is that not every patent listed in the FDA Orange Book will allow for generic entry upon expiration. These "non-critical" patents will become the basis of one of our placebo tests, but they are excluded from our main specifications because there is no resulting shock to a firm's cash flow. In total, we identify 410 branded drugs with patent expiration information data, and that are associated with generic entry.[11]

2.3 Merging loss of market exclusivity events to firm characteristics

We next manually match the owner of each branded drug to company identifiers in Compustat North America. We require a company to be covered by Compustat to obtain standardized accounting information; this requirement nevertheless results in the exclusion of pharmaceutical firms that are based abroad. When a firm's subsidiary owns the branded drug, we identify its parent firm in Compustat. We specifically identify the owner as of the patent expiration date, and this owner may not be the original patent holder. For example, owners of branded drugs can change due to several reasons such as licensing, mergers and acquisitions, corporate spin-offs, or sales of the individual drug. Overall, the sample period from Compustat ranges from 1996 to 2017. This is to ensure three years of data before the first expiration date in 1999 that has available sales data from IMS.

Next, we apply a few filters to our data. First, we drop firms from the sample if R&D or revenues are zero or missing. This is to ensure we have data to measure the impact on R&D,

[11] As we noted in Footnote 8, while there is a patent reporting requirement, there is no formal screening mechanism for which patents get listed in the FDA orange Book. As a result, firms may have have an incentive "over-list" patents. Moreover, not every patent will coer the entirety of a drug so its expiration should not be expected to allow for entry.

and to remove firms whose main role may be purely marketing. Second, we remove firms if their quarterly C.P.I.-adjusted assets or quarterly revenues are smaller than $1 billion or $100 million, respectively. Finally, we exclude firms if their age is younger than 15 years. These latter two filters only remove one drug with loss of market exclusivity from our sample; however, this filter is crucial as the purpose of the study is to determine the impact of the loss of market exclusivity for the affected firms, as compared to a control group of firms that do not experience such a loss. It is, therefore, important to filter on the firm's age to ensure that we are comparing established companies with similar peers, and we correspondingly apply a symmetric filter to our "control" firms.

This procedure yields 115 high-revenue drugs for our sample period that are matched to Compustat firms and meet the above filters. Table 1 lists the 25 drugs with the largest sales during the quarter before the loss of market exclusivity in our sample. Many of these brands and the associated firms are widely recognized even outside the medical field.

We use the IMS MIDAS data to measure revenue specifically in the quarter preceding expiration, and scale this by the total firm revenue, to measure the predicted impact of these events. The branded drug's revenue before expiration is used to determine if the patent's expiration is likely to have a meaningful impact on the firm. That is, even if a drug has substantial sales, it can still be a small portion of overall revenues for one of the largest pharmaceutical firms. If the sales information is not available at the time prior to the loss of market exclusivity (which is the case for events after 2010, for which we do not have IMS data), we use the information of latest sales before the the loss of market exclusivity.

2.4 Drug-level cash flow patterns around the loss of market exclusivity

To illustrate the impact the loss of market exclusivity can have, consider the example of Lipitor, which is marketed by Pfizer. In our sample, Lipitor had the highest revenue before the loss of market exclusivity. It also had the highest annual revenue in the U.S. of all drugs

from 2003 to 2009 and was the second-highest revenue drug in 2010. In November 2011, the patent for Lipitor expired. Figure 1 shows the revenue pattern from Lipitor around the date of the loss of market exclusivity. The event is represented by the vertical line in the middle of the figure. As reported, quarterly global revenues were approximately $2.5 billion for the quarter before the loss of market exclusivity. Following the loss of market exclusivity, quarterly revenues decreased to less than $1 billion within four quarters and continued to fall by another 30 percent the following year. In the two years following the loss of market exclusivity, the annual revenues generated from Lipitor declined by approximately $8 billion.

Unsurprisingly, this significant change in revenue for Lipitor also had a substantial impact on Pfizer's total revenue. Pfizer's 2011 revenues were approximately $65 billion, declining to approximately $55 billion in 2012 and continuing to decline in 2013. Such a significant revenue decrease also affected Pfizer's profitability and cash flow metrics. Importantly, this decrease in revenue was nevertheless predictable based on the loss of market exclusivity date, and the loss-of-exclusivity event by itself contained little information about the NPV of Pfizer's *other* drugs in development and the potential of future research.

In Figure 2, we use all drugs in our sample to study the average change in drug revenues around the loss of market exclusivity. This figure plots the average fraction of revenues for each drug relative to that drug's maximum quarterly revenues in our sample period in event time (quarters) around the quarter when the loss of exclusivity took place. This quarter ($t = 0$) is represented by the vertical line. Scaling by maximum quarterly revenues for each drug is designed to standardize the magnitude of the decline across drugs.

The pattern for this average of scaled revenues around the end of market exclusivity across drugs in our sample is roughly similar to the pattern we saw for Lipitor in Figure 1. This pattern is also consistent with the extant literature (e.g., Branstetter et al. (2016); IMS Institute for Healthcare Informatics (2016); Reiffen and Ward (2005)). Average revenues decline from approximately 80 percent of maximum quarterly revenues the quarter before the loss of market exclusivity to about 30 percent of maximum quarterly revenues the quarter

after the end of market exclusivity. The average of scaled revenues continues to decline to less than 15 percent within two years of the loss of market exclusivity.

Even though generic entry after the loss of market exclusivity occurs relatively quickly, the graph shows that the full impact on the branded drug's revenues does not take place immediately.[12] For example, it may take time for consumers to renew a prescription, at which time state substitution laws would transition the consumer, in most cases, to a generic. Branded drug companies can also seek to moderate the decline, for example, by distributing discount cards to consumers, subsidizing co-pays, and other kinds of rebates to try to extend branded usage. Nevertheless, based on this figure, most of the decline in revenues due to the loss of market exclusivity occurs within the first year.[13]

Since firms know about this expected decrease in revenues resulting from the loss of market exclusivity well before the actual date of expiration, we can use this predetermined event to analyze how critical corporate decisions are affected by the change in cash flows from these "assets in place." In the next section, we consider these effects in the context of pharmaceutical firms experiencing the loss of market exclusivity in terms of their policies regarding investment, R&D, payout, and external financing.

3 Empirical strategy and identification

Our baseline empirical strategy compares firm-level outcomes between firms that experience a loss of market exclusivity ("treated" firms), compared to a control set of pharmaceutical firms that do not experience such a loss over the same period. The underlying identification

[12]This revenue decrease is driven by lower quantities. By contrast, branded drug *prices* often tend to increase as firms are exploiting the relatively more price inelastic consumers that remain on branded drugs even in the presence of generic drugs (Frank and Salkever, 1997).

[13]There remains the nuance of different dosages. For example, suppose a drug is sold in 30 mg and 60 mg forms. Generic entry is form specific; for example, suppose it only applies to the 60 mg tablet. If a consumer took the 60 mg tablet, they would get the 60 mg generic because of state substitution laws. However, their doctor could prescribe twice the amount of 30 mg pill, in which case they would get the 30 mg branded pills. Our revenue data are at the brand-level, not the dosage level, so some of the slower dissipation could be due to the existence of multiple dosages and the rates at which generics come online for additional dosages.

assumption is that the treated firms, in the absence of having experienced the loss of market exclusivity, would have behaved similarly to the control firms.

