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Does Intellectual Property Restrict Output? An Analysis of Pharmaceutical Markets*

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Abstract

Standard normative analysis of intellectual property focuses on the balance between incentives for research and the static welfare costs of reduced price-competition from monopoly. However, static welfare loss from patents is not universal. While patents restrict price competition, they may also provide static welfare benefits by improving incentives for marketing, which is a form of *non*-price competition. We show theoretically how stronger marketing incentives mitigate, and can even offset, the static costs of monopoly pricing. Empirical analysis in the pharmaceutical industry context suggests that, in the short-run, patent expirations *reduce* consumer welfare as a result of decreased marketing effort. In the long-run, patent expirations do benefit consumers, but by 30% less than would be implied by the reduction in price alone. The social value of monopoly marketing to consumers alone is roughly on par with its costs to firms.

Keywords

Intellectual Property; Advertising; Pharmaceuticals

A. Introduction

Intellectual property spurs innovation by raising the rewards for discovery, but it does so by granting a monopoly in the event of discovery. According to standard analysis [cf, 1], the research and development (R&D) benefits of a patent system must be weighed against the associated output lost to patent monopolies, which reduce price-competition. This analysis implies that patent expirations always lead to increased competition, lower prices, and higher market output. From this point of view, Figure 1 is surprising. The figure depicts the percentage change in quantity—comparing the month before patent expiration to the month after—for a sample of US pharmaceutical products whose patents expired between 1992 and

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2002.[1] For about 40% of drugs, output actually *falls* after patent expiration, and expands only modestly for many others.

The figure suggests there may be more to a patent expiration than the end of monopoly pricing alone, and consequently more to the welfare effects of intellectual property (IP) protection. We argue that the standard analysis of IP must incorporate various aspects of non-price competition, which may reinforce or mitigate the effects of monopoly pricing. For example, while monopolists have incentives to restrict quantity through higher prices, they may also have different incentives to promote their product through advertising, to provide durability of goods, and to vertically integrate with upstream or downstream firms. These forms of non-price competition can change the efficiency impact of IP regulations.

Motivated by this idea, this paper examines the effect of marketing — a particularly important form of non-price competition — on the static and dynamic efficiency of patents.[2] Patent expirations decrease the private returns to marketing, which disappear when goods are sold at marginal cost. As a result, expirations may actually reduce output, if they decrease marketing effort by enough to offset the impact of price reductions.

To assess the quantitative importance of these arguments more fully, we estimate the impact of marketing on welfare using patent expirations in the US pharmaceuticals market, between 1990 and 2003. This industry is a natural choice for empirical analysis of R&D and marketing, because it is among the highest-spending industries in both categories. The industry spends approximately 15% of sales on marketing, and 16% of sales on R&D.[3] By comparison, about 2% and 3% of US GDP are allocated to advertising and R&D, respectively.

Figure 6 and Figure 7 provide some intriguing insight from the pharmaceutical context. The figures are based on data -- described in Section C.2 -- from 101 molecules with expiring patents. Each figure depicts monthly time-series, relative to the month of patent expiration, for branded quantity, branded price, total quantity, and total price, at the molecule-level. Figure 6 depicts these trends for molecules that are advertised, while Figure 7 does so for molecules that are not.[4] For all drugs, price declines steadily after the month of expiration. For the non-advertised drugs, quantity rises fairly steadily over this period as well. However, for the advertised drugs, quantity appears flat after patent expiration. This suggests patent expirations may decrease demand among the advertised drugs, but not among their non-advertised peers.

[1]Specifically, the figure shows the percentage decline and growth in prescriptions filled, between the month before and the month after expiration. More detail on the data is given in Section C.2.

[2]Different forms of non-price competition merit separate analyses. For example, monopoly has a range of possible effects on quality provision. Mussa and Rosen showed that monopolists will "over-differentiate" their product and induce a lower quality choice by consumers 2. Mussa, Michael, Sherwin Rosen (1978) Monopoly and Product Quality. Journal of Economic Theory 18: 301–317.. Subsequent authors have demonstrated how these results can be altered or even reversed under different specifications for demand 3. Gabszewicz, Jean J., Xavier Y. Wauthy (2002) Quality underprovision by a monopolist when quality is not costly. Economics Letters 77: 65–72..

[3]Many drugs have seen dramatic increases in direct-to-consumer advertising (DTC) since the change in FDA guidelines on such advertising took place in 1997.

[4]The figures are described in more detail in Section C.3.

To estimate these effects more formally, we use the timing of patent expirations as instruments for the supply-price and marketing incentives of a molecule. Changes in supply induced by patent expiration allow us to identify the demand for drugs as a function of both price and advertising effort. The estimated demand function implies that in the short-run (first five months after expiration), output falls after patent expiration, because the reduction in advertising more than offsets the reduction in price. This output loss is estimated to cost consumers roughly $1 million per month, for each drug whose patent expires. Not until several years have elapsed does the price effect dominate the reduction in advertising. In the long-run, patent expiration benefits consumers, but the reduction in advertising reduces the total gain to consumers from patent expiration by about 30%. In the long-run, patent expiration raises quantity and benefits consumers. However, even from a long-run perspective, monopoly marketing provides benefits to consumers. We estimate that the value to consumers is roughly 20% to 25% of total monopoly revenue, roughly on par with the costs of marketing to firms. Therefore, even if firms did not benefit from marketing, it would be approximately welfare-neutral.

Our project integrates a great deal of work that has separately considered advertising and intellectual property.[5] Several papers have studied the unique aspects of pharmaceutical advertising: Rosenthal et al [12] study direct-to-consumer advertising, while Bhattacharya and Vogt [13] considers how brand loyalty affects pricing under intellectual property. In the economic analysis of intellectual property, an equally extensive literature tackles the question of how to generate efficient R&D effort. There is a large literature analyzing the effects and desirability of public interventions affecting the speed of technological change.[6] Less effort has been devoted to studying the joint problem of advertising and intellectual property, even though the interaction between these two factors has many important normative and positive implications, particularly for the marketing of pharmaceuticals in the US.

The paper proceeds as follows. Section B considers the impact of non-price competition on the welfare effects of patents, and outlines the full impact of patents on static and dynamic

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[6]Representative treatments include Nordhaus 1. Nordhaus, W (1969) Invention, Growth and Welfare. Cambridge, MA: MIT Press., Loury 14. Loury, G.C. (1979) Market Structure and Innovation. Quarterly Journal of Economics 93: 395–410., Wright 15. Wright, Brian D (1983) The Economics of Invention Incentives: Patents Prizes and Research Contracts. American Economic Review 73: 691–707., Judd 16. Judd, Kenneth (1985) On the Performance of Patents. Econometrica 53: 567–585., Gilbert and Shapiro 17. Gilbert, Richard, Carl Shapiro (1990) Optimal Patent Length and Breadth. RAND Journal of Economics 21: 106–112., Klemperer 18. Klemperer, Paul (1990) How Broad Should the Scope of Patent Protection Be? RAND Journal of Economics 21: 113–130., Horstman et al 19. Horstmann, Ignatius, Glenn MacDonald, Alan Slivinski (1993) Patents as Information Transfer Mechanisms: To Patent or (Maybe) Not to Patent. Journal of Political Economy., Gallini 20. Gallini, Nancy (1992) Patent Policy and Costly Imitation. RAND Journal of Economics 23: 52–63., Green and Scotchmer 21. Green, Jerry, Suzanne Scotchmer (1995) On the Division of Profits In Sequential Innovation. RAND Journal of Economics 26, 20–33.: 20–33., and Scotchmer 22. Scotchmer, Suzanne (2004) Innovation and Incentives. Cambridge, MA: MIT Press..

welfare. Section C estimates demand as a function of price and advertising, and infers changes in welfare from marketing and patent expiration. Section D concludes and discusses future research.

B. Marketing and Intellectual Property

From a positive point of view, intellectual property protection has ambiguous effects on quantity provided, depending on the strength of incentives to market. Normatively, the static costs (or benefits) of patents depend on how whether patent protection moves quantity towards or past the efficient level of quantity.

B.1 The Welfare Effects of Patents

Define W_M and W_C as the annual level of aggregate welfare (social surplus) under monopoly and competitive provision of an invention, respectively. The net present value of welfare associated with a patent of length τ years is then given by:

$$W(\tau)=\nu(\tau)W_M+[\nu(\infty)-\nu(\tau)]W_C$$

Here, $\nu(\tau)$ is the date zero present value of a claim that pays one dollar for τ years. The net present value of profits associated with this patent is given by:

$$\pi(\tau)=\nu(\tau)\pi_M$$

where π_M represents monopoly profits. To represent technological investment induced by intellectual property protection, define the increasing, differentiable, and strictly concave function $m(r)$ as the probability of discovering an invention, as a function of R&D investment r. The privately optimal R&D associated with a patent of length τ maximizes expected profits:

$$r(\tau)=argmax_r m(r)\pi(\tau)-r \quad (1)$$

This implies that increases in the profits expected from discovery also stimulate marketing activity, because innovators expect greater rewards [1]. Therefore, innovation is complementary with all investments that stimulate profits, including marketing.

This level of R&D induces the expected social surplus:

$$ES(\tau)=m(r(\tau))W(\tau)-r(\tau) \quad (2)$$

The dynamically optimal patent length that maximizes expected welfare is therefore given by the following first-order necessary condition:

$$r_\tau[m_r W(\tau)-1] \geq m(-W_\tau) \quad (3)$$

The marginal gains from raising R&D levels through IP (left-hand side) are made up of the extra R&D induced by the patent extension, r_τ, multiplied by the net social value of that extra R&D, $m_r W(\tau) - 1$, which consists of the marginal social gain from more invention net of research spending. The optimal patent life equates this marginal benefit of an extension with the marginal cost of the extension, which is the welfare cost of an additional year of monopoly (on the right-hand side). The marginal cost of patent expiration, the loss of welfare once the technology has been discovered, is given by the static welfare effect,

$$\frac{dW}{d\tau}=\frac{d\nu}{d\tau}[S_M+\pi_M-S_C]$$

where S_M and S_C are consumer surplus under monopoly and competition, respectively. Patents are costly on the margin whenever $S_M + \pi_M < S_C$; this is the condition for static deadweight loss from monopoly. Below, we demonstrate that marketing lowers the relative cost of patents, and that it can sometimes lower cost to zero or below. In such cases, infinite patent length is desirable.

B.2 Positive Effects of Advertising Under Patent Monopoly

We first show that advertising limits and sometimes fully offsets the quantity-restricting effects of patent monopoly. Consider the standard monopoly profit-maximization model:[7]

$$\max_{\mathrm{p,A}} Q(p,A)p-MC*(p,A)-A, \quad (1)$$

For simplicity, consider the constant elasticity demand function, $Q(p, A) = A^{\varepsilon} p^{-\gamma}$. Monopoly equilibrium with advertising exists and is well-defined when demand is elastic to price and inelastic to advertising: $\gamma > 1$ and $0 < \varepsilon < 1$.[8] The optimal price is given by the standard Lerner mark-up condition:

$$[p]\colon p=\frac{c\gamma}{\gamma-1}$$

The first-order condition for optimal advertising equates the marginal value of marketing to its marginal cost, according to:

$$[A]\colon \frac{dQ}{dA}(p-c)=1.$$

This expression demonstrates why perfectly competitive firms have zero incentives to advertise. Without a markup, it is not valuable to stimulate more quantity.

[7]The static model is useful and appropriate for advertising. However, a more dynamic approach may be needed for the analysis of other types of non-price competition, like quality, that influence research and development.

[8]The condition on the price-elasticity is standard. The condition on the advertising elasticity follows as a corollary of the Dorfman-Steiner theorem. Observe that:

$$\pi=pq-cq-A=pq\left(1-\frac{cq}{pq}-\frac{A}{pq}\right)=pq\left(1-\frac{c}{p}-\frac{\varepsilon}{\gamma}\right)=pq\frac{(1-\varepsilon)}{\gamma}$$

Nonnegative profits imply that $\varepsilon < 1$.

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Using the constant elasticity form, the first-order condition for advertising can be rewritten as:

$$\varepsilon p^{-\gamma}(p-c)=A^{1-\varepsilon}$$

Combining the two first-order conditions, the equilibrium level of advertising is given by $A^{1-\varepsilon}=\varepsilon c\left(\frac{1}{\gamma-1}\right)$. The monopoly quantity can be written as:

$$Q^M=c^{-\gamma}\left(\frac{\gamma}{\gamma-1}\right)^{-\gamma}A^{\varepsilon}=c^{-\gamma}\left(\frac{\gamma}{\gamma-1}\right)^{-\gamma}\left[\varepsilon c\left(\frac{1}{\gamma-1}\right)\left(\frac{c\gamma}{\gamma-1}\right)^{-\gamma}\right]^{\frac{\varepsilon}{1-\varepsilon}}$$

By comparison, the competitive level of quantity is given by: $Q^C = c^{-\gamma}$. And, the monopoly quantity in the absence of marketing would be: $Q^{M0}=c^{-\gamma}\left(\frac{\gamma}{\gamma-1}\right)^{-\gamma}$. It will always be true that $Q^{M0} < Q^M$, and that marketing leads to higher quantity-provision in the marketplace.[9] However, Q^M may be higher or lower than Q^C, depending on the configuration of parameters.

Observe that $\frac{Q^M}{Q^C}=\left(\frac{\gamma}{\gamma-1}\right)^{-\gamma}A^{\varepsilon}=\left(\frac{c}{p}\right)^{\gamma}A^{\varepsilon}$. The higher the price markup, the greater the restriction in quantity; this is the standard incentive effect of monopoly, encapsulated by the first term. However, monopolists restrict quantity less, when the responsiveness of demand to marketing (ε) is higher.

