INTELLECTUAL PROPERTY AND MARKETING

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## ABSTRACT

Patent protection spurs innovation by raising the rewards for research, but it usually results in less
desirable allocations after the innovation has been discovered. In effect, patents reward inventors with
inefficient monopoly power. However, previous analysis of intellectual property has focused only
on the costs patents impose by restricting price-competition. We analyze the potentially important
but overlooked role played by competition on dimensions other than price. Compared to a patent monopoly,
competitive firms may engage in inefficient levels of non-price competition -- such as marketing --
when these activities confer benefits on competitors. Patent monopolies may thus price less efficiently,
but market more efficiently than competitive firms. We measure the empirical importance of this issue,
using patent-expiration data for the US pharmaceutical industry from 1990 to 2003. Contrary to what
is predicted by price competition alone, we find that patent expirations actually have a negative effect
on output for the first year after expiration. This results from the reduction in marketing effort, which
offsets the reduction in price. The short-run decline in output costs consumers at least $400,000 per
month, for each drug. In the long-run, however, expirations do raise output, but the value of expiration
to consumers is about 15% lower than would be predicted by a model that considers price-competition
alone, without marketing effort. The non-standard effects introduced by non-price competition alter
the analysis of patents' welfare effects.

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## 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 classical theory (cf, Nordhaus, 1969), the additional research and development (R&D) induced by a patent must be weighed against the output loss from monopoly. This implies that patent expirations always lead to increased competition, lower prices, and higher market output. However, Figure 1 suggests that the predicted reductions in output do not always materialize. 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 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 a change in price-competition alone, and consequently more to the welfare effects of intellectual property (IP) protection. We argue that the standard price-competition theory of IP must be extended to include non-price competition, which may induce monopolists to provide more or less quantity than competitive firms. 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. All these types of non-price competition can change the efficiency impact of IP regulations.

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[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.

1

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. For example, patent expirations decrease returns to marketing by each individual firm. As a result, they can actually reduce output, if they decrease marketing effort by enough to offset the impact of price reductions. Therefore, unlike the standard theory of price-competition effects, a theory of non-price competition implies that patent expiration has ambiguous effects on *static* welfare. Moreover, output growth may not always be a good indicator of welfare gains from patent expiration. If advertising is of value to consumers, overall welfare may be lower under competition, even though output is higher.

To assess the quantitative importance of the theory, we estimate the impact of marketing on welfare using patent expirations in the US pharmaceuticals market, between 1990 and 2003. The drug 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.[2] By comparison, about 2% and 3% of US GDP are allocated to advertising and R&D, respectively.

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 (one-year), output falls after patent expiration, because the reduction in advertising more than offsets the reduction in price. During this short-run period, consumers are estimated to lose at least $400,000 of welfare each month, for each drug whose

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[2] 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.

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 15%.

Our project integrates a great deal of work that has separately considered advertising and intellectual property. Kaldor (1949) provides a seminal analysis of advertising, along both positive and normative dimensions. Dixit and Norman (1978) and Telser (1962) provide an initial discussion of the meta-preference approach to welfare analysis of advertising developed formally and systematically by Becker and Murphy (1996). There are also summary treatments of advertising in Tirole (1988), Shapiro (1982), Schmalensee (1996), and Bagwell (2005). Several papers have studied the unique aspects of pharmaceutical advertising: Rosenthal et al (2002) study direct-to-consumer advertising, while Bhattacharya and Vogt (2003) provide an interesting analysis of how brand loyalty and patent incentives explain time-series patterns in drug pricing and provision. 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, including: Nordhaus (1969), Loury (1979), Wright (1983), Judd (1985), Gilbert and Shapiro (1990), Klemperer (1990), Horstman et al (1993), Gallini (1992), Green and Scotchmer (1995), and Scotchmer (2004). 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

welfare. Section C estimates demand as a function of price and advertising, and uses these estimates to infer changes in consumer surplus from patent expiration. Section D concludes.

## B. Non-Price Competition and Intellectual Property

This section analyzes the positive and normative effects of intellectual property, accounting for its effects on both price and marketing, which resembles other types of non-price competition in its effects on static welfare.