In order to ensure comparability between the treated firms and the control firms, we follow the approach in Gormley and Matsa (2011) to construct cohorts of peer firms. A *cohort* consists of all treated and control firms as of a specific calendar quarter. We form such cohorts around every calendar quarter, in which at least one firm experiences a loss of market exclusivity. Around each quarter with such an event, we create groups of treated firms (those that experience a loss) and control firms (those that do not experience a loss around the same time), and analyze these firms in *event time* around the focal quarter. For example, suppose two firms lose market exclusivity in Q1:2002, which we refer to as the "event quarter" ($t = 0$) for the cohort of Q1:2002. Then those two firms are the treated firms of that cohort, and we additionally form a set of control firms for that cohort drawing from other pharmaceutical firms that do not experience loss of market exclusivity in that event quarter. In our analysis, we then compare how these two groups of treated and control firms in the same cohort behave in event time over eight quarters before $(t - 8)$ to eight quarters after $(t + 8)$ the event quarter. We form similar groups of treated and control firms around every other calendar quarter with a loss of market exclusivity.

To construct the set of control firms for each cohort, we start with all firms in the pharmaceutical SIC industry classification ($SIC = 2834$). As we described in the previous section, we apply a set of data filters to the treated firms based on their size, age, and R&D activities, to ensure that these are established pharmaceutical firms that are active in R&D. To ensure comparability, we, therefore, apply symmetric filters to the set of control firms. Specifically, from the set of possible control firms within the pharmaceutical sector, we drop firms that have R&D expenses that are missing or zero, or that have revenues that are missing or zero. We exclude firms with C.P.I-adjusted assets or quarterly revenues that are smaller than \$1 billion or \$100 million, respectively, and firms with age younger than 15 years. The purpose of these filters is to ensure that the activities of established

pharmaceuticals experiencing the loss of market exclusivity are compared to similar peer firms that might be expected to display similar trends over time in the absence of treatment. For example, we would not want established pharmaceutical firms that experience a loss of market exclusivity to be compared to biotechnology start-ups; the latter firms could have patterns of investment that are quite different, thus potentially violating the parallel trends assumption. We validate that this methodology produces similar "pre-trends" between the treated and control firms, which supports the parallel trends assumption.

After pooling all event-time cohorts, we estimate the impact of the loss of market exclusivity on revenue for the treated firms as follows:

$$y_{i,q,c} = \beta_0 + \beta_1 Loss_{i,c} + \beta_2 Post_{q,c} + \beta_3 Loss_{i,c} \times Post_{q,c} + \gamma_{i,c} + \omega_{c,q} + \epsilon_{i,q,c} \tag{1}$$

In Equation 1, $y_{i,q,c}$ is the dependent variable for firm i in event time q and cohort c. The outcome variables we study are the effects on firm revenues, profitability, R&D, capital expenditures, cash, payout, and equity issuance.

Loss is an indicator for whether firm i in cohort c is treated, i.e., whether it experiences a loss of market exclusivity in the focal quarter. *Post* is an indicator variable for whether quarter q is in the post-event period for cohort c, i.e., in the eight quarters following the loss-of-exclusivity. The main coefficient of interest is β_3, which measures how the treated firms alter their behavior after the loss of market exclusivity compared to control firms.

The variable $\gamma_{i,c}$ represents firm-cohort fixed effects, and $\omega_{c,q}$ represents event-time-by-cohort fixed effects. The firm-cohort fixed effects control for any unobservable firm-level characteristics that are time-invariant around the event (these characteristics are only assumed to be constant within a cohort, and we allow them to vary for the same firm across cohorts that represent different event quarters). The event-time-by cohort fixed effects control for any aggregate (e.g., macro- or industry-level effects) that affect all firms in the same cohort over time. These two groups of fixed effects subsume the coefficients on β_1 and β_2,

respectively. We cluster the standard errors across two separate dimensions, at the firm level, and at the time (quarter) level.

This analysis could be confounded if the control firms were to experience a loss of market exclusivity close to the event quarter, in which case they would also be treated for many of the quarters in the eight-quarter window around the focal quarter. This, in turn, would have the effect of biasing down the measured impact of any actual events. For example, suppose that the focal event quarter is Q1:2002, and that a potential "control" firm did not experience a loss in that quarter, but did experience such a loss of market exclusivity in the next quarter (Q2:2002). If this firm were included as a control firm within this cohort, it would distort any difference between the treated and control firms, since the control firm also lost significant revenues during the *post*-period. To mitigate this concern, we remove control firms from the cohort if they also have events within the time window between quarter $t-8$ to $t+8$.

Occasionally, the same treated firm can also have multiple events within a short period. If a firm has two events within eight quarters, then the event for the drug that has the most significant impact on firm revenue is included as the treated quarter, while the event with the smaller revenue is removed. This firm is also excluded from being a control firm around the event quarter associated with the loss of market exclusivity for the smaller-revenue drug.[14] For example, suppose the same firm has an event in Q1:2002 and Q4:2002, but the Q1:2002 event is more significant. Then we remove this firm from the cohort of Q4:2002 (i.e., it is included neither as a treated firm nor as a control firm in that quarter), and further, it is not a control firm in any cohort that is within eight quarters after the latter event or within eight quarters before the earlier event.

Table 2 presents summary statistics for our panel of treated and control firms between 1996 and 2017. The distribution of book assets and firm revenue indicates that these firms tend to be larger and more profitable than the typical firm in Compustat. This table also

[14]This filter reduces the number of events from 115 to 55.

reports the average value for several scaled accounting variables, including revenues, net income, dividends, repurchases, equity issuance, debt issuance, sale of PP&E (property, plant, and equipment), capital expenditures, R&D, and cash. In general, the typical firm in our sample has substantial R&D expenditures, holds large cash balances, and is highly profitable.

4 Results

4.1 Pre-trends analysis

Before turning to our primary analysis, we first investigate whether there are any pre-trends before the loss of market exclusivity that could have the potential to contaminate the main results. In Panel A of Table 3, we regress the average quarterly changes for all of our outcome variables from $t-4$ to $t-1$ on the indicator for loss of market exclusivity (*LossOfExclusivity*) followed by generic entry for the firm in quarter t. This indicator variable is not statistically significant in any of the regressions in Panel A. Crucially, this result shows that there are no differences in trends across any of these variables before the loss of market exclusivity between the treated and control firms.

The finding of no differential trends, particularly in the financial policies, is particularly noteworthy in this setting. This result means that the treated firms did not prepare differently before the loss of market exclusivity in ways that could have softened the impact of the event. For example, the treated firms could have increased their cash reserves before the loss of market exclusivity to ensure a buffer to weather a predictable negative shock to revenues; but our findings suggest that they did not significantly do so.

4.2 Effects on revenues and profitability

Next, we estimate the impact of the loss of market exclusivity on revenues and profitability. These results are reported in Table 4. In Model 1, we find that revenue scaled by lagged assets is significantly lower for the full sample. Quarterly revenue scaled by assets is 3.3 percentage points lower during each quarter on average during the eight quarters following the loss of market exclusivity events for the treated firms as compared to the control firms. Critically, this means that scaled revenue declines by approximately 20 percent compared to its unconditional average reported in Table 2. In Model 2, we examine the analogous specification for net income scaled by lagged assets. While the coefficient estimate is negative, the results are not significant for the full sample.

However, this test about the impact of the loss of market exclusivity may be of limited statistical power because some of the drugs in our sample may represent only a small share of a firm's total revenue. Even though revenues for a specific drug may decline, the overall impact could be limited at the firm level if the drug represents only a small part of its total business. To address this concern, we consider a more restrictive set of loss of market exclusivity events. As in Table 3, we define an indicator as a loss of market exclusivity event for a drug that generates more than 1 percent of the firm's total revenues.