To take a few concrete examples, monopoly quantity is nearly 50% higher than competitive quantity for the parameters $c = 0.1$, $\gamma = 1.6$, and $\varepsilon = 0.9$; under this scenario, more than half of revenue $\left(\frac{0.9}{1.6}\right)$ is spent on marketing. In contrast, for $c = 0.1$, $\gamma = 1.6$, and $\gamma = 0.5$, monopoly quantity is more than 80% below competitive quantity, and less than one-third of revenue $\left(\frac{0.5}{1.6}\right)$ is spent on marketing.

This implies that marketing can partially or completely offset monopoly pricing, and can even “over-correct” for the quantity distortions of monopoly, depending on the strength of incentives to market. Note that the analysis so far is strictly positive in nature, as the competitive level of quantity may be equal to or below the efficient level.

B.3 Normative Analysis of Patents with Advertising

The cost of monopoly is the reduction in quantity suffered by consumers. In the absence of advertising, this is easy to calculate: the quantity provided after patent expiration is assumed to be the competitive and efficient level; the difference between the monopoly quantity and the post-expiration quantity yields the social cost.

[9]Suppose not. In this case, $A^{\varepsilon} < 1$, which implies that $A < 1$, and that on the margin, $D_A < 0$. This cannot be an equilibrium.

The introduction of marketing makes the situation more complex for two reasons. First, competition may increase or decrease quantity. Second, since competition may not produce the efficient level of quantity, the competitive level of output cannot be used as a simple benchmark for efficiency. Nonetheless, the competitive level of quantity can usually help bound the welfare costs of patents, as we show.

In general, the welfare effects of patents are *a priori* ambiguous, because their quantity effects are ambiguous. Recall from Section B.2 that patent expiration has offsetting effects on quantity. Patent expiration raises quantity by lowering the market price, but lowers it by reducing market advertising. Ultimately, the welfare effects depend on the value of changes in quantity, and (sometimes) on the direct consumption value of changes in advertising. The ambiguous effect on quantity thus creates ambiguity for the welfare effects of patents. Moreover, the same forces that move quantity in opposite directions – namely price cuts and advertising reductions -- also move consumer welfare in opposite directions. Therefore, patents may help or harm consumers, depending on the shape of the demand and cost curves of a particular industry.

B.3.1 Advertising as Information—We first consider the welfare effects of patents when advertising provides valuable information about a product, but does not add value to the product itself or provide direct utility to consumers. In this case, advertising does not affect the true value of a good to consumers, but does move perceived value towards its true value. Let $p(x, a)$ represent the inverse demand as a function of quantity (x) and advertising (a) . Price falls in quantity, but rises in advertising. We denote by $p(x)$ the full information demand curve defined by

$$\lim_{a\to\infty} p(x,a)=p(x), \forall x$$

The change in welfare due to patent expiration is given by the change in true social surplus, which is evaluated at the true, fully informed demand curve. We define this as:

$$\Delta_{Info} \equiv S_C - S_M = \int_{x_M}^{x_C} p(q)dq - (p_C x_C - p_M x_M) \quad (4)$$

Figure 2 illustrates this argument graphically, for the case in which patent expiration lowers quantity. The change in quantity is evaluated along the “true” demand curve, which differs from the observed demand curves both before and after patent expiration. In this case, the welfare cost of patent expiration is given by the area *L*, which yields the consumer surplus associated with the additional quantity consumed under monopoly.

Since advertising moves observed demand towards the true demand curve, we can use observed consumer surplus as a lower bound on the true consumer surplus, according to:

$$\int_{x_M}^{x_C} p(q)dq \geq \int_{x_M}^{x_C} p(q, a_M)dq$$

Based on this inequality, our empirical analysis uses the observed change in consumer welfare as a bound on the true change in welfare. In particular, we construct the estimator:

$$\tilde{\Delta}_{Info} \equiv \int_{x_M}^{x_C} p(q, a_M)dq - (p_C x_C - p_M x_M) \quad (5)$$

$\tilde{\Delta}_{Info} \leq \Delta_{Info}$ if and only if patent expiration raises quantity. Therefore, the estimator is a lower bound, in absolute value, on the true increase in welfare.

B.3.2 Advertising as Persuasion—Some forms of advertising seek to persuade rather than inform. An example is the provision of in-kind prescribing incentives to physicians. Informative advertising moves demand towards its fully informed level. Purely persuasive advertising moves demand above its true level and may create socially excessive consumption.[10] To separate this case from that of "advertising as consumption," suppose further that advertising confers no direct consumption benefits upon physicians or patients.

The welfare effects of persuasive advertising depend on the strength of marketing incentives, and whether or not these boost quantity past its efficient level. While persuasive advertising always pushes the demand curve above its efficient level, it does not always push equilibrium quantity past this point. Figure 3 illustrates this case, in which market demand, D_M exceeds the true demand curve D_T. Even though demand is pushed past its efficient level, the monopolist does not choose to boost demand by so much that the equilibrium quantity exceeds its efficient level, X_C. As a result, the "inefficient" growth in demand actually reduces deadweight loss due to under-utilization. Therefore, even persuasive advertising partially offsets the monopoly-restriction on quantity, and thus improves social welfare.

Implicit in this last point is the premise that advertising cost must be strictly less than the additional consumer surplus generated by the growth in utilization. This is a straightforward implication of profit-maximizing behavior by the monopolist, who will never spend more than the incremental value created for consumers. An alternate case is one in which demand rises by so much as to push equilibrium quantity past X_C. In this case, advertising may create static welfare loss due to over-utilization.

Empirically, the only difference with persuasive advertising is that the competitive demand curve coincides with the true demand, and lies below the monopoly demand curve. Therefore, the competitive demand curve serves as the best approximation to true demand.

In this case, we use the estimator:

$$\tilde{\Delta}_{Pers} \equiv \int_{x_M}^{x_C} p(q, a_C)dq - (p_C x_C - p_M x_M) \quad (6)$$

Observe that:

$$\tilde{\Delta}_{Pers} = \tilde{\Delta}_{Info} + \int_{x_M}^{x_C} (p(q, a_C) - p(q, a_M))dq$$

[10]If advertising is only partially persuasive, and fails to raise demand above its true level, the analysis is substantially similar to the "information" case.

The latter expression implies that $\tilde{\Delta}_{Pers} < \tilde{\Delta}_{Info}$. Intuitively, when we assume advertising is persuasive, we are implicitly assuming that the true demand for the product is lower than in the informative advertising case. Under persuasive advertising, therefore, patent expiration benefits consumers by less. As before, this estimator is a lower bound on the true absolute change in welfare due to patent expiration.

B.3.3 Advertising as Consumption—Suppose advertising confers utility through two channels. The first is direct: exposure to advertising produces utility. For example, pharmaceutical companies may provide perquisites to consumers (in the form of samples) or to physicians (in the form of gifts or in-kind transfers). The second is through complementarity with consumption. Advertising may increase the true value of and willingness-to-pay for a product. That is, consumers may derive more utility from using a heavily advertised product. In this case, the consumer welfare effect of patent expiration satisfies:

$$\Delta_C \equiv S_C - S_M = V(a_C) + \int_0^{x_C} p(q, a_C)dq - V(a_M) - \int_0^{x_M} p(q, a_M)dq - [p_C x_C - p_M x_M \quad (7)$$

The terms $V(a_C)$ and $V(a_M)$ represent the direct utility value of competitive and monopoly advertising levels, respectively. When advertising has consumption value, patent expiration can raise output while still lowering welfare: the decline in price raises output and welfare, but the reduction in advertising has a direct negative effect on welfare.

These results can be illustrated by Figure 4, which depicts the change in gross surplus that occurs at patent expiration, when advertising provides utility. In that case, a patent expiration lowers price and shifts demand inward. Regions *G* and *L* show the respective gain and loss in gross social surplus attributable to a simultaneous reduction in advertising and price. The welfare impact is ambiguous and depends on the respective sizes of *G* and *L*. When advertising has value in itself, therefore, care must be taken when inferring changes in welfare from changes in output. For example, it is possible that the optimal patent life is infinite, even when patent expiration increases output.

Another possibility is differential marketing to consumers with different willingness to pay. While price discrimination may be difficult, discrimination through marketing is much easier. This applies to the promotion of drugs to doctors, called "detailing," in pharmaceutical markets. Differential advertising across doctors and markets may act as a form of price discrimination. Since advertising cannot be resold, it is more easily implemented than traditional forms of price-discrimination. Thus, advertising may shrink pricing inefficiencies, and thus lower the marginal cost of patent extension. Discriminatory advertising may lower or even remove the dead-weight losses associated with patent monopolies.

When advertising has consumption value, it is necessary to estimate the direct utility of advertising in order to capture the full value of patent expiration. In the absence of this estimate, we can say that consumers benefit less from patent expiration whenever they derive consumption value from advertising.

C. Empirical Analysis

This section investigates the empirical impact of pharmaceutical marketing on consumer welfare. Our approach is to use patent expirations as a means of identifying the demand curve for pharmaceuticals, where demand depends on both price and advertising effort. These estimates are then used to calculate how much patent expiration benefits (or costs) consumers.

We focus on direct-to-physician marketing, which accounts for about 86% of all pharmaceutical marketing [23]. We estimate the value of marketing under the alternative models of advertising as information (Section B.3.1) and advertising as persuasion (Section B.3.2). We do not have the data necessary to estimate the direct utility value of such marketing to consumers or physicians. If this exists, it would further increase the value of marketing and reduce the cost of patents.

We begin by presenting our empirical model and approach to welfare estimation. We then describe our data and present descriptive analyses of the relationships between patent expiration, quantity changes, and marketing effort. Next, we discuss our approach to measuring advertising and lay out our identification strategy. We finish with our estimated models and welfare effects.

C.1 Model and Approach to Welfare Estimation

The basic framework for this analysis will be the following demand function:

$$\ln x_{it} = \beta_0 + \beta_1 \ln p_{it} + \beta_2 \ln a_{it} + \phi_i + M(t) + \varepsilon_{it} \quad (8)$$

In this equation, p_{it} is the price of molecule i in month t, x_{it} is the corresponding quantity of the molecule, and a_{it} is a measure of advertising. There is also a molecule fixed-effect, φ_i and a polynomial time trend, $M(t)$.

We are particularly interested in using the demand function to ascertain the effects of patent expiration on quantity and on welfare. It is straightforward to assess the quantity effects, but estimating the welfare changes (in terms of consumer surplus) requires more discussion.

The demand function (and its associated inverse demand) implies forms for the changes in consumer surplus presented in Section B.3. Consider first the cost of quantity-restriction alone, which would be present without advertising. Suppose $p(q)$ represents demand at the consumer's true valuation of the good. Monopoly quantity is given by x_M. Finally, define by $x_C^{'}$ the counterfactual quantity that would obtain under competition if prices changed, but advertising remained at its monopoly level. If $\frac{dp}{p}$ is the percent change in price due to patent expiration, we can define $x_C^{'} \equiv x_M \left(1+\left(\frac{dp}{p}\right)\varepsilon\right)$. The cost of quantity-restriction to the consumer is then defined by:

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$$\int_{x_M}^{x_C'} p(q)dq - p_C x_C' - p_M x_M \quad (9)$$

Substituting in the logarithmic form for the inverse demand function, and integrating yields the final expression:

$$\Delta_Q = exp\left(\frac{-\beta_0 - \phi_i - M(t=-1) - \beta_2 \ln(a_M)}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left(x_C'^{\,1+\frac{1}{\beta_1}} - x_M^{\,1+\frac{1}{\beta_1}}\right) - [p_C x_C' - p_M x_M] \quad (10)$$

The time trend is evaluated at $t = -1$, the last month of patent protection. This expression can be calculated in the short-run and the long-run by calculating x_C' according to either the short-run or long-run reduction in price due to patent expiration. This distinction allows us to calculate either the "short-run" or "long-run" change in welfare.

The short-run price change is defined as the change observed in the first few months immediately following patent expiration. Since the long-run price change due to patent expiration is unobserved to us, we estimate it by assuming that the long-run competitive price is equal to marginal cost. The demand curve then implies an associated long-run quantity, based on the estimated price elasticity of demand. Further details on the methods for estimating short- and long-run consumer surplus appear in the appendix.

In the case of informative advertising, the true expected change in consumer surplus is given by:

$$\Delta_{Info} = \int_{x_M}^{x_C} p(q)dq - (p_C x_C - p_M x_M) \quad (11)$$

This differs from Δ_Q in its use of the equilibrium competitive quantity x_C that includes the effects of both price and advertising changes. Above, we defined the conservative bound on this quantity:

$$\tilde{\Delta}_{Info} = \int_{x_M}^{x_C} p(q, a_M)dq - (p_C x_C - p_M x_M) \quad (12)$$

The functional form of the demand curve provides an explicit expression for this term:

$$\tilde{\Delta}_{Info} = exp\left(\frac{-\beta_0 - \phi_i - M(t=-1) - \beta_2 \ln(a_M)}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left(x_C^{\,1+\frac{1}{\beta_1}} - x_M^{\,1+\frac{1}{\beta_1}}\right) - [p_C x_C - p_M x_M] \quad (13)$$

Next, the value to consumers of monopoly-level informational advertising can be obtained as:

$$InfoAdvValue = \tilde{\Delta}_Q - \tilde{\Delta}_{Info} \quad (14)$$

Finally, consider the case of persuasive advertising. Recall that the value of patent expiration in this case is given by $\tilde{\Delta}_{Pers} \equiv \tilde{\Delta}_{Info} + \int_{x_M}^{x_C} (p(q, a_C) - p(q, a_M))dq$. The functional form of the demand curve then implies:

$$\tilde{\Delta}_{Pers}=\tilde{\Delta}_{Info}+\exp\left(\frac{-\beta_0-\phi-M(t=-1)}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left(1-a^{\frac{\beta_2}{\beta_1}}\right)\left[{x_C}^{1+\frac{1}{\beta_1}}-{x_M}^{1+\frac{1}{\beta_1}}\right]$$

As above, the value to consumers of monopoly-level persuasive advertising can then be obtained as:

$$PersAdvValue=\tilde{\Delta}_{Pers}-\tilde{\Delta}_{Q}$$

C.2 Data

The IMS Generic Spectra database contains data on 101 unique molecules, whose patents expired between 1992 and 2002.[11] For each one, it reports 6 years of monthly data, which span the interval from 3 years prior to 3 years after patent expiration. The monthly data include prices, quantities, and advertising effort. Table 1 lists the variables we have available. Drug quantity is available in grams. Prices (per gram) are estimated as total revenues from the drug divided by grams of the drug sold; IMS collects both the revenue and grams data. Revenue data are collected at the retail level (through both retail and hospital pharmacies), and at the wholesale level. IMS then estimates the wholesale price paid to the pharmaceutical company. Therefore, in the case of a patented drug, this can be thought of as the price paid to the monopolist, rather than the price paid by insured or uninsured consumers. We also have three measures of direct-to-physician advertising: monthly expenditures on medical journal advertisements, monthly visits to doctors by the company's sales representatives (called "detailing visits"), and the number of drug samples dispensed by representatives to doctors.