### 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 $\tau$ years is then given by:

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

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

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

where $\pi_M$ 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 investments $r$. The privately optimal R&D associated with a patent of length $\tau$ maximizes expected profits:

$$r(\tau) = \arg\max_r m(r)\pi(\tau) - r \tag{1}$$

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

$$ES(\tau) = m(r(\tau))(W(\tau)) - r(\tau) \tag{2}$$

4

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

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

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, $r_\tau$, times 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

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

where $S_M$ and $S_C$ are consumer surplus under monopoly and competition, respectively. As we now show, introducing non-price competition into this problem may reverse the standard welfare conclusions about patents, because it is no longer clear that $S_C > S_M + \pi_M$.

### B.2   Quantity and Welfare Effects of Patent Expirations under Monopoly

Consider first the standard case of price-competition only. Quantity rises from the monopoly level $x_M$ to the competitive level $x_C$ and the welfare effect of patent expiration $\frac{dW}{d\tau}$ is negative, due to the deadweight loss from monopoly. In other words, patent-extension has a positive cost that needs to be weighed against its dynamic benefits.

Now consider monopoly provision under advertising, taking as a framework the canonical Dorfman-Steiner model (Dorfman and Steiner, 1954), in which profits are

5

$$\pi(a, x) = p(a, x)x - c(x) - a$$

In this model, profit-maximization implies equality between the share of revenues devoted to advertising, and the ratio between the advertising and price elasticities, as follows:

$$\frac{a_M}{px_M} = \frac{\varepsilon_a}{\varepsilon_p}$$

Defining $c^*$ as minimum average cost, this model implies the total effect of patent expiration on quantity:

$$x(a_M, p_M) - x(0, c^*)$$

After patent expiration, there is perfect competition, under which advertising has no benefit for any given firm. At this time, no advertising takes place, and pricing is cost-based. It follows that patent expiration has two offsetting effects on quantity: expiration raises quantity due to lower prices, but reduces quantity due to the reduction of advertising.

If we denote by $W(a, p)$ the welfare under a given level of advertising and price then the welfare effect of patent expiration is

$$W(a_M, p_M) - W(0, c)$$

In this model, monopoly always provides too high a price, but it may provide a higher and more efficient level of advertising. This is consistent with the empirical evidence, which suggests that competitive drug manufacturers invest virtually nothing in marketing. In this case, patent expiration has offsetting effects on social efficiency, and the welfare effect of patent expiration becomes indeterminate. If the under-provision of advertising outweighs the price increase of monopoly, then $S_M + \pi_M > S_C$. If this is true for all points in time, patents are costless, and optimal patent length is infinite. Moreover, welfare effects from IP cannot be determined by

quantity changes alone. Given price-competition alone, output growth after patent expiration is a necessary and sufficient condition for a gain in static welfare. However, the introduction of non-price competition breaks the equivalence in sign between output changes and welfare changes. Though expirations always lower profits, the effects of expirations on consumer surplus are more difficult to characterize generally, and will depend on the nature and function of advertising, as we discuss below.

### B.2.1 *Advertising as Information*

We first consider the consumer welfare effects of patents when advertising confers no direct utility upon consumers, but provides only information about a product. In this case, advertising does not affect the true value of a good to consumers, but it does affect its perceived value. Let $p(x,a)$ represent 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 — that is, social surplus evaluated at the true, fully informed demand curve. We can define this as $\Delta_{NC}$, according to:

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

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:

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

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:

$$\tilde{\Delta}_{NC} \equiv S_C - S_M = \int_{x_M}^{x_C} p(q, a_M) dq - (p_C x_C - p_M x_M) \tag{5}$$

$\tilde{\Delta}_{NC} \leq \Delta_{NC}$ if and only if patent expiration raises quantity. This allows us to infer the direction of change in consumer welfare from our estimator.

1. Suppose $\tilde{\Delta}_{NC} < 0$. This implies that $x_C < x_M$. Therefore, $0 > \tilde{\Delta}_{NC} \geq \Delta_{NC}$.