In Models 3 and 4, we show that focusing on these events, which excludes the relatively less economically important events, further increases the coefficient estimates compared to the results for the whole sample (Models 1 and 2). The magnitude of the relevant coefficient increases by about 20 percent for the revenue specification (Model 3) and remains strongly significant, and the coefficient estimate more than doubles for the net income specification (Model 4) and becomes statistically significant at the 5 percent level. The estimated coefficient in Model 4 suggests that net income declines by approximately 30 percent, on average, relative to the unconditional mean in Table 1 during the eight quarters following the loss of market exclusivity around these economically more important events.

Collectively, these results on revenues and net incomes are not very surprising insofar as when a drug loses market exclusivity, we would naturally expect a firm's revenues and net income to drop. However, this table provides a sense of the magnitude of the "first stage", that is, how large this drop is in economic terms. Moreover, the presence of a decline or drop illustrates how challenging lifecycle management is in the pharmaceutical industry. We can now turn to comparing these magnitudes to the actions that firms take in response in terms of their investment and financial policies, which we analyze in the next sections.

4.3 Effects on R&D and investment policies

In Table 5, we estimate the impact of the loss of market exclusivity on a firm's investment decisions. We use Equation (1) with the following dependent variables: (1) capital expenditures (CapEx) scaled by lagged assets, (2) research and development expenditures (R&D) scaled by lagged assets, and (3) the sum of these two variables, which we label investment.

First, we find that the impact of the loss of market exclusivity on capital expenditures by itself is not statistically significant (model 1). On the other hand, we find a large and negative effect on R&D (model 2) around these events. The coefficient estimate indicates that R&D spending declines by 0.6 percentage points. Compared to the baseline level of R&D spending of 2.4 percent in Table 2, this change implies a 25 percent reduction in R&D spending. The third measure, total investment, represents the sum of capital expenditures and R&D, and also displays a significantly negative effect after losses of market exclusivity.

In Models 4–6, we revisit this relation using a more restrictive set of loss of market exclusivity events for drugs generating more than 1 percent of firm revenue. We find the same statistical pattern for all three specifications, although the economic effects are now slightly larger, as might be expected as these are, on average, more significant events. These findings show that losing market exclusivity for a previous drug has a negative effect on spending in support of long-term investment opportunities.

This key result illustrates an essential role that revenues from assets in place have on

investments in R&D. The fact that we find relatively stronger effects for R&D compared to capital expenditures is not particularly surprising because R&D is a much larger and more volatile component of spending compared to capital expenditures among the pharmaceutical firms in our sample. These differences between capital expenditures and R&D may also be driven by the differences in the horizon until cash flows from these different types of projects materialize. While building a plant to manufacture a drug that has already been approved could be considered a late-stage investment that will generate cash flow in the near term, cutting R&D, by contrast, implies cutting the search for new opportunities, which will only affect cash flows in the more distant future.

4.4 Effects on financial policies

In Table 6, we analyze the effects on financial policies including dividends (Model 1), repurchases (Model 2), sale of equity (Model 3), debt issuance (Model 4), cash (Model 5), and total payout (Model 6), where the total payout is the sum of dividends and repurchases. Again, all of these variables are scaled by lagged total assets. Panel A represents results for the full sample, while Panel B presents results for drugs that represent more than 1 percent of firm revenues.

Models (1) and (2) focus on how firms adjust payout policies when they experience a loss of market exclusivity. Somewhat surprisingly, we find that dividends tend to *increase* following these events, despite lower revenues and income. On the other hand, we find that firms drastically cut repurchases, and this cut is larger in total economic terms than the increase in dividends, resulting in lower total payouts (as shown in Model (6)).

One possible way for firms to buffer any shock to investment would be to increase their use of external financing by issuing new equity or debt. However, in Models (3) and (4), we do not find any statistically significant responses in terms of increased equity or debt issuance.

Firms could also seek to buffer some of the impacts on investment by saving less cash or

by spending more of their internal cash stock. We test this in Model (5) and find a negative and statistically significant response whereby the affected firms are significantly spending down their cash relative to the control firms. This effect is substantial and quite similar in economic magnitude to the result for revenues (Model 1, Table 4). When firms suffer a loss of market exclusivity, they appear to respond by spending internal cash. However, even despite these cuts in cash, there remains a significant residual impact on investment, as shown in the previous section.

In Panel B, we again find that these effects tend to be larger for the more significant events, except in the case of dividends. This suggests that the positive effect on dividends mainly tends to be driven by the relatively smaller loss of market exclusivity events, where it is plausible that firms might be increasing dividends as a signal that they remain stable even in the presence of this shock. Additionally, as in Panel A, the economic magnitude of the decline in repurchases also exceeds the increase in dividends, resulting in less total payouts.

4.5 Cross-sectional evidence: The role of financial constraints

To the extent that financing frictions, i.e., costly external financing, drive the effects on investment, we would expect these effects to be larger for firms that are more likely to be subject to such frictions and thus less able to substitute the loss of internal cash flows with other sources of financing. We explore this hypothesis in Table 7. In this table, our proxy for (the lack of) financing frictions is whether a firm is in the Top-10 percent of revenues (*RevTop10*) within the Compustat universe, which roughly corresponds with the set of S&P500 firms.

We choose this proxy based on the literature, which has established that smaller firms tend to be relatively more financially constrained in terms of having worse access to external financing (e.g., Hadlock and Pierce (2010)). Other possible proxies for financing constraints that exist in the literature tend to yield little variation within our sample; for example,

virtually all of the firms in our sample have investment-grade credit ratings, which is another commonly used proxy(e.g., Campello, Graham, and Harvey, 2010).

To study the cross-sectional differences in these effects, we expand Equation (1) to include a triple interaction with *RevTop10*. The first two models of Table 7 focus on firm investment policies while the remaining models focus on financial policies (payout, cash, and issuance). This table also focuses on firms with loss of market exclusivity events representing more than 1 percent of firm revenues.

Models (1) and (2) suggest that the effects on R&D and total investment are significantly larger for the smaller, and thus more financially constrained firms, while the coefficient on the triple interaction shows that the effect for larger firms is significantly attenuated. For example, the effect on R&D for smaller firms is -1.795 percent, but only $-1.795 + 1.271 = -0.524$ for the largest firms. These results suggest that the largest firms are better able to buffer investment effects from the adverse cash flow shocks.

There are also differences across these groups in terms of how they adjust their payout and issuance policies (Models 3 and 4). In Model 3, we see that the dividend increases we found in the previous section is an effect that is limited to only the larger firms. This result suggests that our prior finding on dividends (Model 1, Table 6) appears to be driven by larger firms, whereas we do not observe any dividend increases on average among smaller firms around these events.

On the other hand, the relatively smaller firms are decreasing their equity issuance more (Model 5) and significantly increase their debt issuances more (Model 6) as compared to larger firms. Finally, smaller firms tend to draw down more of their cash compared to larger firms (Model 7).

Overall, our investment results in Table 7 are consistent with a pecking-order hypothesis. Treated firms suffer a large negative shock to internal cash flows. This is followed by adjustments across multiple margins, including investment, payout, external financing, and internal cash policies. However, the adjustments in terms of payout, external financing, and

internal cash, when taken together, are still insufficient to buffer the shock to investment policies, which a baseline model of capital budgeting would predict should be unaffected. Importantly, the only exception is among larger firms, which have better access to external financing, and thus appear to be better able to isolate their investments from these negative cash flow shocks due to losses of market exclusively.