Price, quantity, and advertising data are available separately for the branded and generic producers of the molecule, and for the overall market. Total market price is constructed as total revenues divided by total grams, and similarly for the branded and generic prices. In estimating market demand, we use total market prices and quantities.

Table 2 reports a breakdown of the 101 included molecules by therapeutic class and advertising status. In our descriptive presentations, we call a drug "fully advertised" if it reports some advertising activity in each of the three advertising categories we have, and vice-versa. Not surprisingly, advertising effort is much higher for heavily used drugs: Drugs not fully advertised account for about 28% of the molecules, but less than 10% of total revenues.

C.3 Descriptive Analysis

An initial examination of the data reveals some interesting patterns that suggest the interplay of quantity-restriction and advertising effects.

[11]The full data include 106 molecules, but 5 are dropped. We drop Aventyl (Eli Lily, patent expiry in July 1992), Prinivil (Merck, patent expiry in June 2002), and Betoptic (Alcon, patent expiry in June 2000), because generic sales for these drugs include other branded products, creating a measurement problem. We also dropped Bumex (Roche, patent expiry in January 1995), and Toradol (Roche, patent expiry in May 1997), both of which had a duplicate formulation in the data.

C.3.1 Patent Expiration and Changes in Quantity—Figure 1 demonstrates that for about 40% of drugs, the total market quantity consumed falls in the short-run, immediately after patent expiration. The figure depicts the percentage change in quantity from the month immediately prior to expiration to the month immediately following expiration. This suggests that patent expiration is doing more than simply removing the monopolist's incentive to restrict quantity.

Figure 5 depicts trends in price and quantity for the average drug, as a function of time until (or after) the month of expiration. As others have noted, before expiration, price tends to rise and quantity to fall over time. Bhattacharya and Vogt [13] argue that this occurs because a drug is an "experience good" in the sense that consumers have to use it before they can judge its value. Therefore, inducing more use by lowering the price can lead to permanent increases in consumption by creating "loyal customers." The incentive to win more customers is highest early in the life of the patent, and erodes as the month of expiration looms. This is consistent with the trends in price and quantity prior to expiration.

After patent expiration, the price of the branded drug remains largely unchanged, even rising slightly, while the price of generic forms falls precipitously. The deviations from the typical expectations we have about patent expiration seem at least correlated with advertising. Drugs that are not fully advertised, according to the definition above, tend to behave according to the standard theory of monopoly. Compare Figure 6 and Figure 7, which show trends, respectively, for advertised and non-advertised drugs. Trends for the less advertised drugs look fairly standard: after patent expiration, quantity rises and remains at a permanently higher level. Moreover, the price of the branded drug falls after expiration, although it always remains higher than the generic price. In contrast, for the more advertised drugs, the brand price steadily rises after expiration, and total market quantity ends up falling after expiration, after a brief initial rise.

C.3.2 Trends in Advertising—Figures 8, 9, and 10 document trends in journal advertising, detailing visits, and samples dispensed. Advertising expenditures decline throughout the life of the product, since the pay-off to advertising falls with the length of the patent horizon. At the month of patent expiration, there is a short-lived jump in advertising, as generic firms spend some effort publicizing their product. In percentage terms, this jump is most pronounced in the case of journal advertising, but still occurs for samples dispensed and detailing visits.

C.4 Measurement of Advertising

The nature of these three types of advertising activities differs considerably. Ideally, we would like to estimate the impact of prices and the independent impact of all three forms of direct-to-physician advertising.[12] However, we lack enough identifying variation to estimate the impacts of all three measures. Therefore, we focus on the estimates using samples dispensed, which account for almost two-thirds of direct-to-physician advertising

[12]The IMS Generic Spectra database does not contain information on direct-to-consumer advertising, which makes up approximately 14% of total advertising spending 23. Kaiser Family Foundation (2003) Impact of Direct-to-Consumer Advertising on Prescription Drug Spending. Menlo Park, CA: Kaiser Family Foundation. 6084 6084..

expenditures [23]. In contrast, journal advertising accounts for roughly 2% of spending, with detailing visits accounting for the rest.

An additional empirical reason to study samples, instead of detailing visits, is the issue of attribution to specific molecules. It is clear how to assign samples dispensed by a manufacturer to a particular brand. Apportioning detailing visits is much more ambiguous. This is consistent with our finding that the standard errors on detailing effects are consistently larger (by nearly an order of magnitude) than the corresponding errors on journal advertisements or samples dispensed.

To be sure, a drawback of focusing on a single advertising measure is the exclusion of other marketing activities. However, analyzing a single marketing activity ought to provide quantitatively generalizable insights. In a simple model, the marginal dollar spent on every marketing activity ought to be equally valuable in terms of generating additional units of demand.[13] Therefore, the demand response generated by a dollar of spending on samples ought to be roughly comparable to the response generated by a dollar spent on detailing, or a dollar spent on dispensing samples. The elasticities on individual activities are related, according to: $\varepsilon_{A_i} = \varepsilon_A \sigma_{A_i}$, where ε_A is the elasticity on total advertising, ε_{A_i} is the elasticity on advertising activity *i*, and σ_{A_i} is the share of activity *i* in total advertising spending.

This helps clarify the effect of focusing on one type of advertising. If other forms of advertising change at patent expiration, an omitted variables problem ensues. If all forms of marketing are positively correlated, the estimated elasticity on activity *i*, $\hat{\varepsilon}_{A_i}$, will be biased towards the total elasticity ε_A. If correlation is perfect, $\hat{\varepsilon}_{A_i}$ will equal ε_A itself. In our context, therefore, we know that the estimated elasticity on samples will lie between the true elasticity on samples and the true total advertising elasticity. The bias is bounded above by $|\varepsilon_A - \varepsilon_{A_i}| = \varepsilon_A |1 - \sigma_{A_i}|$. To be conservative about the value of advertising, we assume that all forms of advertising are perfectly correlated, and that the bias is maximized. As a result, we treat the elasticity on samples as if it were the elasticity on total advertising and assume $\hat{\varepsilon}_{A_i} = \varepsilon_A$. This weakly understates the value of advertising.

C.5 Identification

To identify the demand for drugs, our approach is to isolate movements along the demand curve, as distinct from shifts of the curve itself.

C.5.1 Approach—The general strategy is to treat “large” changes in price and advertising sufficiently “close” to the date of expiration as being related to the patent expiration, and not to shifts in the demand curve. The trend breaks in price, advertising, and quantity are then used to calculate demand elasticities.

[13] Specifically, if demand depends on two advertising activities, according to (p, A_1, A_2), where A_1 and A_2 are both denominated in dollars, profit-maximization implies that $\frac{\partial D}{\partial A_1} = \frac{\partial D}{\partial A_2}$.

To lay out this approach, consider first a formulation that treats advertising effort as exogenous. This involves estimating the following first- and second-stage equations via instrumental variables:

$$\ln p_{it}=\alpha_0+\alpha_1 Expired_{it}+\alpha_2\ln(a_{it})+\phi_i+M_p(t)+\eta_{it} \quad (15)$$

$$\ln x_{it}=\beta_0+\beta_1\ln p_{it}+\beta_2\ln a_{it}+\phi_i+M_x(t)+\varepsilon_{it} \quad (16)$$

Price (p_{it}) is a function of advertising (a_{it}), a molecule fixed-effect (φ_i), and a polynomial in month (M_p (t)). Quantity (x_{it}) depends on price, advertising, a molecule fixed-effect, and a polynomial in month (M_x (t)). The expiration variable identifies the within-molecule break in the polynomial trend that occurs at expiration for changes in price and quantity. These trend breaks, which imply percentage changes in quantity and price, are then implicitly used to estimate the demand elasticity. Breaks in trend at the date of expiration are attributed to the expiration itself; they are assumed independent of unobserved changes in demand and used to estimate movement along the demand curve. Later, we will present some evidence in favor of this identifying assumption.

To identify the effects of endogenous advertising effort, we extend the strategy above, which relies on changes in price and quantity at the precise moment of patent expiration. In reality, however, the effect of expiration is not immediate. Competitors enter slowly and at an uncertain pace, due to the vagaries of the FDA approval process, and to non-patent entry barriers like fixed start-up costs. If expiration has lagged effects, we can obtain more identifying variation. We adapt the expiration window strategy by considering the lagged effect of expiration, in addition to the immediate effect. Formally, this is implemented by the following model:

$$\ln(p_{it})=\alpha_0+\alpha_1 Expired_{it}+\alpha_2 ExpiredLag_{it}+\phi_i+M_p(t)+\eta_{it} \quad (17)$$

$$\ln(a_{it})=\delta_0+\delta_1 Expired_{it}+\delta_2 ExpiredLag_{it}+\phi_i+M_a(t)+\omega_{it} \quad (18)$$

$$\ln(x_{it})=\beta_0+\beta_1\ln(p_{it})+\beta_2\ln(a_{it})+\phi_i+M_x(t)+\varepsilon_{it} \quad (19)$$

As before, $Expired_{it}$ is a dummy variable for the month immediately following expiration. $ExpiredLag_{it}$ is a dummy for the lagged effect of expiration: we consider specifications using two months, three months, four months, and five months after expiration; these produce similar results, as shown in Table 7 below.

C.5.2 Validity Tests—The identification strategy rests on the validity of using patent expiration as an instrument for estimating the demand for pharmaceuticals. The instrument will be valid if patent expiration has no direct effects on the demand curve. It seems reasonable to assume that consumers do not derive direct utility from a molecule being on- or off-patent, even if they may value using branded drugs over generics. However, there may be indirect effects of patent expiration on demand, if expiration causes competitors to respond strategically. For example, monopolistic competitors may manipulate prices or marketing in response to a patent expiration.

To investigate the importance of this behavior, we run the following regression:

$$\ln(S_{jm})=\eta_0+\eta_1 Expired_{im}+M_S(t)+\phi_i+\kappa_{jm} \quad (20)$$

The dependent variable is a measure of strategic behavior — measured as competitors' prices, or marketing activity — either for the own-molecule, or the molecule's competitors. We define the set of competitors as molecules in the same (5-digit USC) therapeutic class. The explanatory variable $M_S(t)$ is a quartic in months until the expiration of the patent on molecule i,[14] and φ_i is a fixed-effect for molecule i . Intuitively, these regressions assess whether patent expirations affect pricing or advertising decisions for a molecule's competitors.

Table 3 presents the results. The table has three columns: one for the molecule itself; one for the entire therapeutic class, including the molecule itself; and one for the molecule's competitors, where quantity is defined as the class-level quantity minus the quantity for the molecule itself. Patent expirations reduce price and marketing effort for the on-patent molecule, as expected. However, for price and these three marketing measures, there is no effect on the behavior of competitors. With the exception of the price regression, the effects for competitors are more precisely estimated than the own-molecule effects, suggesting that the competitor regressions would be precise enough to detect the own-molecule effects, and that wider confidence intervals cannot explain the difference in significance. Finally, the molecules being studied comprise 30% of class-level grams sold, on average. Therefore, if patent expiration had no effects on competitors, one would expect the class-level effects to be about 30% as large as the own-molecule effects. One can never reject this hypothesis statistically, for any of the four measures; moreover, 6 of the 8 point estimates are within one-half standard deviation of that 30% level.

C.6 Naïve Estimates with Exogenous Advertising

We first present the 3-stage least squares coefficients that treat advertising as exogenous in Table 4, which reports results for 4 versions of the model. Here, we are estimating equations 15 and 16. The first two models include samples dispensed as a measure of advertising, and differ with respect to the form of the polynomial time trend. The second two include all three measures of direct-to-physician marketing in our data.

The estimated price elasticities are just above 1.0 in the fully specified model and around 1.5 in the model with samples alone. The theory of monopoly predicts that the absolute value of the demand elasticity equals the inverse of the monopoly markup. In the case of drugs, the long-run price of generic equivalents tends to be approximately 10 to 20 percent of the brand price at the date of expiration [24]. This implies that the demand elasticity at expiration is predicted to be between 1.1 and 1.25. These numbers lie within one standard deviation of all four estimates.

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[14]Similar results were obtained using cubic and quadratic specifications.

The first-stage estimates suggest that patent expiration immediately lowers price by six to ten percent. This is predicted to raise quantity by slightly more. One month after patent expiration, the model predicts that quantity will be about 9.5% higher. This number is largely invariant across the four specifications. In the long-run, however, price typically falls by 80 percent [24]. Given the likely demand elasticities, therefore, patent expiration raises quantity by more than 80 percent in the long-run.