2. Suppose $\tilde{\Delta}_{NC} > 0$. This implies $x_C > x_M$, and $0 < \tilde{\Delta}_{NC} \leq \Delta_{NC}$.

### B.2.2 *Advertising as Consumption*

When advertising confers utility directly, the consumer welfare effect of patent expiration satisfies

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

Consider the case when a monopoly advertises more but at higher prices:

$$a_M \geq a_C, p_M \geq p_C \tag{6}$$

Under these conditions, it is possible that 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. If the welfare cost of reduced advertising exceeds the gain from extra output, ex post welfare can fall with patent expiration. On the other hand though, it continues to be true that a reduction in output signals a reduction in (gross) ex post welfare, because advertising always falls with patent expiration. Output growth is therefore a *necessary*, but not *sufficient*, condition for a welfare gain.

8

These results can be easily illustrated by Figure 2, 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. Note that region G exists only if output rises with the reduction in advertising and price. Therefore, if output contracts upon expiration, welfare is always decreased. If output expands, 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 raised by marketing and similar forms of non-price competition 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 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 the pricing inefficiencies that arise because the monopolist cannot price-discriminate, and thus lower the marginal cost of patent extension. Discriminatory advertising may lower or even remove the dead-weight losses associated with patent monopolies.

### B.3 Quantity and Welfare Effects of Patent Expirations under Oligopoly Competition

The previous analysis assumed that patent expirations do not affect the prices for other goods, as would be the case when other markets are competitive. This section analyzes the alternative case,

where other markets may fail to be competitive. In this case, patent expiration can affect the prices, quantities, and marketing of other, related goods.

### B.3.1 *Positive Implications of Oligopoly*

Consider imperfect competition between patented products, commonly referred to as "therapeutic competition" for drugs. This type of imperfect competition represents an alternative explanation for small or zero changes in quantity upon patent expiration.

More precisely, consider demand functions $x_E(p_E, p_N)$ and $x_N(p_E, p_N)$ for the expiring and non-expiring goods as determined by their two prices. Adopt the conventional assumption that prices are strategic complements of the two firms, in the sense that the best-response functions $p_E(p_N)$ and $p_N(p_E)$ are monotonically increasing, as shown in Figure 3.

The figure shows the two upward sloping best-response functions of the firms. The intersection is the Nash-equilibrium $(p_N^*, p_E^*)$ prior to expiration.[3] The horizontal function at marginal cost represents the price of the expired good in a competitive market after the patent has expired. After expiration, competition forces the price to marginal cost, regardless of the other firm's behavior. It follows that the Nash equilibrium moves to $(p_N(c), c))$ after expiration. The strategic complementarity of prices implies that when one price falls due to a patent expiration, then the price of the non-expired good will fall as well. More precisely, the effect of expiration on the quantity of the expired good is

$$x_E(p_N^*, p_E^*) - x_E(p_N(c), c)$$

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[3] Substitutability is *necessary but not sufficient* for a lack of price response on the non-expiring drug. A counter example to sufficiency is when demand is of constant elasticity, as in $x_N = A*(p_N^*)^e (p_E^*)^{e'}$. In that case, the other price shifts the demand curve but does not affect the elasticity so that the optimal price is the same. Best response functions are vertical and horizontal lines in pricing space of Figure 3 and hence the price of the non-expired drug does not change at expiration.

Strategic complementarity limits the quantity response in the expired good, because the price of the substitute good falls as well. Non-competitive markets for substitutes could thus represent an alternative explanation of minimal quantity responses to patent expiration. In the extreme case of perfect substitutes, competing goods would have to come down in price to the expired good in order to be demanded in equilibrium. In that case, only prices would change, and quantities would remain unchanged.

The oligopoly model can be distinguished from the competing explanation of pure monopoly with advertising. First, the oligopoly model implies that patent expiration always raises quantity, but monopoly advertising implies that quantity may even fall with expiration, if marketing falls by enough. Second, oligopoly implies that patent expiration will affect the price and marketing effort of firms producing substitutable products. As discussed below in our empirical analysis, we find evidence that pharmaceutical patent expiration sometimes lowers quantity, even over very short time-horizons where demand is likely to be fixed. Second, we find little evidence that expiration of one patent affects the price and marketing behavior of competing firms. Both these facts suggest that marketing may represent a more viable explanation than oligopoly in the market for pharmaceuticals, even though it does not rule out oligopoly as an important theory in other contexts.