4.6 Placebo tests

In an attempt to supply additional support for our identification strategy, we run a series of placebo tests in Tables 8 and 9. In Table 8, the first placebo test we run considers the impact of patent expirations that are not followed by generic entry (we call these "non-critical patents"). As discussed earlier, firms are required to list relevant patents for an approved drug in the FDA Orange Book. Given that these patents are not formally screened, patents of marginal value sometimes get listed (Bulow (2004); Hemphill and Sampat (2011, 2012)). The net effect of this regulatory anomaly is that the expiration of some of the patents attached to an approved drug will not result in generic entry (i.e., the loss of market exclusivity). In Table 9, on the other hand, we run a second placebo test that considers small-market drugs or those for which a loss of market exclusivity event should have negligible effects on the focal firm.

In Table 8, we begin by redefining the event indicator to consider the impact of the expiration of a non-critical patent that is *not* followed by generic entry. In the absence of generic entry, the impact of these events on all aspects of firm performance that we have discussed previously should be negligible. This is what we find in Model ; the estimated coefficient on revenue is not statistically significant. Likewise, we find the same in Model 2; the effect on profitability is not statistically significant. These findings suggest that the procedures for identifying the timing of patent expiration and loss of market exclusivity do not artificially generate the statistically significant decline in revenue and profitability observed in Table 4.

Proceeding to the remaining models in Table 8, we find that there is no significant relation between the expiration of a non-critical patent and most of the variables measuring investment or financing decisions. The results in Models 3 and 4 are particularly important. The relation between R&D (Model 3) and investments (Model 4) and non-critical patent expiration without generic entry are both not statistically significant. This makes us more confident in the significant impacts we previously found because of the loss of market exclusively on R&D (Table 5, Model 5) and investments (Table 5, Model 6). Similarly, the results for repurchases (Model 6), cash holdings (Model 7), and total payout (Model 8) are not statistically significant and again provide additional confidence in our main findings (Models 2, 5 and 6, Table 6). On the other hand, the significant result for dividends scaled by assets in this context suggests that the positive and statistically significant result in Table 6 should be interpreted with some caution.

Finally, Table 9 revisits the specifications with significant results in Tables 4–6, but using an alternative measure of an event which should *not* be associated with substantial effects for the focal firms. In this case, the sample of placebo events is defined by the loss of market exclusivity for a drug that generates less than 1 percent of firm revenue. Except for Model 7 that estimates the impact on cash holdings, the coefficient estimates are not statistically significant. In sum, these placebo results in Table 8 and Table 9 provide further support for our identification strategy and core findings.

5 Conclusion

The expiration of patent protection and the resulting loss of market exclusively can cause a substantial negative impact on a drug maker's revenues and profitability. However, because the timing of this change in firm cash flows is predetermined more than a decade in advance, the event itself is predictable and contains little news about the profitability of the firm's future projects. The traditional capital budgeting theory would thus suggest that a firm's

fundamental decisions about the long-term investment, such as R&D spending, would be unrelated to this event.

Our results are inconsistent with this fundamental prediction of traditional capital budgeting. We show that pharmaceutical firms' R&D declines by approximately 25 percent during the eight quarters when their previous high-revenue drugs lose market exclusivity. Total investment, defined as the sum of capital expenditures and R&D spending, is also significantly lower during the quarters following these events.

Firms' financing decisions also indicate other margins of adjustment. We find that firms do significantly fewer share buybacks after these events and also consume their cash. On the other hand, debt issuances and equity issuances do not change. Our paper speaks to the crucial role that a firm's *existing* cash flows have for the development of future products, even when reductions in those cash flows contain no news about the profitability of those future cash flows.

We focused on chemical-based or small molecule drugs. This restriction was made because generic biologics or "biosimilars" were not present during our sample period; the first biosimilar was not approved in the U.S. market until 2015. There are important distinctions between these drugs and the chemical-based or small molecules drugs we considered in this paper. First, biologic-based drugs receive 12 years of data exclusivity, as opposed to five years for most chemical-based drugs.[15] Importantly, the process that biosimilars take to get approved is different from generics for chemical-based drugs. There is no equivalent Paragraph IV pathway for biosimilars, so their only route of entry is equivalent to Paragraph III entry or waiting until the loss of market exclusivity. Because of their nature, biosimilars are required to undergo limited clinical testing, which dramatically increases their cost to develop and limits the kinds of firms that can engage in this activity.

Longer European experience with biosimilars (Morton, Stern, and Stern, 2018) suggests that entry is much less frequent, occurs at a later point in the product lifecycle, and offers

[15]The section of the Affordable Care Act that details entry provisions for biologics is referred to as the Biologics Products Competition and Innovation Act (BPCIA).

a much smaller price discount relative to the innovator drug than has been the case for generic entry in chemistry-based drug markets. This implies that the revenue shock that we find in this paper, related to chemical-based drugs, may not be as stark or significant with biologic-based drugs. This could create yet another incentive for pharmaceutical firms to begin to rotate their focus from chemical- to biologic-based drugs (Branstetter et al., 2014). While we are unable to comment on the welfare implications of such a shift, we can say that it would alter the *nature* of innovation and dramatically increase the future cost of drugs given their significant price differences.

Finally, our work has significant implications for product lifecycle management. The pharmaceutical industry is unique in that it has such a long development product lifecycle. This should, theoretically, provide ample opportunity for firms to plan for these loss-of-market-exclusivity events. Our evidence suggests that their efforts, whether they be from internal or external activities, on average, are failing. This result is all the more surprising given the active nature of external technology markets in the biopharmaceutical space. This suggests that unanticipated frictions may exist in these markets. These results could also suggest that clinical trials and FDA approval periods are more difficult to time. We leave these questions for future research.

References

Acemoglu, D., and J. Linn. 2004. Market size in innovation: Theory and evidence from the pharmaceutical industry. *Quarterly Journal of Economics* 199:1049–1090.

Amoresano, G. V. 2007. Branded drug reformulation: The next brand vs. generic antitrust battleground. *Food and Drug Law Journal* 62:249–56.

Baker, M., R. Ruback, and J. Wurgler. 2007. Behavioral Corporate Finance: A Survey. In E. Eckbo (ed.), *The Handbook of Corporate Finance: Empirical Corporate Finance*. Elsevier/North Holland.

Berndt, E. R., P. M. Danzon, and G. B. Kruse. 2007. Dynamic competition in pharmaceuticals: Cross-national evidence from new drug diffusion. *Managerial and Decision Economics* 28:231–250.

Branstetter, L., C. Chatterjee, and M. J. Higgins. 2014. Starving (or Fattening) the Golden Goose?: Generic Entry and the Incentives for Early-Stage Pharmaceutical Innovation. Working Paper 20532, National Bureau of Economic Research. URL `http://www.nber.org/papers/w20532`.

Branstetter, L., C. Chatterjee, and M. J. Higgins. 2016. Regulation and welfare: Evidence from Paragraph IV generic entry in the pharmaceutical industry. *The RAND Journal of Economics* 47:857–890.

Bulow, J. 2004. The gaming of pharmaceutical oatents. *Innovation Policy and the Economy* 4:145–187.

Campello, M., J. R. Graham, and C. R. Harvey. 2010. The real effects of financial constraints: Evidence from a financial crisis. *Journal of financial Economics* 97:470–487.

Dubois, P., O. d. Mouzon, F. Scott-Morton, and P. Seabright. 2015. Market size and pharmaceutical innovation. *The RAND Journal of Economics* 46:844–871.