In the models with only samples dispensed, the naïve advertising elasticity is around 0.12 to 0.13. Including the other measures of marketing lowers this number, but the combined effect of increasing all marketing measures proportionally results in a similarly sized response.

C.7 The Full Model of Advertising

The full model treats advertising as an outcome variable, as specified in equations 17, 18, and 19. The results are given in Table 5. The table reports estimates from two different models, one using a cubic polynomial in month, and one using a quartic. The results are reasonably stable across the two specifications. The price elasticity of demand is estimated to be at or near unity, while the advertising elasticity ranges from 0.32 to 0.36. Both sets of estimates imply that, for the average molecule, total quantity falls by about 5% on net, after 5 months of patent expiration. Our price elasticity estimates continue to be within one standard deviation of 1.1 and 1.25.

Theory also provides predictions on the size of the advertising elasticity; the ratio of advertising to price elasticities ought to equal the share of advertising in sales [25].[15] To calibrate the elasticity, we need to calculate the share of advertising in sales for on-patent molecules. Unfortunately, our data do not contain expenditures on samples, but we can calculate the advertising share in revenues indirectly. The overall share of marketing expenditures in total pharmaceutical revenue is approximately 14% [23]. About 75% of total revenues go to drugs that are currently on patent [26]. Assuming that marketing is negligible for generics and off-patent drugs, this implies that marketing is about 19% of revenues for the relevant drugs.

Finally, our sample of drugs is more heavily marketed than the average drug, in part because these drugs are selected to have sales throughout their product life-cycle. As such, they will tend to be more successful than average. To calibrate this difference, we compare marketing expenditures on detailing in our data to that for the average on-patent drug. Overall, 29% of marketing expenditures go to detailing [23]. Since marketing expenditure is approximately 19% of on-patent drug spending, this implies that 5.5% of on-patent drug revenues are spent on detailing. In our data, we estimate that 6.8% of revenues are spent on detailing, while drugs are on patent.[16] Along this dimension, marketing effort is roughly 24% higher for our drugs. Applying this correction would imply that marketing is roughly 23% of revenues for our drugs. Theory predicts the price elasticity ranges from 1.1 to 1.25. These price

[15]The “Dorfman-Steiner Theorem” follows most simply from the analysis of a static monopoly maximization problem 25. Dorfman, Robert, Peter O. Steiner (1954) Optimal Advertising and Optimal Quality. The American Economic Review 44: 826–836..

[16]We assume that each detailing visit costs $138 27. Neslin, Scott (2001) ROI Analysis of Pharmaceutical Promotion (RAPP): An Independent Study. Amos Tuck School of Business, Dartmouth College.. We then calculate total spending on detailing as a fraction of total revenue for each month, and compute the mean fraction for all on-patent drug-months.

elasticities coupled with our rough estimates of the revenue share spent on advertising implies total advertising elasticities between 0.25 and 0.29. Our estimates are slightly higher, but fairly close, and not statistically distinguishable from these crude predictions.

The table also presents weak instrument diagnostics. For the purpose of diagnosing weak instruments, Stock and Yogo [28] derive critical values for use with the Cragg-Donald statistic. Unlike the conventional F-test for weak instruments, their methods are applicable to cases with multiple included endogenous regressors. In particular, they show that the Cragg-Donald statistic can be used to infer maximum Wald test sizes. For example, they show that a Cragg-Donald statistic above 3.95 implies that a Wald test at the 5% level will have a maximum size of 20% -- i.e., it will be rejected no more than 20% of the time. A typical threshold for declaring instruments "strong" is a maximum size of 10%.

As Table 5 demonstrates, the maximum test sizes lie above this threshold and thus indicate weak instruments. To address this problem, we report the Stock-Wright "s-statistic," which is a weak-instrument-robust procedure for testing hypotheses concerning the coefficients on the included endogenous regressors [29]. According to the Stock-Wright statistic, we can reject the null hypothesis that the coefficients on price and advertising are jointly zero in our models. Nonetheless, care should be taken in interpreting our confidence intervals, as our standard errors are likely to be biased downwards.

C.7.1 Consumer Surplus from Patent Expiration—Estimating the full demand functions allows us to infer the changes in consumer surplus associated with patent expiration, quantity restriction, and monopoly marketing. Conceptually, we estimate three kinds of welfare changes: (1) Cost of quantity-restriction, (2) Cost of patents, and (3) Value of monopoly marketing. The second and third types of welfare change are estimated under both the persuasive and informational advertising cases.

The cost of quantity-restriction is the consumer's cost of the higher prices induced by patents.[17] The overall cost of patents, on the other hand, combines this cost with the consumer value of increased output due to higher advertising.[18] Theoretically, the cost of quantity-restriction must always be positive. But the cost of patents may be positive or negative, as shown in our theoretical discussion. Finally, the value of monopoly marketing is the value to consumers of the marketing induced by patents, holding price fixed.[19]

In our benchmark estimation, we define the short-run as the first five months after patent expiration:[20] the price and advertising changes that take place over this initial period define short-run costs. The long-run welfare changes are the total gains that would accrue to consumers in a long-run steady-state. These are computed using the following results: in the long-run, competition drives price to marginal cost and advertising effort to zero. Since

[17]This is given by equation 13, evaluated at the value of x_C that would obtain if patent expiration had no impact on marketing effort. The evaluation procedure is described in the Appendix, under "Cost of Quantity-Restriction."

[18]This is given by equation 13, evaluated at the actual competitive value of x_C. The evaluation procedure for the informational advertising case appears in the Appendix, under "Consumer Surplus with Informational Advertising." For the persuasive advertising case, the Appendix section "Consumer Surplus with Persuasive Advertising" provides details.

[19]This is given by equation 14.

[20]Table 7 demonstrates the robustness of our results to one-month, two-month, three-month, and four-month definitions of the short-run.

long-run generic prices are about 10–20% of monopoly prices, we assume that in the long-run, price falls by 90%, while advertising falls by 100%. More detail on the calculation of these consumer surplus changes appears in the appendix.

The consumer surplus calculations depend on: the price elasticity, the advertising elasticity, and the short-run impact of patent expiration on price. Our model estimates all three of these underlying quantities and allows calculation of consumer surplus. Table 5 lists the estimated change in consumer surplus associated with each model estimate.

The per-molecule cost of quantity restriction to consumers is $1.9m to $2.4m in the short-run. Conceptually, this means that 5 months after patent expiration, consumers receive about $2m of additional value per month (from one molecule) due to the reduction in price alone. This value rises to about $12.7m in the long-run. In other words, the price reduction delivered by a competitive market, compared to the last month of a patent monopoly, would yield at least $12.7m of value to consumers per month.

These calculations do not account for the effect of patents in encouraging advertising and thus raising quantity. Accounting for the effects on advertising, patent expiration either has small positive or even negative effects on consumers in the short-run. In the long-run, consumers still benefit from patent expiration, but by less than the cost of quantity-restriction alone. In the long-run, competition creates $8.1m to $9.5m of additional value for consumers, per month. This is approximately 30% lower than the value created by the price reduction alone. The marketing induced by patents generates consumer surplus approximately equal to 22% to 26% of total pharmaceutical spending. Earlier, we roughly estimated that firms spend about 23% of total revenues for the marketing of on-patent drugs in our sample. Therefore, the value of marketing to consumers alone — excluding the value to firms — is approximately equal to its cost.

Note also that the estimates are fairly similar for the cases of persuasive and informative advertising. Under persuasive advertising, we assume that the true value of the product is lower than under informational advertising. As a result, the cost of patent monopoly is also somewhat lower, and the value of monopoly-induced marketing relatively higher. These are, however, modest differences, as the table indicates. By and large, the welfare effects of advertising do not hinge upon the precise model of advertising adopted. Finally, our estimates do not incorporate the direct consumption value of marketing, if any. Consumption value lowers the social cost of patents and raises the value of monopoly marketing.

The implications of weak instruments for these estimates are not clear. Relative bias in an exactly-identified IV model is undefined, as is the expected value of the IV coefficient [30]. In the absence of clear econometric evidence, it is useful to reiterate the finding that the coefficient estimates agree with the simple economic theory of pricing and advertising by monopolists. At a minimum, therefore, our numbers can be thought of as extensions of this simple theory, calibrated to real-world data on advertising expenditures and price markups.

C.7.2 Class-Level Results—Both marketing and price reductions increase quantity for a molecule itself, but their welfare benefits might be smaller if they "steal" business from competitors, rather than generate new consumption among untreated patients. By replacing molecule-level quantity and price from our earlier models with measures of class-level quantity and price, we can gain some insight into this issue. We analyze both the entire therapeutic class, including the expiring molecule itself, and separately analyze the "rest of the class," excluding the molecule with the expiring patent.

Table 6 displays the results of this approach. It is analogous to the models reported in Table 5, in that it estimates equations 17, 18, and 19 at the level of the therapeutic class. Table 6 shows that marketing effort and price reductions for a particular molecule increase class-level consumption, but have no statistically detectable effect on consumption in the rest of the class. On average, expiring molecules comprise 30% of class-level grams sold. Therefore, if advertising only increases the consumption of the advertised molecule, and has no impacts on competitors, the estimated advertising effects should be roughly 30% as large as they were in Table 5. This would suggest a class-level advertising elasticity between 0.09 and 0.11. Our point estimate is considerably larger than this, although we cannot statistically reject values smaller than these levels, due to the width of the confidence interval. Taking the point estimates at face value though would suggest *positive* spillovers from a molecule to its competitors. Positive spillovers are consistent with the decrease in marketing effort, and the increase in molecule-level price [as reported in 13], that occur as patent expiration approaches. In any event, there is no evidence of market-stealing in our data. This argues in favor of our welfare calculation approach, which treats own-molecule quantity growth as a pure welfare gain, rather than "theft" of competitors' market share.

A caveat to the results in Table 6 concerns the apparent presence of weak instruments, which likely widen the confidence intervals further around the coefficients of interest. The Cragg-Donald statistics imply that under-rejection of hypothesis tests is likely [28]. Specifically, they imply that hypothesis tests at the 5% level are likely to be rejected 25% of the time, or more; this suggests that the significance levels reported might be too low. Moreover, unlike in Table 5, hypothesis tests that are robust to weak instruments – using the Stock-Wright s-statistic – fail to reject that the price and advertising coefficients are jointly zero. As such, these results should be viewed as suggestive. We cannot detect effects of market-stealing, but this may be due to a lack of power and instrument strength.

C.8 Sensitivity Analyses

We analyzed the sensitivity of our results to changes in the dynamics of patent expiration. The models above were identified using the month of patent expiration and 5 months after patent expiration as instruments. We also explored using 4 months, 3 months, and 2 months after expiration as a second instrument. Using the shorter-run estimates tended to reduce both the size and precision of the price elasticity estimates, most of which were statistically indistinguishable from zero. However, the advertising elasticities remained stable. The value of advertising relative to revenues rose somewhat, as did the magnitude of some of the welfare effects. The results appear in Table 7.

Second, we analyzed the impact of "line-extensions," or the launch of redesigned molecules by the original patent-holder, in an effort to retain some patent protection. Specifically, we limited our analysis to those 37 molecules without any line extensions. Both the price elasticity and advertising elasticity rise in absolute value, and the price elasticity becomes borderline insignificant. However, the welfare calculations are little changed. The value of marketing is about 19% of revenue. Considering monopoly advertising lowers the cost of patents by approximately 30%. Both these numbers are extremely similar to our preferred estimates.

D. Conclusion

Conventional wisdom analyzes optimal patent design as a trade-off between innovation incentives and static welfare. While this trade-off is real, it paints an incomplete picture. Patents have a variety of effects on static welfare, some of which can be positive. We demonstrated that patents improve the efficiency of marketing incentives and generate static value for consumers in this respect. Theoretically, this effect can mitigate or even fully offset the standard monopoly losses from patents. In the specific context of the market for pharmaceuticals, we estimated that monopoly marketing generates value for consumers that partially offsets the costs of monopoly pricing. Moreover, the value of advertising to consumers is roughly on par with its cost to firms; this suggests that, even if advertising generated no private value for firms, it would be approximately welfare-neutral. These estimates are robust to views of advertising as persuasive, rather than informative.

The paper suggests several avenues of future research. First, other forms of non-price competition should be studied in the IP context. Quality-provision, for instance, differs somewhat from marketing, in that monopolies may or may not have stronger incentives for quality. Future research should clarify the link between patents and product quality, and the welfare implications for consumers.

Second, using patent-expirations as an exogenous increase in competition may prove useful as a means of testing theories of market structure or estimating demand parameters in other markets. For example, our data shed light on the often-debated question of whether increased competition reduces advertising. When branded drugs have to compete with identical generic substitutes, advertising effort falls, as does utilization. Other predictions about the effects of market structure on industry conduct may be tested in a similar manner.

Third, our findings may alter the welfare interpretation of generic entry upon patent expiration. Generic entry clearly lowers price, but it also lowers advertising. It is necessary to consider both effects to capture the full value (or cost) of generic entry. At a minimum, our analysis suggests that considering price reductions alone leads to an upward bias in the estimation of welfare effects.

In general, little is known about efficient patent design in presence of non-price competition. More work is needed to better understand this issue, particularly in industries such as the US market for pharmaceuticals, where output declines often result from patent expirations.

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Appendix

This appendix describes the methods for calculating short-run and long-run consumer surplus.

Cost of Quantity-Restriction

In the text, we derived an explicit expression for the cost of quantity-restriction, consistent with the econometric specification of the demand curve:

$$\Delta_Q = \exp\left(\frac{-\beta_0 - \phi_i - M(t=-1) - \beta_2 \ln a_m}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left({x_{c0}}^{1+\frac{1}{\beta_1}} - {x_m}^{1+\frac{1}{\beta_1}}\right) - [p_C x_{c0} - p_M x_M. \quad (21)$$

We define x_M as the quantity in the last month of patent protection, at $t = -1$.[24] Conceptually, x_{c0} is the quantity that would obtain in the absence of a patent, but holding advertising fixed at its monopoly level.