### B.3.2 *Normative Implications of Oligopoly*

The welfare implications of oligopoly also differ somewhat from monopoly with advertising. In the canonical case of pure monopoly, the welfare effects of patent expiration depended only on the reduction in price of the expiring good. Under oligopoly, the welfare effect also depends on the reduction in price of the non-expiring good. For instance, abstracting from marketing effects, the welfare impact of patent expiration is given by $W(p_N^*, p_E^*) - W(p_N(c), c)$.

Incorporating marketing creates additional links: the welfare effects of patent expiration depend on the marketing efforts of the expiring firm *and* those of its non-expiring competitor. The nature of this relationship depends on whether advertising is more or less efficient under competition. Above, we developed the case where advertising is less efficient under perfect competition than under a patent monopoly. An alternative, and often-considered case, is one in which incomplete competition results in excessive advertising. Firms with patent monopolies on therapeutic substitutes, for instance, may engage in wasteful advertising designed to steal market share from their competitors. Patent expiration would eliminate this incentive, since firms would no longer be able to capture the returns on their advertising efforts. In this case, patent expiration makes advertising more efficient.[4]

## C. Empirical Analysis

This section investigates the empirical impact of non-price competition on consumer welfare, in the context of marketing in the pharmaceutical industry. 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 (Kaiser Family Foundation, 2003). In this particular case, advertising is unlikely to have direct utility benefits for consumers and is more likely to be purely informative. As a result, we operate under the model presented in Section B.2.1.

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[4] The opposite might be true if patent expiration moves the market from monopoly to oligopoly. This would be true in the absence of therapeutic substitutes, but the presence of non-patent entry barriers that preclude perfect competition after expiration.

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:

$$\ln x_{it} = \beta_0 + \beta_1 \ln p_{it} + \beta_2 \ln a_{it} + \phi_i + M(t) + \varepsilon_{it} \tag{7}$$

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, $\phi_i$ 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.2.1. Consider first the case without advertising, where $\beta_2 = 0$, and the empirical demand curve is exactly equal to consumer's true valuations. The change in consumer surplus is defined by:

$$\Delta \equiv \left\{ \int_{x_m}^{x_c} p(q)dq - \left( p_C x_C - p_M x_M \right) \right\} \tag{8}$$

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

13

$$\Delta = \exp\left(\frac{-\beta_0 - \phi_i - M(t=-1)}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left(x_C^{1+\frac{1}{\beta_1}} - x_M^{1+\frac{1}{\beta_1}}\right) - \left[p_C^* x_C - p_M^* x_M\right] \qquad (9)$$

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.

Short-run consumer surplus is the gain that accrues from the increase in quantity observed in the first few months immediately following patent expiration. The term $x_C$ is thus defined as competitive quantity immediately after expiration.

Long-run consumer surplus, on the other hand, is the total gain that would accrue if the patent were never in place. Since long-run competitive quantity is unobserved, 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 relevant case of purely informative advertising, the true expected change in consumer surplus is given by:

$$\Delta_{NC} = \left\{\int_{x_M}^{x_C} p(q)dq - \left(p_C^* x_C - p_M^* x_M\right)\right\} \qquad (10)$$

Above, we defined the conservative bound on this quantity:

$$\tilde{\Delta}_{NC} = \left\{\int_{x_M}^{x_C} p(q,a_M)dq - \left(p_C^* x_C - p_M^* x_M\right)\right\} \qquad (11)$$

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

$$\tilde{\Delta}_{NC} = \exp\left(\frac{-\beta_0 - \phi_i - M(t=-1) - \beta_2 \ln a_M}{\beta_1}\right)\left(\frac{\beta_1}{1+\beta_1}\right)\left(x_C^{1+\frac{1}{\beta_1}} - x_M^{1+\frac{1}{\beta_1}}\right) - \left[p_C x_C - p_M x_M\right] \qquad (12)$$