Ellison, G., and S. F. Ellison. 2011. Strategic entry deterrence and the behavior of pharmaceutical incumbents prior to patent expiration. *AEJ: Microeconomics* 3:1–36.

Federal Trade Commission. 2002. *Generic Drug Entry Prior to Patent Expiration: An FTC Study*. U.S. Government Printing Office, Washington, D.C.

Frank, R. G., and D. S. Salkever. 1997. Generic entry and the pricing of pharmaceuticals. *Journal of Economics & Management Strategy* 6:75–90.

Gormley, T. A., and D. A. Matsa. 2011. Growing out of trouble? Corporate responses to liability risk. *The Review of Financial Studies* 24:2781–2821.

Grabowski, H. G., and M. Kyle. 2007. Generic competition and market exclusivity periods in pharmaceuticals. *Managerial and Decision Economics* 28:491–502.

Hadlock, C. J., and J. R. Pierce. 2010. New evidence on measuring financial constraints: Moving beyond the KZ index. *The Review of Financial Studies* 23:1909–1940.

Hemphill, C. S., and B. N. Sampat. 2011. When do generics challenge drug patents? *Journal of Empirical Legal Studies* 8:613–649.

Hemphill, C. S., and B. N. Sampat. 2012. Evergreening, patent challenges, and effective market life in pharmaceuticals. *Journal of Health Economics* 31:327–39.

Higgins, M. J., and S. J. H. Graham. 2009. Balancing innovation and access: Patent challenges tip the scales. *Science* 326:370–371.

IMS Institute for Healthcare Informatics. 2016. Price Declines After Branded Medicines Lose Exclusivity in the US. Tech. rep.

Lemley, M. A., and C. Shapiro. 2005. Probabilistic patents. *Journal of Economic Perspectives* 19:75–98.

Modigliani, F., and M. H. Miller. 1958. The cost of capital, corporation finance and the theory of investment. *American Economic Review* 48:261–297.

Morton, F., A. Stern, and S. Stern. 2018. The impact of the entry of biosimilars: Evidence from Europe. *Review of Industrial Organization* 53:73–210.

Mossinghoff, G. J. 1999. Overview of the Hatch-Waxman Act and its impact on the drug development process. *Food and Drug Law Journal* 54:187–94.

Murphy, S. 2017. *Essays in Pharmaceutical Economics*. Ph.D. thesis, MIT Dissertation: Chapter 2.

Myers, S., and N. Majluf. 1984. Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics* 13:187–217.

Palermo, V., M. J. Higgins, and M. Ceccagnoli. 2019. How reliable is the market for technology? *Review of Economics and Statistics* 101:107–120.

Panattoni, L. E. 2011. The effect of Paragraph IV decisions and generic entry before patent expiration on brand pharmaceutical firms. *Journal of Health Economics* 30:126–145.

Prajapati, V., and H. Dureja. 2012. Product lifecycle management in pharmaceuticals. *Journal of Medical Marketing: Device, Diagnostic and Pharmaceutical Marketing* 12:150–158.

Reiffen, D., and M. R. Ward. 2005. Generic drug industry dynamics. *Review of Economics and Statistics* 87:37–49.

Stein, J. C. 1996. Rational capital budgeting in an irrational world. *Journal of Business* 69:429–455.

Voet, M. 2016. *The Generic Challenge: Understanding Patents, FDA and Pharmaceutical Life-cycle Management.* Universal-Publishers.

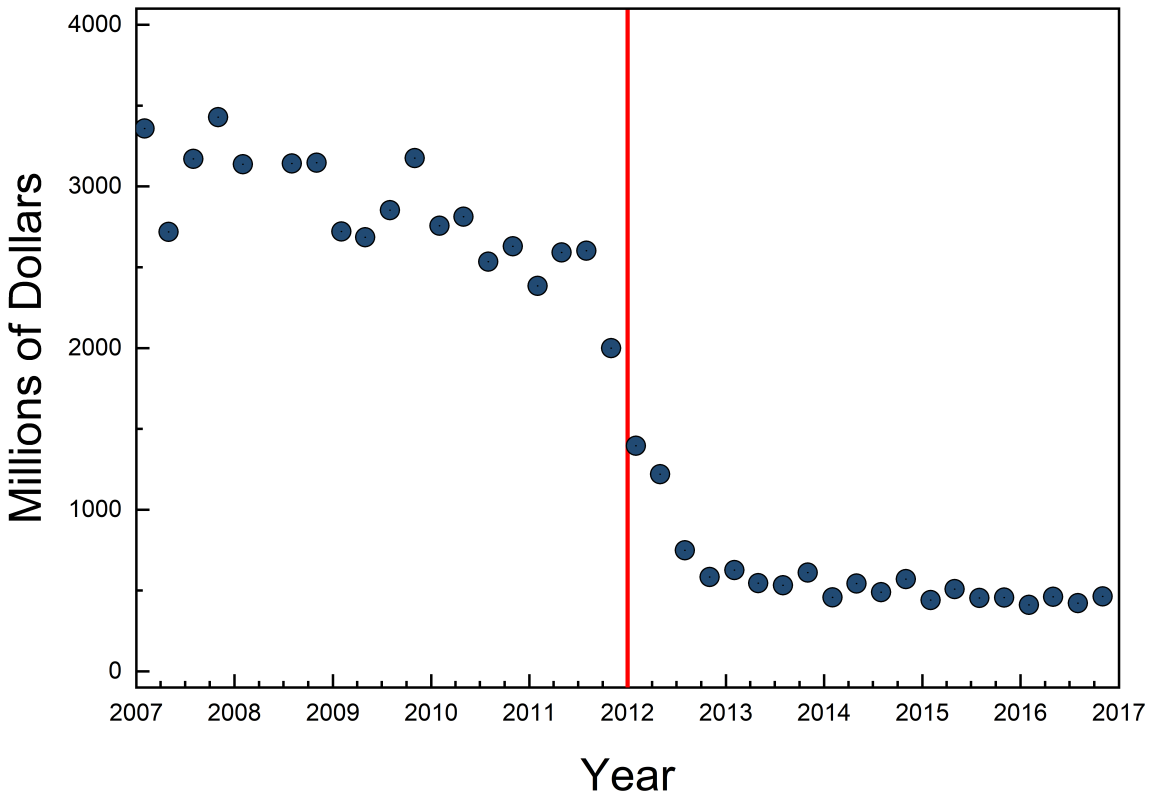

Figure 1
This figure displays quarterly global revenue in millions of U.S. dollars for Lipitor from 2007 to 2017. This drug was manufactured and marketed by Pfizer and the loss of market exclusivity occured at the end of November 2011.