For the short-run consumer surplus calculation, we use the change in price associated with the short-run expiration of the patent, or α_1 from the first-stage estimating equation. This leads to:

$$x_c^{short-run} = x_m(1+\alpha_1\beta_1)\; p_C^{short-run} = p(x_c^{short-run}; a_m) \quad (22)$$

Operationally, p is calculated as the fitted empirical inverse demand function, evaluated at the date of patent expiration, or

$p_C^{short-run} = \exp\left(\frac{\ln x_c^{short-run} - \beta_0 - \phi_i - M(t=-1) - \beta_2 \ln a_m}{\beta_1}\right)$. Note that here, and elsewhere, we fix the inverse demand curve at its monopoly level when calculating p_C.[25] This is in order to focus on valuing the change in quantity, rather than changes in the equilibrium inverse demand curve. Our quantitative conclusions concerning the relative importance of advertising, compared to revenues, are largely insensitive to this assumption, which uniformly affects the levels of all the consumer surplus calculations.

The long-run consumer surplus uses the quantity and price that would be associated with marginal cost production. Since marginal cost is 90% lower than the last observed monopoly price, the long-run competitive values can be obtained as:

$$x_c^{long-run} \equiv x_m(1 - 0.9(\beta_1))\; p_C^{long-run} = p(x_c^{long-run}; a_m) \quad (23)$$

Consumer Surplus with Informational Advertising

In this case, consumer surplus can be written as:

[24] Here and elsewhere, x_c is defined as x_m, multiplied by the percent change in quantity implied by the expiration of the patent. This percent change is defined as the percent change in price associated with expiration, multiplied by the price elasticity of demand.

[25] We take the same approach when calculating Δ_Q under "persuasive" advertising.

$$\tilde{\Delta}_{Info}=\int_{x_M}^{x_C} p(q,a_M)dq-(p_C x_C-p_M x_M) \quad (24)$$

The form of the demand function allows us to rewrite this as:

$$\tilde{\Delta}_{Info}=\exp\left(\frac{-\beta_0-\phi_i-M(t=-1)-\beta_2 ln a_M}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left(x_c^{1+\frac{1}{\beta_1}}-x_M^{1+\frac{1}{\beta_1}}\right)-[p_C x_{c0}-p_M x_M$$

This is similar to the expression above, but with a term for advertising added. We use samples in the last month of patent protection in order to estimate ln a_M; since we are estimating the fitted demand function, it is appropriate to use the advertising measure that is included in the regression. We now define the short-run prices and quantities as:

$$x_c^{short-run}=x_m(1+\alpha_1\beta_1+\alpha_2\beta_2)\ p_C^{short-run}=p(x_c^{short-run};a_m)$$

The long-run prices and quantities are:

$$x_c^{long-run}=x_m(1-0.9(\beta_1)-1.0(\beta_2))\ p_C^{long-run}=p(x_c^{long-run};a_m) \quad (25)$$

Consumer Surplus with Persuasive Advertising

In this case, consumer surplus can be written as:

$$\tilde{\Delta}_{Pers}=\tilde{\Delta}_{Info}+\int_{x_M}^{x_C}(p(q,a_C)-p(q,a_M))dq$$

This can be operationalized as:

$$\tilde{\Delta}_{Pers}=\tilde{\Delta}_{Info}+\exp\left(\frac{-\beta_0-\phi-M(t=-1)}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left(1-a_M^{-\frac{\beta_2}{\beta_1}}\right)\left[x_C^{1+\frac{1}{\beta_1}}-x_M^{1+\frac{1}{\beta_1}}\right.$$

We use samples in the last month of patent protection in order to estimate a_M; since we are estimating the fitted demand function, it is appropriate to use the advertising measure that is included in the regression. We now define the short-run prices and quantities as:

$$x_c^{short-run}=x_m(1+\alpha_1\beta_1+\alpha_2\beta_2)\ p_C^{short-run}=p(x_c^{short-run};a_m)$$

The long-run prices and quantities are:

$$x_c^{long-run}\equiv x_m(1-0.9(\beta_1)-1.0(\beta_2))\ p_C^{long-run}=p(x_c^{long-run};a_m) \quad (26)$$

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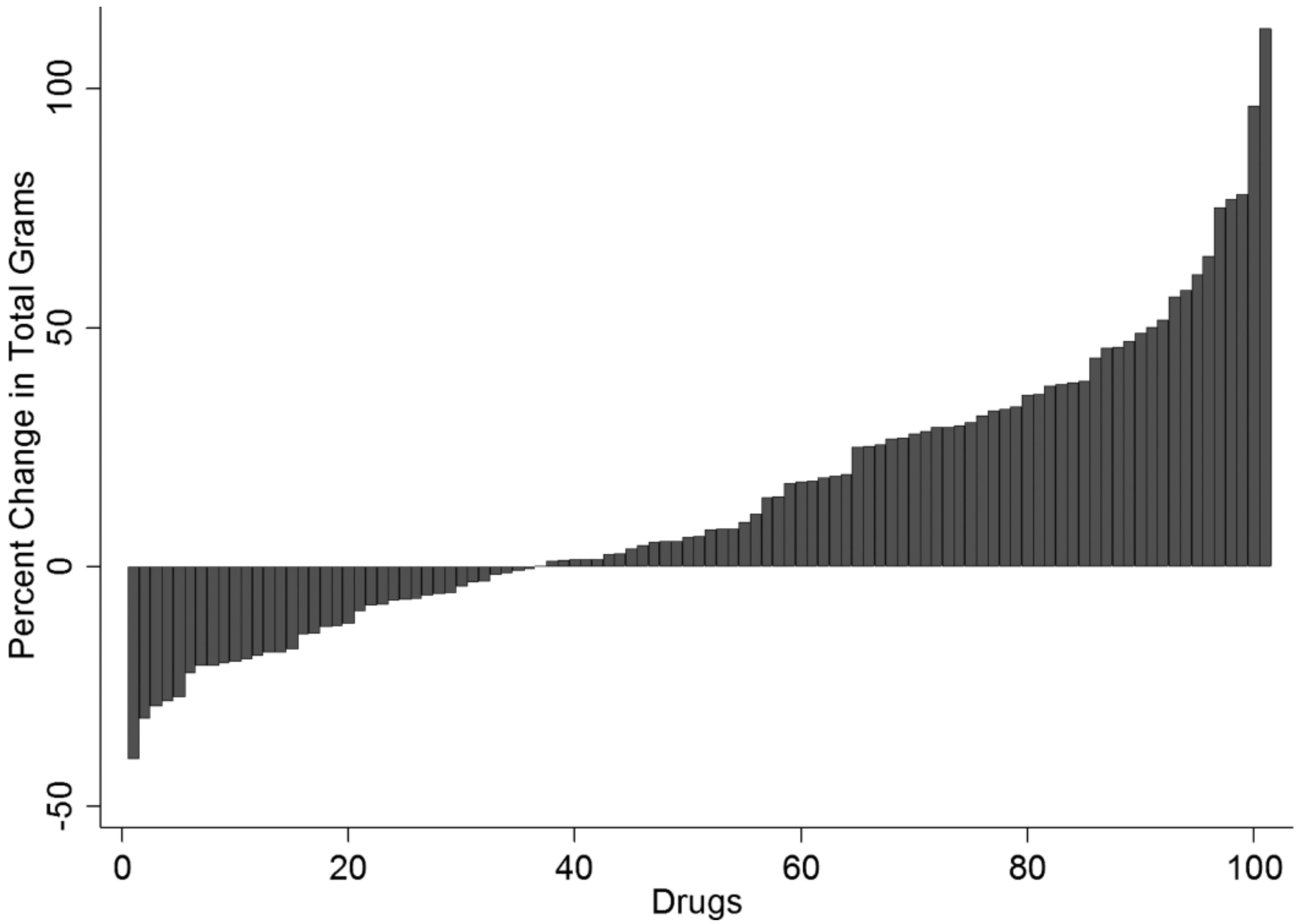

Figure 1.
Distribution of quantity changes by molecule, from patent expiration to one month after expiration
Source: IMS Generic Spectra database. Graph shows the percent change between grams in the month of patent expiration and the month immediately after expiration.

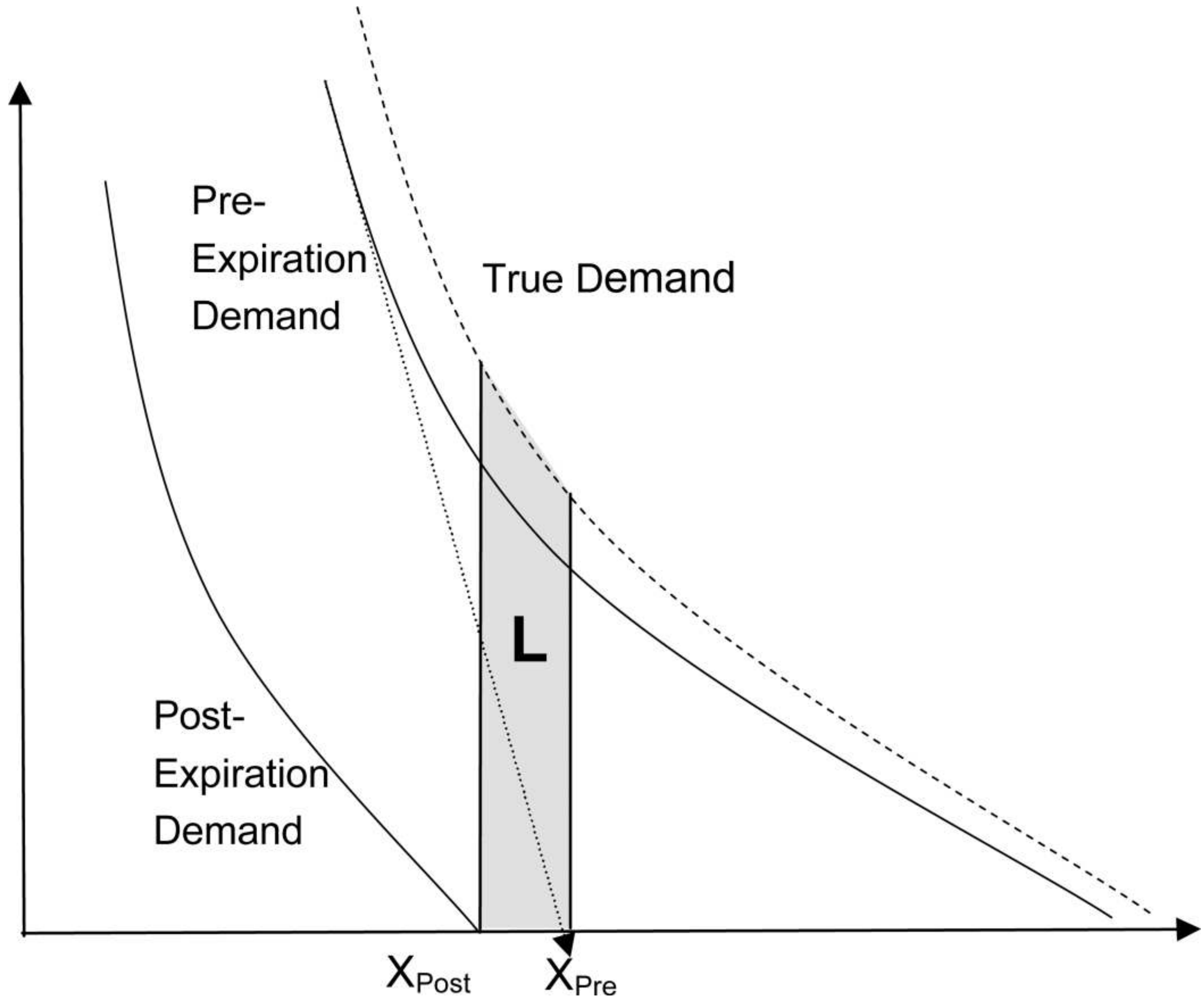

Figure 2.

Welfare effects of patent expiration under informative advertising.

Notes: The L region measures the welfare loss from patent expiration, assuming zero marginal cost of production.