Finally, we can derive a measure for the value of monopoly advertising to consumers. Define as $\widetilde{\Delta}_{NC}^{adv}$ the change in consumer surplus that would occur if the patent expired, but advertising did not fall from its monopoly level. Define $x_C^{'}$ as the competitive quantity that would obtain under this counterfactual circumstance. Given these definitions, $\widetilde{\Delta}_{NC}^{adv}$ can be calculated simply by replacing $x_C$ with $x_C^{'}$ in the above expression. The value to consumers of monopoly-level advertising can then be obtained as:

$$AdvValue = \widetilde{\Delta}_{NC}^{adv} - \widetilde{\Delta}_{NC} \tag{13}$$

## C.2  Data

The IMS Generic Spectra database contains data on 101 unique molecules, whose patents expired between 1992 and 2002.[5] 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). IMS then adjusts the revenue data, using proprietary estimates of drug mark-ups, to estimate the implied wholesale revenue. The result is an estimate of 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

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[5] 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.

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.

#### 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 month 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. Over longer intervals of time, the proportion of drugs

with decreases in quantity rises, likely due to the additional effect of secular declines in the demand for a molecule.

Figure 4 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 (2003) 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 lure in 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. Moreover, while total quantity rises immediately after expiration, much of this gain disappears after the passage of three years without a patent. These trends differ from those one might expect when quantity-restriction is the only effect of monopoly, in which case prices can be expected to fall for both branded and generic drugs, and quantity can be expected to increase.

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 5 and Figure 6, 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.

The effect of monopoly on advertising incentives is one way of understanding these divergent patterns. For drugs with weak or no incentives to advertise, patent expiration eliminates the incentive to restrict quantity, but has no other effects. With advertising, however, the patent expiration has competing effects, which can lead to ambiguous changes in total market quantity.

C.3.2 *Trends in Advertising*

Figures 7, 8, and 9 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.[6] 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 expenditures (Kaiser

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[6] The IMS Generic Spectra database does not contain information on direct-to-consumer advertising, which makes up approximately 14% of total advertising spending (Kaiser Family Foundation, 2003).

Family Foundation, 2003). In contrast, journal advertising accounts for roughly 2% of spending, with detailing visits accounting for the rest.

There are two additional empirical reasons in favor of studying samples, instead of detailing visits, which are the other significant source of advertising spending. First, patent expiration has less of an impact on detailing visits for a particular molecule (perhaps due to this problem). This makes it harder to identify the effects on demand. In addition, samples dispensed are more likely to be "purely informational" than detailing visits, which also provide perquisites and gifts to individual physicians.

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.[7] 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.

### 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.

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

### 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.

To lay out this approach, consider first a formulation that treats advertising effort as

exogenous. This strategy involves estimating the following first- and second-stage equations via

instrumental variables:

$$\ln p_{it} = \alpha_0 + \alpha_1 Expired_{it} + \alpha_2 \ln(a_{it}) + \phi_i + M_p(t) + \eta_{it} \tag{14}$$

$$\ln x_{it} = \beta_0 + \beta_1 \ln p_{it} + \beta_2 \ln a_{it} + \phi_i + M_x(t) + \varepsilon_{it} \tag{15}$$

Price ($p_{it}$) is a function of advertising ($a_{it}$), a molecule fixed-effect ($\phi_i$), and a polynomial in

month ($M_p(t)$). Quantity ($x_{it}$) depends on price, advertising, a molecule fixed-effect, and a

possibly different polynomial in month ($M_x(t)$). The expiration variable identifies the break in

the polynomial trend that occurs at expiration for within-molecule 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 barriers to

entry 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:

$$\ln(p_{it}) = \alpha_0 + \alpha_1 Expired_{it} + \alpha_2 ExpiredLag_{it} + \phi_i + M_p(t) + \eta_{it} \tag{16}$$

$$\ln(a_{it}) = \delta_0 + \delta_1 Expired_{it} + \delta_2 ExpiredLag_{it} + \phi_i + M_a(t) + \eta_{it} \tag{17}$$

$$\ln(x_{it}) = \beta_0 + \beta_1 \ln(p_{it}) + \beta_2 \ln(a_{it}) + \phi_i + M_x(t) + \varepsilon_{it} \tag{18}$$

As before, $Expired_{it}$ is a dummy variable for the month immediately following expiration. $ExpiredLag$ is a dummy for the lagged effect of expiration: we consider specifications using two months, three months, four months, and five months after expiration.