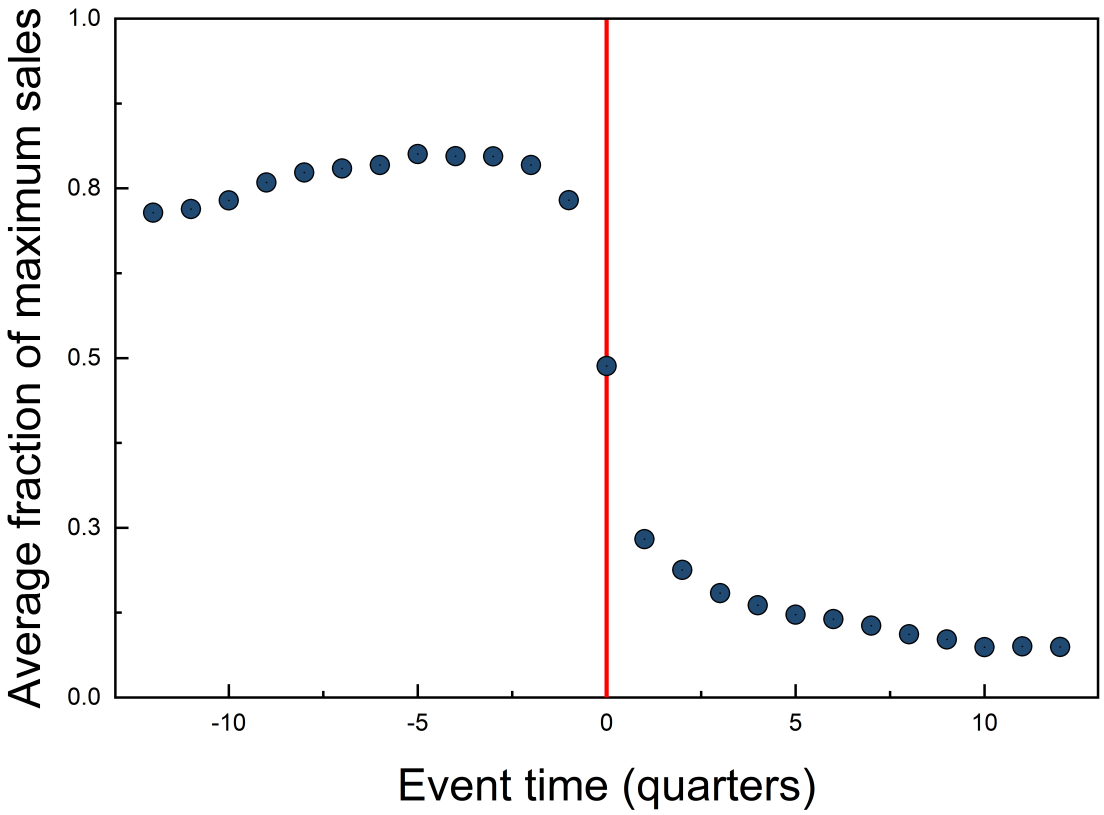

Figure 2
This figure plots quarterly sales as a fraction of maximum sales in event time (quarters) around the loss of market exclusivity for the period 2000 to 2010. Sales are averaged across all drugs available in IMS MIDAS data. The vertical line in the figure denotes the event time ($t = 0$) signifying the event time quarter for the loss of market exclusivity for drugs in our sample.

Table 1
Top 25 Drugs by U.S. Sales

This table lists the top 25 branded drugs in the U.S. by sales in our sample. Sales are reported in IMS MIDAS. Columns 2 and 3 report the name of branded drugs and the company that holds the patent for the drugs respectively. Column 4 reports the U.S. quarterly sales in millions in the quarter before the loss of market exclusivity. If the sales information is not available at the time prior to the loss of market exclusivity, we use the information of latest sales before the the loss of market exclusivity.

Rank	Brand	Company	U.S. Sales (millilons)
(1)	(2)	(3)	(4)
1	LIPITOR	Pfizer	1,859,901
2	PLAVIX	Bristol-Myers Squibb	1,569,903
3	SEROQUEL	Astra Zeneca	1,042,518
4	SINGULAIR	Merck	1,034,608
5	CYMBALTA	Eli Lilly	833,599
6	ZYPREXA	Eli Lilly	749,349
7	LEXAPRO	Forest Labratories	726,017
8	AMBIEN	Sanofi	618,902
9	ARICEPT	Pfizer	469,089
10	CELEBREX	Pfizer	433,257
11	LEVAQUIN	Johnson & Johnson	417,539
12	ZOLOFT	Pfizer	414,424
13	DIOVAN HCT	Pfizer	402,851
14	GLEEVEC	Novartis	352,320
15	VYTORIN	Merck	314,735
16	GEODON	Pfizer	313,502
17	ZOCOR	Merck	312,999
18	LOTREL	Novartis	309,310
19	PROVIGIL	Teva Pharmaceuticals	290,544
20	TAXOTERE	Sanofi	286,633
21	ACIPHEX	Eisai	266,423
22	FLONASE	GlaxoSmithKline	239,249
23	AVELOX	Bayer	207,686
24	PROZAC	Eli Lilly	194,954
25	BUSPAR	Bristol-Myers Squibb	192,192

Table 2
Summary Statistics

The table provides summary statistics for pharmaceutical firms that have important patents expire during the sample period from 1996 to 2017. The firms should be listed in the Compustat and CRSP databases. In Panel A, we report the total numbers, means, standard deviations, and 1, 25, 50, 75 and 99 percentiles for assets and revenues. In Panel B, we report variables scaled by lagged total assets for revenue, net income, dividends, repurchases, equity issuance, debt issuance, sale of PP&E, capital expenditures (CapEx), research and development (R&D), investment, and cash. Revenue, net income, dividends, equity issuance, sale of PP&E, R&D and cash are Compustat quarterly items. Investment is defined as capital expenditures plus R&D expenses. Repurchases are defined as treasury stocks minus lagged treasury stocks or purchase of common and preferred stock minus sale of common and preferred stock if firms do not have treasury stock. Debt issuance is defined as long-term debt issuance minus long-term debt reduction minus current debt changes.

Panel A: Assets and Revenues

Variable	Mean	Std. dev.	p1	p25	p50	p75	p99	No. Obs.
Assets	34444.54	41051.57	1089.334	3727.79	18933.43	49985.06	168244.8	2754
Revenue	5101.124	5586.117	122.4992	601.225	3127.717	7663.464	23316.81	2751

Panel B: Asset-scaled Variables

Variable	Mean	Std. dev.	p1	p25	p50	p75	p99	No. Obs.
Revenue / Assets	16.89%	7.14%	5.11%	11.83%	15.65%	20.80%	36.85%	2626
Net Income / Assets	8.64%	15.22%	-42.26%	3.94%	9.32%	14.59%	45.62%	2623
Dividends / Assets	0.78%	0.87%	0.00%	0.00%	0.45%	1.43%	3.85%	2492
Repurchases / Assets	0.68%	1.31%	0.00%	0.00%	0.00%	0.75%	5.15%	2408
Equity Issuance / Assets	0.54%	2.22%	0.00%	0.03%	0.17%	0.47%	5.63%	2301
Debt Issuance / Assets	0.62%	5.01%	-9.39%	-0.52%	0.00%	0.33%	30.43%	2628
Sale of PP&E / Assets	0.02%	0.09%	-0.01%	0.00%	0.00%	0.00%	0.43%	1551
CapEx / Assets	0.89%	0.70%	0.06%	0.42%	0.72%	1.18%	3.38%	2562
R&D / Assets	2.36%	2.10%	0.00%	1.07%	2.01%	3.01%	10.90%	2628
Investment / Assets	3.25%	2.44%	0.35%	1.80%	2.76%	3.97%	12.77%	2628
Cash / Assets	19.55%	15.44%	1.13%	8.46%	15.66%	26.05%	68.48%	2604

Table 3
Pre-trends for Dependent Variables

This table reports coefficients from firm-panel regressions of firm investment and payout policy on an indicator for the the loss of market exclusivity from quarters t-4 to t-1 prior to the event to test pre-trends. Loss of exclusivity is an indicator for whether loss of market exclusivity occurs in quarter t. We use variables from the quarterly Compustat database for capital expenditures (CapEx), research and development (R&D), cash, dividends and sale of stock. Repurchases are defined as treasury stocks minus lagged treasury stocks or purchase of common and preferred stock minus sale of common and preferred stock if firms do not have treasury stocks. Debt issuance is defined as long-term debt issuance minus long-term debt reduction minus current debt changes. All control variables are scaled by lagged total assets one quarter before the loss of market exclusivity. The sample period is from 1996 to 2017. The numbers in parentheses are t-statistics and all standard errors are clustered at the quarter-cohort level. *, **, and *** denote statistical significance at 10, 5, and 1% levels, respectively.