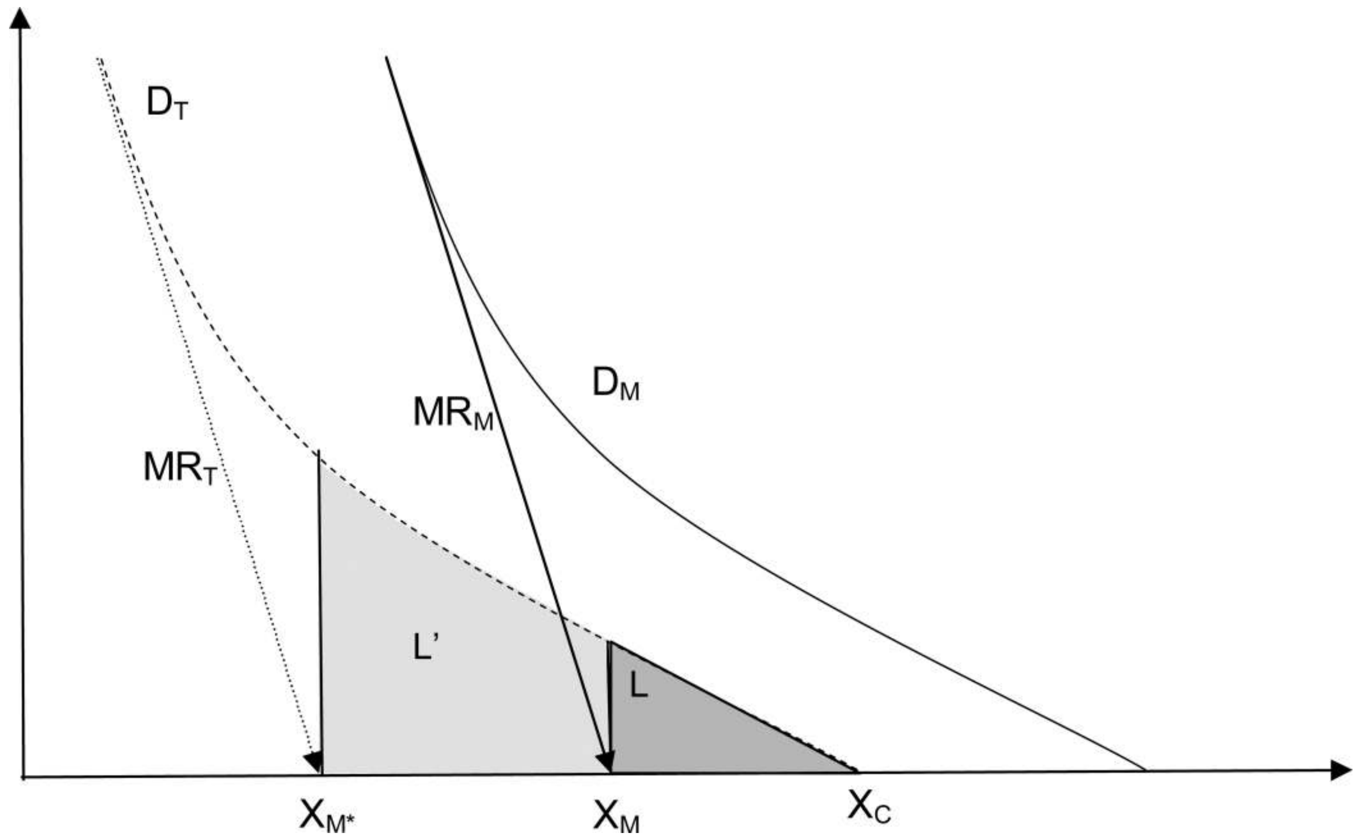

Figure 3.
Welfare effects of patent expiration under persuasive advertising.
The region L shows welfare loss due to patent monopoly with persuasive advertising. The combined regions L' and L show this loss for patent monopoly without advertising.

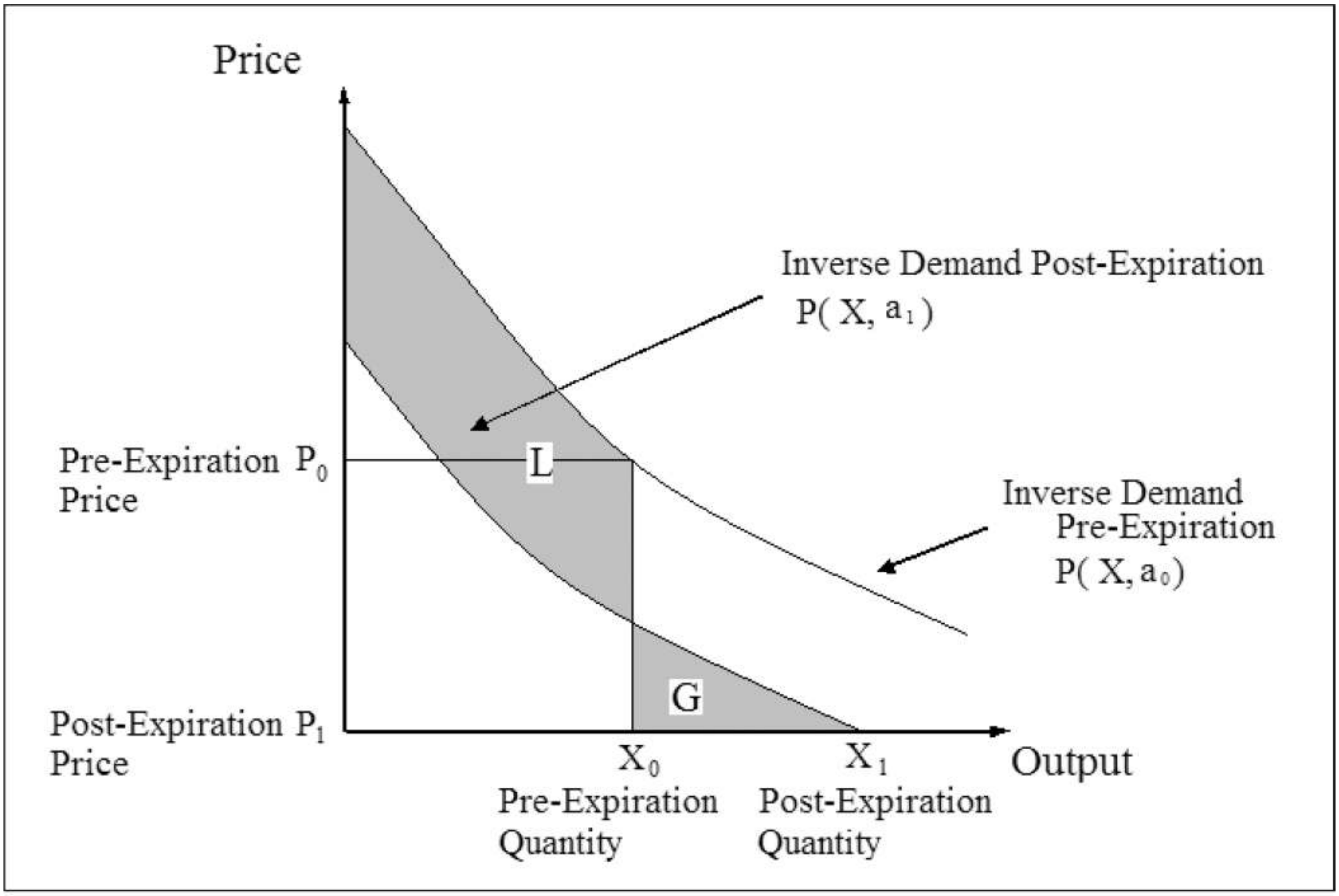

Figure 4.
Welfare Effects of Patent Expiration Under Advertising as Consumption
Notes: The region L shows the gross social loss from patent expiration, while G shows the gross gain, when advertising has consumption value.

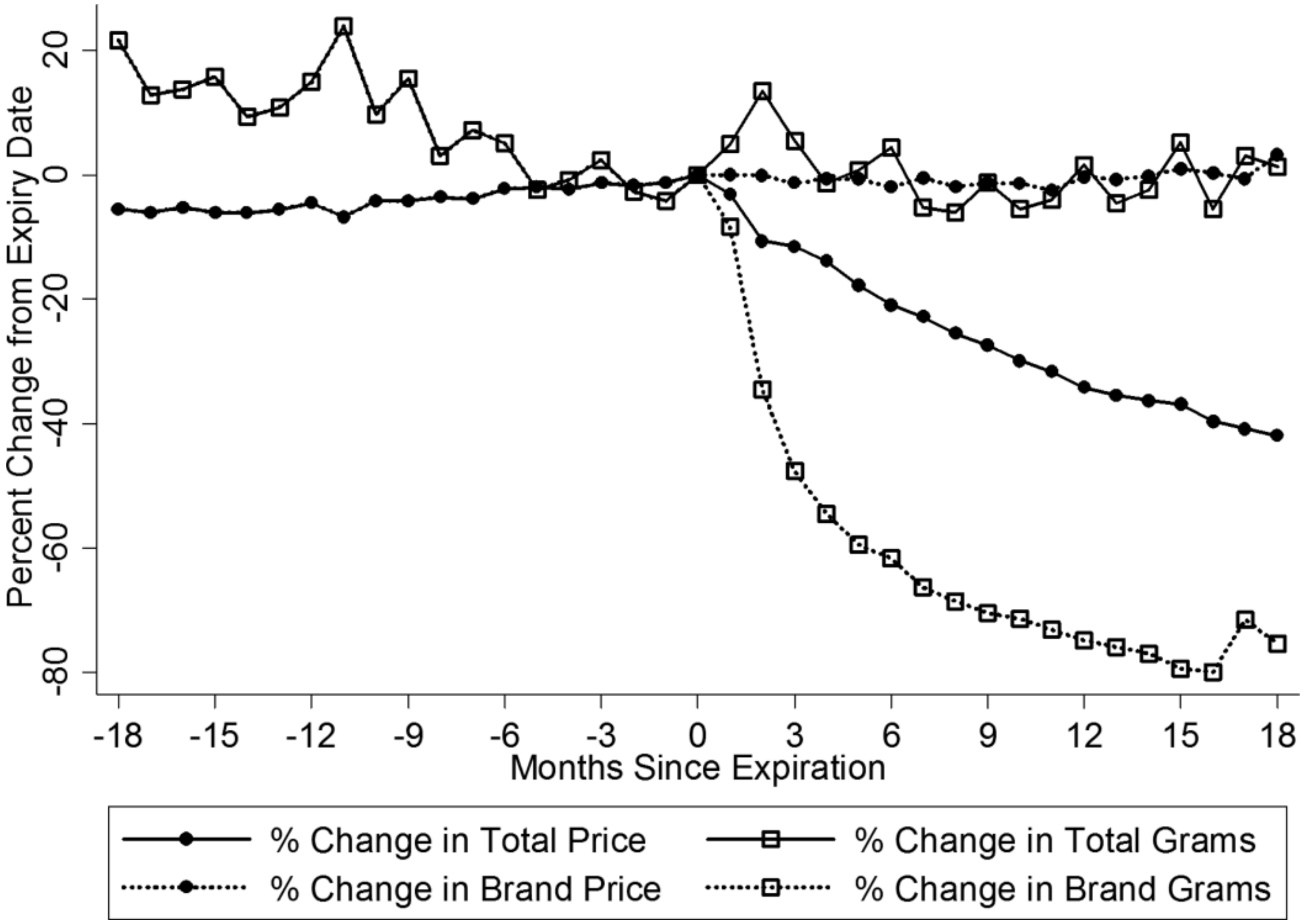

Figure 5.

Trends in price and quantity for the average drug.

Source: IMS Generic Spectra database. Graph shows the percent change between the month of patent expiration and the month shown on the x-axis. In all cases, price is per gram.

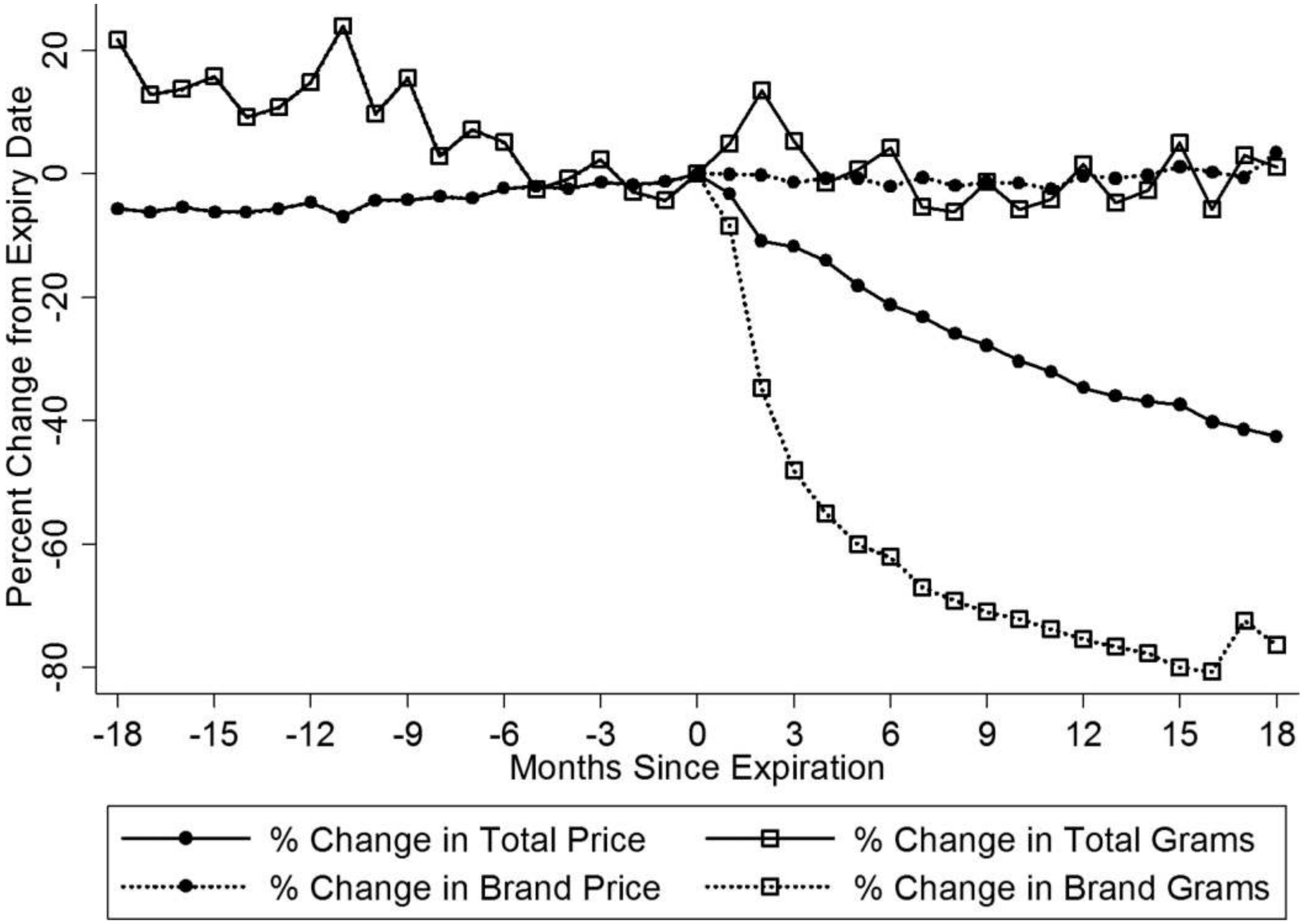

Figure 6.