### 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 quite 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, as in Section B.3. As shown in that section, 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:

$$\ln(S_{jm}) = \eta_0 + \eta_1 Expired_{im} + M_S(t) + \phi_i + \kappa_{jm} \tag{19}$$

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 $i$,[8] and $\phi_i$ 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. Overall, patent expiration affects the pricing and marketing behavior for a molecule itself, but has no discernible effects on the behavior of competitors in the rest of the therapeutic class. Moreover, the class-level effects — including the molecule itself — are smaller than the own-molecule effects, and also quantitatively consistent with the hypothesis that competitors do not respond.

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

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

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 half of one standard deviation from 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 14 and 15. 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 is equal to the inverse of the monopoly markup. In the case of drugs, the markup is approximately 80 to 90 percent, since the long-run price of generic equivalents tends to be approximately 10 to 20 percent of the brand price at the date of expiration (Grabowski and Vernon, 1992). 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.

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 falls by 80 percent. Given the likely demand elasticities, patent expiration raises quantity by more than 80 percent.

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 16, 17, and 18. 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 of 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.[9] 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% (Kaiser Family Foundation, 2003). About 75% of total revenues go to drugs that are currently on patent (Hughes, Moore, and Snyder, 2002). Assuming that marketing is negligible for generics and off-patent drugs, this implies that marketing is about 19% of revenues for the relevant drugs.

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[9] This well-known result, often referred to as the Dorfman-Steiner Theorem, follows most simply from the analysis of a static monopoly maximization problem (Dorfman and Steiner, 1954).

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 (Kaiser Family Foundation, 2003). 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.[10] 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 elasticities coupled with our rough estimates of the revenue share spent on advertising implies advertising elasticities between 0.25 and 0.29. Our estimates are slightly higher, but fairly close, and not statistically distinguishable from these crude predictions.

### 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.

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[10] We assume that each detailing visit costs $138 (Neslin, 2001). 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.

The cost of quantity-restriction is the consumer's cost of the higher prices induced by patents.[11] The overall cost of patents, on the other hand, combines this cost with the consumer value of increased output due to higher advertising.[12] Theoretically, therefore, the cost of quantity-restriction must always be positive, but the cost of patents may be positive or negative. Finally, the value of monopoly marketing is the value to consumers of the marketing induced by patents, holding price fixed.[13]

We estimate each of these quantities in the short-run and the long-run. We define the short-run as the first five months after patent expiration: 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 observations: in the long-run, competition drives price to marginal cost and advertising effort to zero. Since mark-ups in the pharmaceutical industry are 80-90%, 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 and advertising elasticities, along with the short-run impact of patent expiration on price. Our model estimates all three of these quantities. Table 5 lists the estimated change in consumer surplus associated with each model estimate.

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[11] This is given by equation 12, evaluated at the value of $x_C$ that would obtain if patent expiration had no impact on marketing effort.

[12] This is given by equation 12, evaluated at the actual competitive value of $x_C$.

[13] This is given by equation 13.

The per-molecule cost of quantity restriction to consumers is $2.1m to $2.5m in the short-run. Conceptually, this means that 5 months after patent expiration, consumers receive $2.1m of additional value per month (from one molecule) due to the reduction in price alone. This value rises to $13.3m to $14.3m 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 $13.3m of value to consumers per month. Observe that these are all monthly costs.

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 $9.5m to $10m 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 20% of total pharmaceutical spending. Earlier, we roughly estimated that firms spend about 23% of total revenues for the marketing of on-patent drugs. Therefore, the value of marketing to consumers alone — excluding the value to firms — is approximately equal to its cost.

### 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. 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 Bhattacharya and Vogt, 2003), 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.

### 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 the both the size and precision of the price elasticity estimates, most of which were statistically indistinguishable from zero. However, the advertising elasticities remained stable, as did the

28

estimated welfare effects. If anything, these specification checks yielded higher estimates for the consumer value of marketing, as a proportion of revenues. 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 only 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

Patents are generally believed by economists to be second-best methods of stimulating innovation, because they reward it with inefficient monopoly power. However, this reasoning neglects the impact of monopoly on non-price competition, of which marketing is a particularly important example. Our empirical analysis of the US pharmaceutical market suggested that considering advertising reduces the estimated long-run cost of patents by about 15%. Moreover, in the short-run, patent expirations actually harm consumers, because the reduction in output from decreased advertising to physicians is worth more than the increase in output from lower prices. We estimate that the value advertising generates for consumers justifies its cost, before even considering its value to firms. As a result of this considerable value, the costs of patents are lower than previously believed in the long-run, and may even be negative in the short-run.