	CapEx / Assets	R&D / Assets	Investment / Assets	Cash / Assets	Dividends / Assets	Repurchases / Assets	Equity Issuance / Assets	Debt Issuance / Assets
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss of exclusivity	-0.004	-0.035	-0.0490	-0.473	-0.005	0.083	0.054	0.107
	(-0.29)	(-1.54)	(-1.49)	(-1.47)	(-0.24)	(1.05)	(1.30)	(0.52)
Event time fixed effects	X	X	X	X	X	X	X	X
R2	0.047	0.029	0.033	0.052	0.053	0.092	0.044	0.055
N	714	729	729	723	699	671	669	729

Table 4
Firm Revenue and Profitability Following the Loss of Market Exclusivity

Models 1 and 2 report difference-in-differences regression coefficients of profit before and after 8 quarters on the loss of market exclusivity. The firm-quarter level observations are included in the data in the 8 quarters and 8 quarters after each event time. Loss of exclusivity is an indicator whether a patent expires and it followed by generic entry. Post is an indicator for the post-event period. We use variables from the quarterly Compustat database for revenues, assets and net income. Revenues and net income are scaled by lagged total assets one quarter before the loss of market exclusivity as dependent variables. In Models 3 and 4, similar specifications are used and the independent variable is an indicator whether the drug's share of firm sales is larger than 1% and the loss of market exclusivity at quarter t. The sample period is from 1996 to 2017. The numbers in parentheses are t-statistics. Standard errors are double clustered at the firm-quarter level to simultaneously adjust for autocorrelation and contemporaneous cross-correlation of unknown form. *, **, and *** denote statistical significance at 10, 5, and 1% levels, respectively.

	8 Quarters			
Dependent variable	Revenue / Assets	Net income / Assets	Revenue / Assets	Net income / Assets
	(1)	(2)	(3)	(4)
Loss of exclusivity* Post	-3.310***	-1.209		
	(-4.15)	(-1.04)		
Loss of exclusivity with firm's revenue >1% * Post			-4.216***	-2.650**
			(-4.90)	(-2.14)
Quarter-Cohort fixed effects	X	X	X	X
Firm-Cohort fixed effects	X	X	X	X
R2	0.759	0.412	0.758	0.413
N	11888	11809	11640	11562

Table 5
Firm Investment Following the Loss of Market Exclusivity

Models 1, 2 and 3 report difference-in-differences regression coefficients of capital expenditures (CapEx), research and development expenditures (R&D), and the combination of CapEx and R&D (Investment) before and after 8 quarters around the loss of market exclusivity. The firm-quarter level observations are included in the data in the 8 quarters and 8 quarters after each event time. Loss of exclusivity is an indicator whether the loss of market exclusivity occurs at quarter t. Post is an indicator for the post-event period. We use variables from the quarterly Compustat database for capital expenditures, R&D and assets. Capital expenditures and R&D are scaled by lagged total assets one quarter before the loss of market exclusivity as dependent variables. Investment is defined as capital expenditures plus R&D expenses. In Models 4, 5 and 6, similar specifications are used and the independent variable is an indicator whether the drug's share of firm sales is larger than 1% and the loss of market exclusivity occurs at quarter t. The sample period is from 1996 to 2017. The numbers in parentheses are t-statistics. Standard errors are double clustered at the firm-quarter level to simultaneously adjust for autocorrelation and contemporaneous cross-correlation of unknown form. *, **, and *** denote statistical significance at 10, 5, and and 1% levels, respectively.

	8 Quarters					
Dependent variable	CapEx / Assets	R&D / Assets	Investment / Assets	CapEx / Assets	R&D / Assets	Investment / Assets
	(1)	(2)	(3)	(4)	(5)	(6)
Loss of exclusivity* Post	-0.083	-0.591***	-0.689***			
	(-1.12)	(-3.07)	(-2.71)			
Loss of exclusivity with firm's revenue >1% * Post				-0.113	-0.653***	-0.798***
				(-1.42)	(-2.92)	(-2.81)
Quarter-Cohort fixed effects	X	X	X	X	X	X
Firm-Cohort fixed effects	X	X	X	X	X	X
R2	0.627	0.684	0.627	0.625	0.687	0.631
N	11606	11896	11896	11367	11647	11647

Table 6
Financial Decisions Following the Loss of Market Exclusivity

This table reports difference-in-differences regression coefficients of financing before and after 8 quarters around the loss of market exclusivity. The firm-quarter level observations are included in the data in the 8 quarters and 8 quarters after each event time. In Panel A, Loss of exclusivity is an indicator whether the loss of market exclusivity occurs at quarter t. Post is an indicator for the post-event period. We use variables from the quarterly Compustat database for dividends, sale of stocks, cash and assets. Repurchases are defined as treasury stocks minus lagged treasury stocks or purchase of common and preferred stock minus sale of common and preferred stock if firms do not have treasury stocks. Debt issuance is defined as long-term debt issuance minus long-term debt reduction minus current debt changes. All dependent variables are scaled by lagged total assets one quarter before the patent expiration. In Panel B, similar specifications are used and the independent variable is an indicator whether the drug's share of firm sales is larger than 1% and the loss of market exclusivity occurs at quarter t. The sample period is from 1996 to 2017. The numbers in parentheses are t-statistics. Standard errors are double clustered at the firm-quarter level to simultaneously adjust for autocorrelation and contemporaneous cross-correlation of unknown form. *, **, and *** denote statistical significance at 10, 5, and and 1% levels, respectively.

Panel A: Loss of market exclusivity						
	Dividends / Assets	Repurchase / Assets	Equity issuance / Assets	Debt issuance / Assets	Cash / Assets	Total Payout / Assets
	(1)	(2)	(3)	(4)	(5)	(6)
Loss of exclusivity * Post	0.138***	-0.320**	0.036	0.525	-3.882*	-0.305
	(3.03)	(1.21)	(0.27)	(1.40)	(-1.93)	(-1.39)
Quarter-Cohort fixed effects	X	X	X	X	X	X
Firm-Cohort fixed effects	X	X	X	X	X	X
R2	0.704	0.459	0.171	0.131	0.771	0.381
N	11342	10838	10631	11896	11808	10547
Panel B: Loss of market exclusivity with firm's revenue >1%						
	Dividends / Assets	Repurchase / Assets	Equity issuance / Assets	Debt issuance / Assets	Cash / Assets	Total Payout / Assets
	(1)	(2)	(3)	(4)	(5)	(6)
Loss of exclusivity with	0.079*	-0.510**	0.052	0.615	-4.889**	-0.549**
Firm's Revenue >1% * Post	(1.93)	(-2.45)	(0.33)	(1.34)	(-2.43)	(-2.10)
Quarter-Cohort fixed effects	X	X	X	X	X	X
Firm-Cohort fixed effects	X	X	X	X	X	X
R2	0.700	0.463	0.172	0.134	0.771	0.38
N	11128	10618	10423	11647	11559	10335

Table 7
Financial Constraints Measured By Revenue

This table reports difference-in-difference-in-differences regression coefficients of investment and financing decisions before and after 8 quarters around the loss of market exclusivity. The firm-quarter level observations are included in the data in the 8 quarters and 8 quarters after each event time. The independent variable is an indicator whether the drug's share of firm sales is larger than 1% and the loss of market exclusivity occurs at quarter t. Post is an indicator for the post-event period. RevTop10 is calculated as the decile of revenues adjusted for CPI as of December 2016. We use variables from the quarterly Compustat database for capital expenditures, R&D, dividends, sale of stocks, cash and assets. Investment is defined as capital expenditures plus R&D expenses. Repurchases are defined as treasury stocks minus lagged treasury stocks or purchase of common and preferred stock minus sale of common and preferred stock if firms do not have treasury stocks. Debt issuance is defined as long-term debt issuance minus long-term debt reduction minus current debt changes. All dependent variables are scaled by lagged total assets one quarter before the the loss of market exclusivity. The sample period is from 1996 to 2017. The numbers in parentheses are t-statistics. Standard errors are double clustered at the firm-quarter level to simultaneously adjust for autocorrelation and contemporaneous crosscorrelation of unknown form. *, **, and *** denote statistical significance at 10, 5, and 1% levels, respectively.