Mean trends in price and quantity for fully advertised drugs.

Source: IMS Generic Spectra database. Graph shows the percent change between the month of patent expiration and the month shown on the x-axis. In all cases, price is per gram. A fully advertised drug has: at least one month of nonzero samples dispensed, at least one month of nonzero detailing visits, and at least one month of nonzero medical journal advertisements.

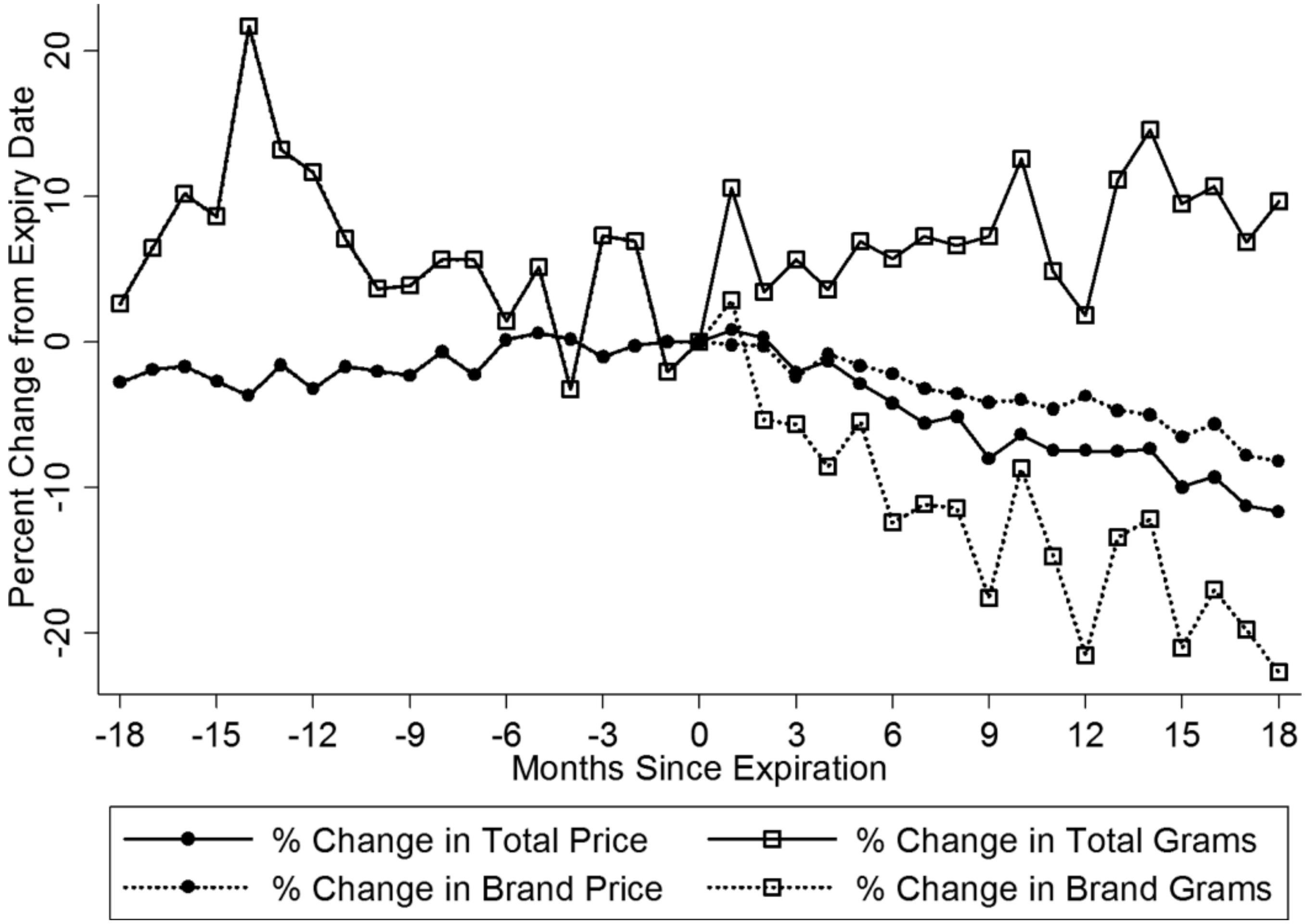

Figure 7.

Mean trends in price and quantity for drugs not fully advertised.

Source: IMS Generic Spectra database. Graph shows the percent change between the month of patent expiration and the month shown on the x-axis. In all cases, price is per gram. A fully advertised drug has: at least one month of nonzero samples dispensed, at least one month of nonzero detailing visits, and at least one month of nonzero medical journal advertisements. Drugs that do not meet these criteria are considered “not fully advertised.”

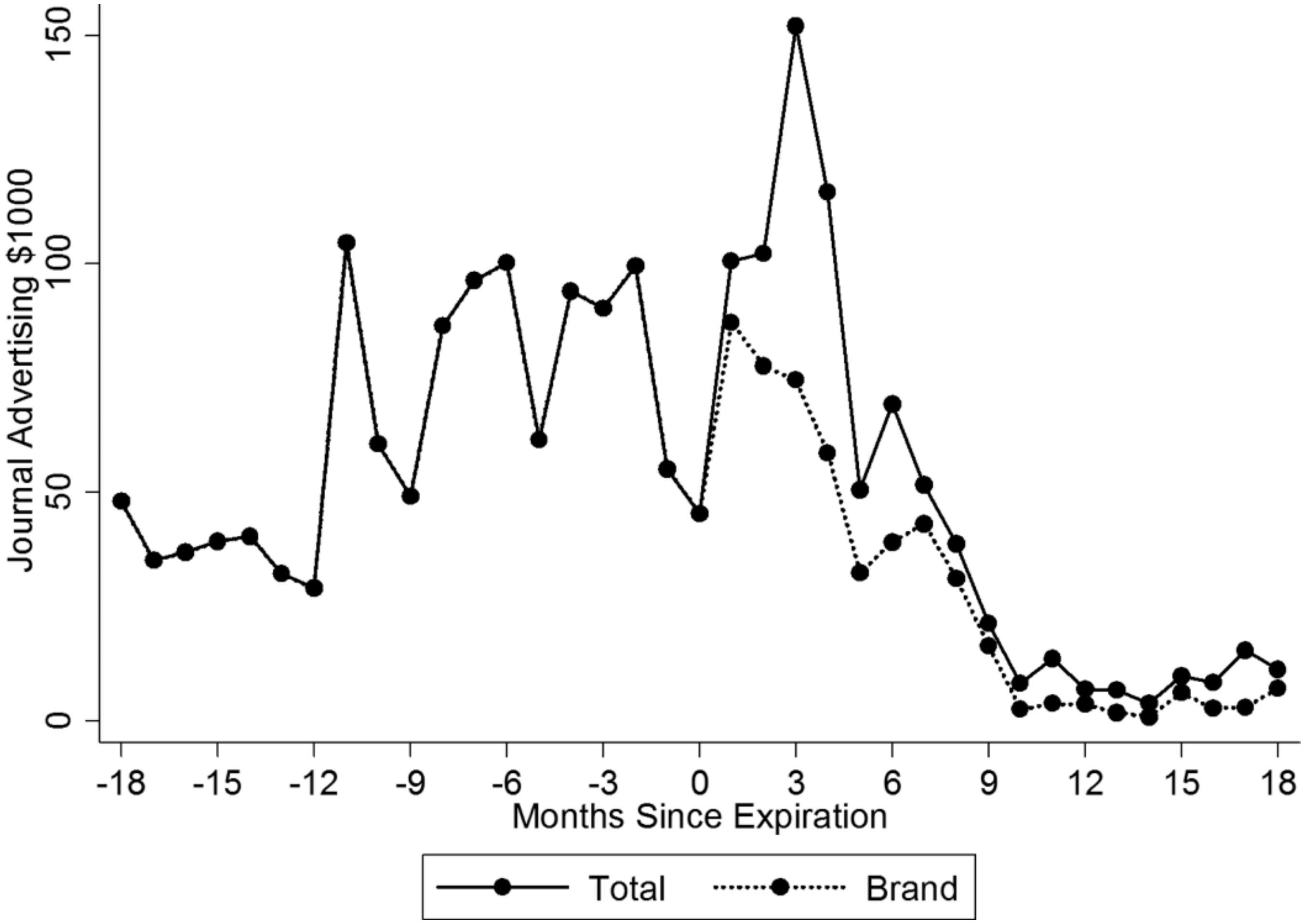

Figure 8.

Mean monthly spending on journal advertising.

Source: IMS Generic Spectra database. Graph shows journal advertisement spending for the average molecule and the average branded molecule.

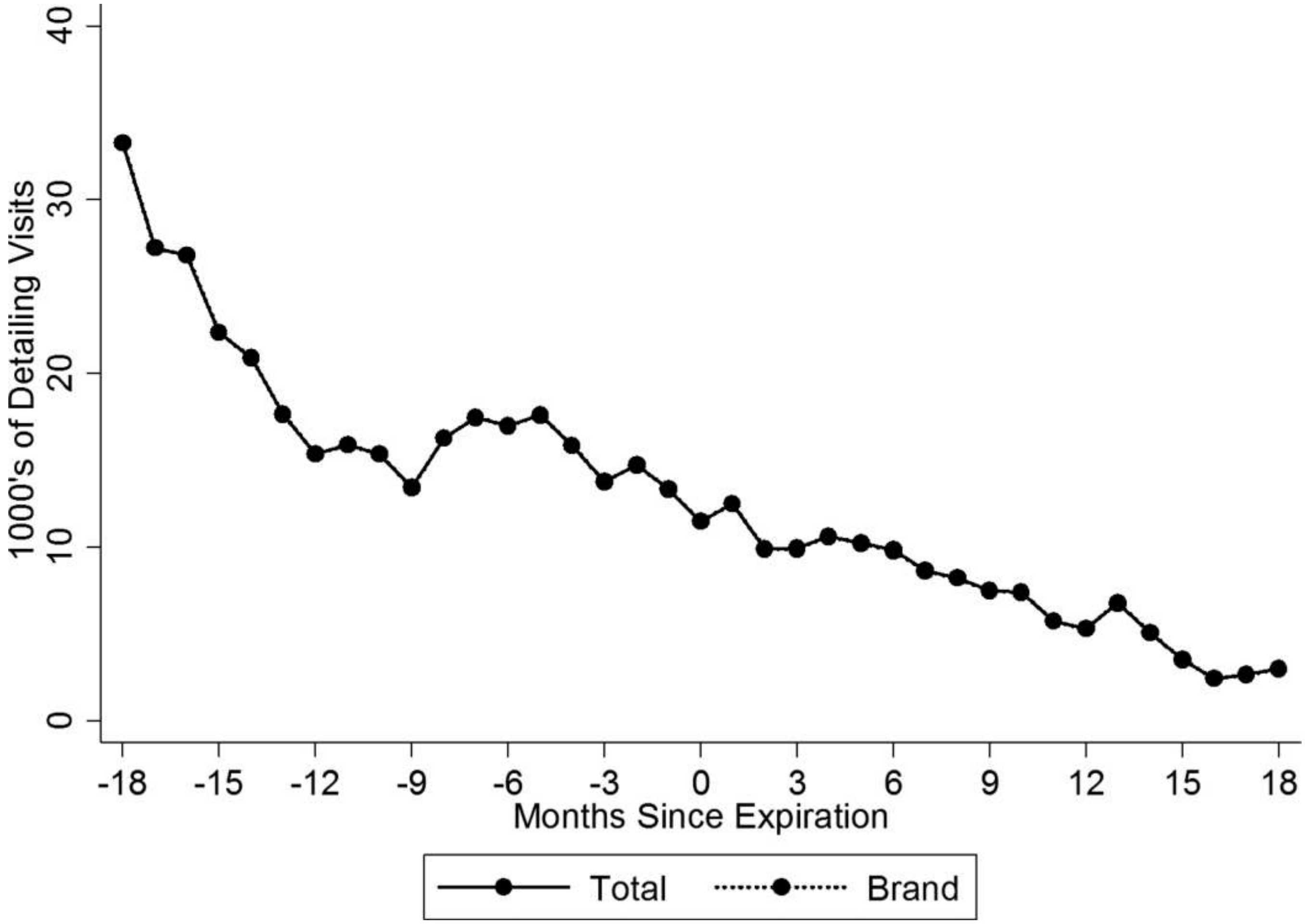

Figure 9.

Mean monthly visits by pharmaceutical company representatives.

Source: IMS Generic Spectra database. Graph shows the number of detailing visits for the average molecule and the average branded molecule.