The paper suggests several avenues of future research. First, our analysis can be generalized to other forms of non-price competition. If the monopoly power induced by patents has effects

beyond price-competition — and its attendant restriction in quantity —those effects may offset or reinforce the traditional costs of patents. In particular, advertising—when viewed as a complement to the good advertised—resembles quality provision more generally. Therefore, quality competition might have similar effects on the analysis of intellectual property.

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. 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.

# Appendix

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

Standard Consumer Surplus

In the text, we derived an explicit expression for standard consumer surplus, consistent with the econometric specification of the demand curve:

$$\Delta = \exp\left(\frac{-\beta_0 - \phi_i - M(t = -1) - \beta_2 \ln a_m}{\beta_1}\right)\left(\frac{\beta_1}{1 + \beta_1}\right)\left(x_{c0}^{1 + \frac{1}{\beta_1}} - x_m^{1 + \frac{1}{\beta_1}}\right) - \left[p_C x_{c0} - p_M x_m\right](20)$$

We define $x_m$ as the quantity in the last month of patent protection, at $t = -1$.[18] 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 $\alpha_1$ from the first-stage estimating equation. This leads to:

$$\begin{aligned} x_c^{short-run} &= x_m(1 + \alpha_1 \beta_1) \\ p_C^{short-run} &= p(x_c^{short-run}; a_m) \end{aligned} \tag{21}$$

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

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[18] 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.

$p_C$.  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:

$$x_c^{long-run} \equiv x_m(1 - 0.9(\beta_1))$$
$$p_C^{long-run} = p(x_c^{long-run}; a_m) \tag{22}$$

Consumer Surplus with Informational Advertising

In this case, consumer surplus can be written as:

$$\tilde{\Delta}_{NC} = \left\{ \int_{x_m}^{x_c} p(q, a_m)dq - \left( p_c x_c - p_m x_m \right) \right\} \tag{23}$$

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

$$\tilde{\Delta}_{NC} = \exp\left( \frac{-\beta_0 - \phi_i - M(t=-1) - \beta_2 \ln a_m}{\beta_1} \right)\left( \frac{\beta_1}{1+\beta_1} \right)\left( x_c^{1+\frac{1}{\beta_1}} - x_m^{1+\frac{1}{\beta_1}} \right) - \left[ p_C x_c - p_M x_m \right]$$

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:

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

(24)

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**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 expira

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**

| 2-digit USC Category | Number of Drugs | | |
| --- | --- | --- | --- |
| | 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 li
span, nonzero advertising in each of the three advertising
categories:  journal advertising, contacts, 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 | -0.016 | 0.160 |
|  | (0.009)** | (0.023) | (0.161) |
| 5 months | -0.079 | -0.022 | -0.071 |
|  | (0.018)*** | (0.016) | (0.103) |
| Observations | 4063 | 6097 | 3766 |
| **Dependent variable: ln(samples)** |  |  |  |
| Patent expired for: |  |  |  |
| 1 month | 0.010 | -0.012 | -0.044 |
|  | (0.155) | (0.084) | (0.087) |
| 5 months | -0.342 | -0.079 | 0.040 |
|  | (0.155)** | (0.080) | (0.072) |
| Observations | 3313 | 5066 | 4487 |
| **Dependent variable: ln(visits)** |  |  |  |
| Patent expired for: |  |  |  |
| 1 month | -0.166 | -0.038 | 0.073 |
|  | (0.097)* | (0.080) | (0.095) |
| 5 months | -0.188 | -0.124 | -0.024 |
|  | (0.100)* | (0.062)** | (0.055) |
| Observations | 4562 | 5912 | 5363 |
| **Dependent variable: ln(journal)** |  |  |  |
| Patent expired for: |  |  |  |
| 1 month | 0.192 | 0.133 | 0.006 |
|  | (0.169) | (0.092) | (0.093) |
| 5 months | -0.433 | -0.131 | 0.026 |
|  | (0.131)*** | (0.075)* | (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 molecul
* significant at 10%; ** significant at 5%; *** significant at 1%