	Loss of market exclusivity with firm's revenue >1%							
Dependent variable	R&D / Assets	Investment / Assets	Dividends / Assets	Repurchases / Assets	Equity Issuance / Assets	Debt issuance / Assets	Cash / Assets	Total Payout / Assets
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss of exclusivity with firm's revenue >1% * Post	-1.795***	-2.532***	-0.012	-0.316	-0.571***	6.838***	-9.199**	-0.303
	(-4.66)	(-4.71)	(-0.72)	(-1.28)	(-3.48)	(4.32)	(-2.01)	(-1.30)
RevTop10 * Post	-0.371	-0.305	0.138***	-0.143	-0.149	0.637	-3.668	0.013
	(-1.57)	(-1.01)	(3.35)	(-0.99)	(-0.54)	(1.43)	(-1.12)	(0.09)
Loss of exclusivity with firm's revenue >1% * Post * RevTop10	1.271***	1.866***	0.059*	-0.174	0.689***	-6.582***	5.374	-0.139
	(4.29)	(4.42)	(1.79)	(-0.55)	(3.60)	(-4.08)	(1.13)	(-0.44)
Quarter-Cohort fixed effects	X	X	X	X	X	X	X	X
Firm-Cohort fixed effects	X	X	X	X	X	X	X	X
R2	0.688	0.631	0.702	0.463	0.172	0.135	0.772	0.477
N	11647	11647	11128	10618	10423	11647	11559	10335

Table 8
Placebo Test - No generic entry

This table reports difference-in-differences regression coefficients of financing before and after 8 quarters around the loss of market exclusivity with no generic competition. The firm-quarter level observations are included in the data in the 8 quarters and 8 quarters after each event time. The independent variable is an indicator whether the drug's share of firm sales is larger than 1% and the loss of market exclusivity occurs at quarter t. Post is an indicator for the post-event period. We use variables from the quarterly Compustat database for revenues, net income, R&D expenses, dividends, cash and assets. Investment is defined as capital expenditures plus R&D expenses. Repurchases are defined as treasury stocks minus lagged treasury stocks or purchase of common and preferred stock minus sale of common and preferred stock if firms do not have treasury stocks. All dependent variables are scaled by lagged total assets one quarter before the loss of market exclusivity. The sample period is from 1996 to 2017. The numbers in parentheses are t-statistics. Standard errors are double clustered at the firm-quarter level to simultaneously adjust for autocorrelation and contemporaneous cross-correlation of unknown form. *, **, and *** denote statistical significance at 10, 5, and 1% levels, respectively.

Loss of market exclusivity with firm's revenue >1%								
Dependent variable	Revenue / Assets	Net income / Assets	R&D / Assets	Investment / Assets	Dividends / Assets	Repurchases / Assets	Cash / Assets	Total Payout / Assets
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss of exclusivity with firm's revenue >1% * Post	0.472	-3.366	-0.003	0.207	0.122**	-0.262	-2.333	-0.329
	(0.41)	(-0.76)	(-0.01)	(0.53)	(2.21)	(-0.65)	(-0.85)	(-0.70)
Quarter-Cohort fixed effects	X	X	X	X	X	X	X	X
Firm-Cohort fixed effects	X	X	X	X	X	X	X	X
R2	0.836	0.373	0.692	0.667	0.877	0.4530	0.785	0.447
N	8843	8797	8843	8843	8490	8164	8793	7974

Table 9
Placebo Test - Loss of market exclusivity with firm's revenue less than 1%

This table reports difference-in-differences regression coefficients of financing before and after 8 quarters around the loss of market exclusivity with generic competition. The firm-quarter level observations are included in the data in the 8 quarters before and 8 quarters after each event time. Loss of exclusivity with firm's revenue <1% is an indicator whether the drug's share of firm sales is less than 1% and the loss of market exclusivity occurs at quarter t. Post is an indicator for the post-event period. We use variables from the quarterly Compustat database for revenues, net income, capital expenditures, R&D, dividends, sale of stocks, cash and assets. Investment is defined as capital expenditures plus R&D expenses. Repurchases are defined as treasury stocks minus lagged treasury stocks or purchase of common and preferred stock minus sale of common and preferred stock if firms do not have treasury stocks. Debt issuance is defined as long-term debt issuance minus long-term debt reduction minus current debt changes. All dependent variables are scaled by lagged total assets one quarter before the the loss of market exclusivity. The sample period is from 1996 to 2017. The numbers in parentheses are t-statistics. Standard errors are double clustered at the firm-quarter level to simultaneously adjust for autocorrelation and contemporaneous cross-correlation of unknown form. *, **, and *** denote statistical significance at 10, 5, and 1% levels, respectively.

	Loss of market exclusivity with firm's revenue <1%							
Dependent variable	Revenue / Assets	Net income / Assets	R&D / Assets	Investment / Assets	Dividends / Assets	Repurchases / Asset	Cash / Assets	Total Payout / Assets
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss of exclusivity with firm's revenue <1% * Post	0.8473	2.1977	-0.1256	-0.0047	0.2090	-0.1912	4.2363**	-0.0339
	(0.91)	(0.93)	(-0.49)	(-0.01)	(0.91)	(-0.58)	(2.02)	(-0.07)
Quarter-Cohort fixed effects	X	X	X	X	X	X	X	X
Firm-Cohort fixed effects	X	X	X	X	X	X	X	X
R2	0.739	0.423	0.735	0.666	0.499	0.4810	0.768	0.449
N	8480	8403	8483	8483	8106	7591	8435	7376

Appendix Figure 1. Regulatory Framework. This figure demonstrates the two types of protection conferred on new chemical-based or small-molecule drugs by the Hatch-Waxman Act. When a new chemical-based drug is approved by the FDA the first five-year period (seven years for orphan drugs and 5 ½ years for pediatric drugs) carries with it a regulatory protection called 'data exclusivity' that runs concurrent with underlying patent protection. Data exclusivity protects the underlying clinical data and provides monopoly protection in the case that a drug's underlying patent term has expired. At the conclusion of data exclusivity, a drug is protected only by its patents until they expire, a period termed 'market exclusivity'. Upon the loss of market exclusivity (**A**), Paragraph III generic entry may occur. Paragraph IV challenges occur only during the market exclusivity period (**B**). If generic manufactures are successful in the ensuing litigation, early generic entry may occur. As we note in the text, entry occurring at **A** is well anticipated, however, early generic entry during **B** is unanticipated and probabilistic. We also note that patents are generally applied for and granted well before a drug is approved by the FDA.