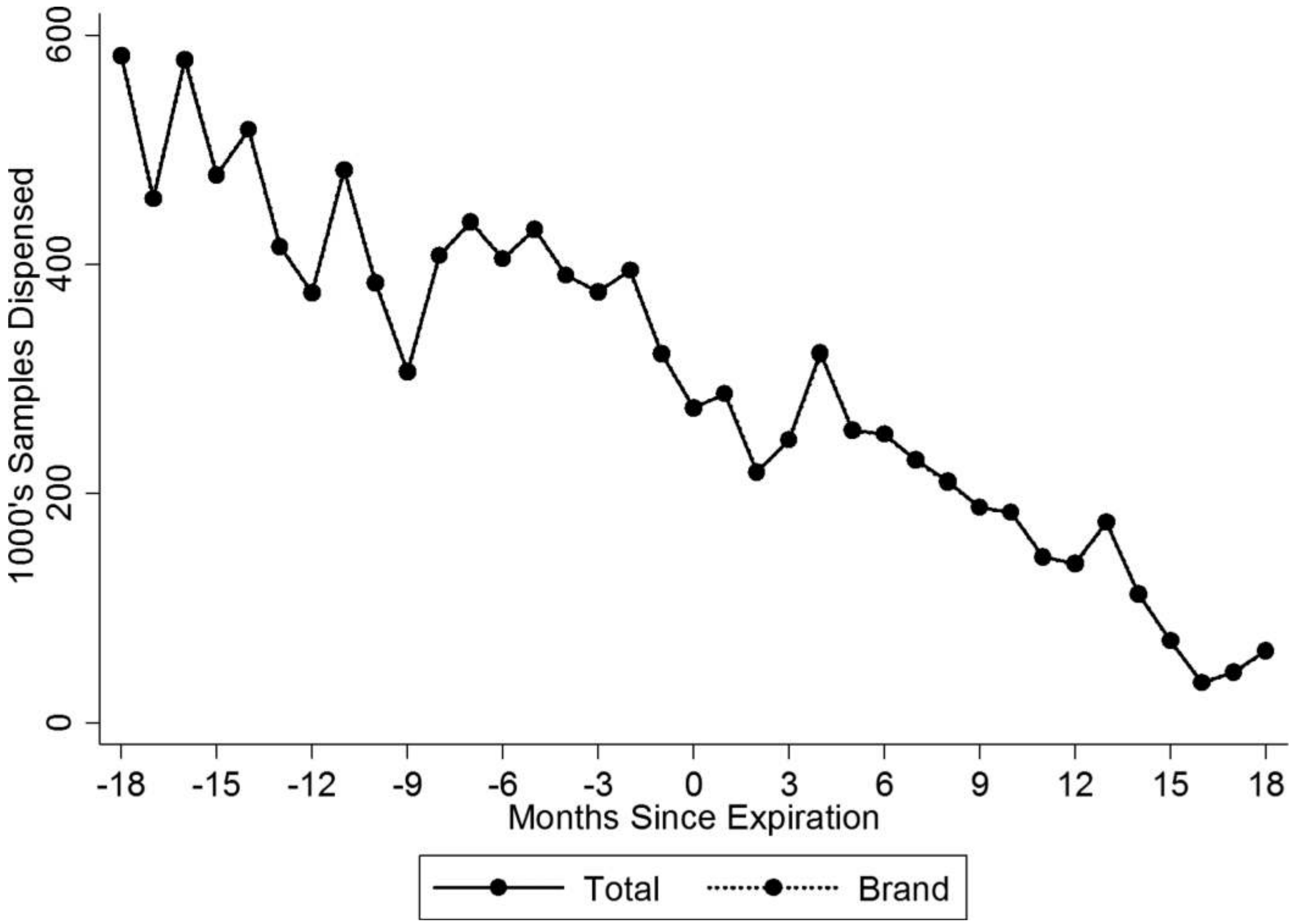

Figure 10.
Mean monthly samples dispensed by pharmaceutical company
Source: IMS Generic Spectra database. Graph shows the number of samples dispensed monthly, for the average molecule and the average branded molecule.

Table 1

Monthly Molecule-Level Variables Available in IMS

Variable	Definition
Quantity	Grams of the drug sold by retailers
Price	Revenues[1] divided by grams sold
Journal Advertising	Total cost of journal advertising space
Detailing Visits	Visits by pharmaceutical rep's to physicians
Samples	Number of drug samples dispensed to physicians
Generic Competitors	Number of competing producers of the molecule

Note: All variables are available monthly, 36 months prior to and since expiration. All data are taken from the IMS Generic Spectra database, except for "Generic Competitors," which comes from the MIDAS database.

[1]Revenues are collected for both retail and hospital channels and converted to reflect ex-manufacturer prices and quantities. No adjustments are made for confidential rebates to health plans.

Table 2

Types of molecules represented in IMS Generic Spectra Database.

	Number of Drugs		
2-digit USC Category	**Not Fully Advertised**	**Fully Advertised**	**TOTAL**
Analgesics		4	4
Anesthetics	2		2
Anti-arthritics		7	7
Hemostat modifiers		2	2
Antihistamines		1	1
Anti-infectives	2	3	5
Anti-malarials		1	1
Neurological Treatments	2	4	6
Gastro-Intestinal Drugs		6	6
Bile Therapy		1	1
Beta-Blockers		2	2
Cardiac Agents	2	4	6
Anti-neoplasm	3	3	6
Ace-Inhibitors	2	14	16
Anti-hyperlipidemic		3	3
Anti-Fungal Agents		2	2
Diabetes Therapy		3	3
Diuretics	1	1	2
Hormones	1	2	3
Musculoskeletal	2	1	3
Opthalmic		3	3
Psychotherapeutics	4	6	10
Sedatives		2	2
Tuberculosis Therapy	1		1
Anti-viral		2	
Immunologic		2	
TOTAL	22	79	101

Notes: "Fully advertised drugs" have, at some point in their lifespan, nonzero advertising in each of the three advertising categories: journal advertising, detailing visits, and samples.

Table 3

Effect of patent expiration on own-molecule, competitor molecules, and entire class.

	Molecule-Level	Class-Level	Rest of Class
Dependent variable: ln(price)			
Patent expired for: 1 month	−0.020 (0.009)**	−0.016 (0.023)	0.160 (0.161)
5 months	−0.079 (0.018)***	−0.022 (0.016)	−0.071 (0.103)
Observations	4063	6097	3766
Dependent variable: ln(samples)			
Patent expired for: 1 month	0.010 (0.155)	−0.012 (0.084)	−0.044 (0.087)
5 months	−0.342 (0.155)**	−0.079 (0.080)	0.040 (0.072)
Observations	3313	5066	4487
Dependent variable: ln(visits)			
Patent expired for: 1 month	−0.166 (0.097)*	−0.038 (0.080)	0.073 (0.095)
5 months	−0.188 (0.100)*	−0.124 (0.062)**	−0.024 (0.055)
Observations	4562	5912	5363
Dependent variable: ln(journal)			
Patent expired for: 1 month	0.192 (0.169)	0.133 (0.092)	0.006 (0.093)
5 months	−0.433 (0.131)***	−0.131 (0.075)*	0.026 (0.083)
Observations	2364	5173	4529

Notes: Robust standard errors in parentheses. "Class-level" regressions measure quantities in the same 5-digit USC therapeutic class as the molecule with the expiring patents. "Rest of class" regressions measure class-level quantities minus the molecule itself.

* significant at 10%;

** significant at 5%;

*** significant at 1%

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Table 4

Estimated Demand Elasticities for Drugs, with "Naïve" Model of Advertising.

	Model 1		Model 2		Model 3		Model 4	
	In(price)	**In(grams)**	**In(price)**	**In(grams)**	**In(price)**	**In(grams)**	**In(price)**	**In(grams)**
Expired for 1 month	−0.063 (0.020)***		−0.065 (0.020)***		−0.096 (0.020)***		−0.094 (0.020)***	
log total price (revenues/ gram)		−1.501 (0.558)***		−1.467 (0.534)***		−1.018 (0.387)***		−1.041 (0.399)***
Log total samples dispensed	0.062 (0.003)***	0.130 (0.035)***	0.061 (0.003)***	0.126 (0.033)***	0.031 (0.005)***	0.051 (0.015)***	0.028 (0.005)***	0.049 (0.014)***
Log total detailing visits					0.049 (0.008)***	0.077 (0.024)***	0.051 (0.007)***	0.079 (0.025)***
Log total journal advertising					0.036 (0.004)***	0.038 (0.016)**	0.035 (0.004)***	0.038 (0.016)**
Time Trend	Cubic in Month		Quartic in Month		Cubic in Month		Quartic in Month	
Observations	2276	2276	2276	2276	1034	1034	1034	1034

Notes: Table reports 3-stage least squares coefficients and standard errors using dummies for 1 month since expiration as an instrument for In(price). All equations include molecule-specific fixed-effects.

* significant at 10%;

** significant at 5%;

*** significant at 1%

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Table 5

Joint Effects of Price and Advertising on Pharmaceutical Demand

	Model 1			Model 2		
	In(price)	In(samples)	In(grams)	In(price)	In(samples)	In(grams)
Expired for 1 month	−0.015 (0.023)	0.313 (0.133)**		−0.027 (0.023)	0.257 (0.134)*	
Expired for 5 month	−0.131 (0.023)***	−0.566 (0.132)***		−0.100 (0.024)***	−0.417 (0.139)***	
log total price (sales/gram)			−1.004 (0.480)**			−0.937 (0.530)*
Log total samples			0.318 (0.117)***			0.360 (0.142)**
Time Trend		Cubic in Month			Quartic in Month	
Cragg-Donald stat (size)		3.95 (20%)			3.241 (>25%)	
Stock-Wright stat (p-value)		16.7(0.0002)			15.06(0.0005)	
Observations	2276	2276	2276	2276	2276	2276
Short-run cost of quantity restriction ($/month)		$2,400,000			$1,900,000	
Long-run cost of quantity restriction ($/month)		$12,700,000			$12,700,000	
Informational Advertising:						
Short-run patent cost ($/month)		−$1,000,000			−$1,200,000	
Long-run patent cost ($/month)		$9,500,000			$8,300,000	
Value to consumers of monopoly marketing (% of revenue)		20%			25%	
Persuasive Advertisina:						
Short-run patent cost ($/month)		−$1,000,000			−$1,200,000	
Long-run patent cost ($/month)		$8,800,000			$8,100,000	
Value to consumers of monopoly marketing (% of revenue)		22%			26%	

Notes: Table reports 3-stage least squares coefficients and standard errors using dummies for months since expiration as instruments for In(price) and ln(samples). All equations include molecule-specific fixed-effects. Costs of quantity restriction represents the cost of monopoly restrictions on quantity alone. Patent costs measure the total welfare impact of patents under alternative views of advertising. The short-run is a 5-month period, while the long-run assumes that, under competition, advertising goes to zero and prices go to marginal cost.

* significant at 10%;

** significant at 5%;

*** significant at 1%

Table 6

Effect of price and marketing on class-level quantity.

	In(price)	In(samples)	In(grams)	In(price)	In(samples)	In(grams)
Expired for 1 months	−0.059 (0.031)*	−0.003 (0.112)		0.267 (0.101)***	0.298 (0.143)**	
Expired for 5 months	−0.029 (0.033)	−0.366 (0.121)***		0.015 (0.104)	−0.431 (0.146)***	
Log total samples of molecule			0.209 (0.123)*			−0.055 (0.455)
Log class-level price						−0.464 (0.721)
Log price in rest of class			−1.348 (0.577)**			
Time Trend		Quartic in month			Quartic in month	
Cragg-Donald stat (size)		1.702 (>25%)			3.236 (>25%)	
Stock-Wright stat (p-value)		3.25 (0.20)			0.516(0.773)	
Observations	3217	3217	3217	2024	2024	2024

Notes: All models include molecule-specific fixed-effects. 3-stage least squares standard errors appear in parentheses. Class-level price is defined as total dollar sales per grams sold in the class, and "samples" is monthly samples dispensed for the molecule.

* significant at 10%;

** significant at 5%;

*** significant at 1%

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Table 7

Robustness of demand analyses to dynamics of patent expiration effects.

	In(price)	In(samp)	In(gram)	In(price)	In(samp)	In(gram)	In(price)	In(samp)	In(gram)
Expired for 1 months	0.041 (0.036)	0.395 (0.209)*		0.019 (0.027)	0.394 (0.160)**		0.001 (0.024)	0.331 (0.142)**	
Expired for 2 months	−0.120 (0.036)***	−0.319 (0.209)							
Expired for 3 months				−0.121 (0.028)***	−0.413 (0.161)**				
Expired for 4 months							−0.127 (0.024)***	−0.426 (0.141)***	
log total price (sales/ gram)			−0.817 (0.544)			−0.837 (0.529)			−0.802 (0.530)
Log total samples			0.390 (0.206)*			0.382 (0.163)**			0.395 (0.163)**
Time Trend		Cubic in Month			Cubic in Month			Cubic in Month	
Cragg-Donald stat (size)		1.71 (>25%)			2.82 (>25%)			2.99 (>25%)	
Stock-Wright stat (p-val)		14.02 (0.0009)			16.4 (0.0003)			18.6 (0.00009)	
Observations	2276	2276	2276	2276	2276	2276	2276	2276	2276
Short-run cost of quantity restriction ($/ month)		$2,300,000			$3,100,000			$3,500,000	
Long-run cost of quantity restriction ($/ month)		$12,900,000			$17,100,000			$18,700,000	
Informational Advertising:									
Short-run patent cost ($/ month)		−$700,000			−$1,900,000			−$2,600,000	
Long-run patent cost ($/ month)		$7,100,000			$9,900,000			$10,000,000	
Value to consumers of monopoly marketing (% of revenue)		35%			32%			36%	
Persuasive Advertising:									
Short-run patent cost ($/ month)		−$700,000			−$1,900,000			−$2,600,000	
Long-run patent cost ($/ month)		$7,100,000			$9,800,000			$9,900,000	
Value to consumers of monopoly marketing (% of revenue)		35%			33%			37%	

Notes: Table reports 3-stage least squares coefficients and standard errors using dummies for months since expiration as instruments for In(price) and ln(samples). All equations include molecule-specific fixed-effects. Costs of quantity restriction represent the gains to consumers from the short-run and long-run reductions in price resulting from patent expiration. Costs of patents represent the short-run and long-run gains to consumers from patent expiration, which includes the reductions in both price and advertising effort.

* significant at 10%;

** significant at 5%;

*** significant at 1%