**Table 4:  Estimated Demand Elasticities for Drugs.**

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|
| | ln(price) | ln(grams) | ln(price) | ln(grams) | ln(price) | ln(grams) | ln(price) | ln(grams) |
| Expired for 1 month | -0.063<br>(0.020)*** | | -0.065<br>(0.020)*** | | -0.096<br>(0.020)*** | | -0.094<br>(0.020)*** | |
| log total price (revenues/gram) | | -1.501<br>(0.558)*** | | -1.467<br>(0.534)*** | | -1.018<br>(0.387)*** | | -1.041<br>(0.399)*** |
| Log total samples dispensed | 0.062<br>(0.003)*** | 0.130<br>(0.035)*** | 0.061<br>(0.003)*** | 0.126<br>(0.033)*** | 0.031<br>(0.005)*** | 0.051<br>(0.015)*** | 0.028<br>(0.005)*** | 0.049<br>(0.014)*** |
| Log total detailing visits | | | | | 0.049<br>(0.008)*** | 0.077<br>(0.024)*** | 0.051<br>(0.007)*** | 0.079<br>(0.025)*** |
| Log total journal advertising | | | | | 0.036<br>(0.004)*** | 0.038<br>(0.016)** | 0.035<br>(0.004)*** | 0.038<br>(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 ln(price).  All equations include molecule-specific fixed-effects.
* significant at 10%; ** significant at 5%; *** significant at 1%

## Table 5: Effects of Price and Advertising on Pharmaceutical Demand

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | ln(price) | ln(samples) | ln(grams) | ln(price) | ln(samples) | ln(grams) |
| Expired for 1 month | -0.015 | 0.313 | | -0.027 | 0.257 | |
| | (0.023) | (0.133)** | | (0.023) | (0.134)* | |
| Expired for 5 months | -0.131 | -0.566 | | -0.100 | -0.417 | |
| | (0.023)*** | (0.132)*** | | (0.024)*** | (0.139)*** | |
| log total price (sales/gram) | | | -1.004 | | | -0.937 |
| | | | (0.480)** | | | (0.530)* |
| Log total samples | | | 0.318 | | | 0.360 |
| | | | (0.117)*** | | | (0.142)** |
| Time Trend | Cubic in Month | | | Quartic in Month | | |
| | | | | | | |
| Observations | 2276 | 2276 | 2276 | 2276 | 2276 | 2276 |
| Short-run cost of quantity restriction ($/month) | | $2,500,000 | | | $2,100,000 | |
| Long-run cost of quantity restriction ($/month) | | $13,300,000 | | | $14,300,000 | |
| Short-run patent cost ($/month) | | -$1,000,000 | | | $300,000 | |
| Long-run patent cost ($/month) | | $9,500,000 | | | $10,000,000 | |
| Value to consumers of monopoly marketing (% of revenue) | | 20% | | | 21% | |

Notes: Table reports 3-stage least squares coefficients and standard errors using dummies for months since expiration as instruments for ln(price) and ln(samples). All equations include molecule-specific fixed-effects. Costs of quantity restriction rep
* significant at 10%; ** significant at 5%; *** significant at 1%

**Table 6: Effect of price and marketing on class-level quantity.**

| | Therapeutic Class | | | Rest of Class | | |
|---|---|---|---|---|---|---|
| | ln(price) | ln(samples) | ln(grams) | ln(price) | ln(samples) | ln(grams) |
| Expired for 1 months | -0.059 | -0.003 | | 0.267 | 0.298 | |
| | (0.031)* | (0.112) | | (0.101)*** | (0.143)** | |
| | | | | | | |
| Expired for 5 months | -0.029 | -0.366 | | 0.015 | -0.431 | |
| | (0.033) | (0.121)*** | | (0.104) | (0.146)*** | |
| | | | | | | |
| Log total samples of molecule | | | 0.209 | | | -0.055 |
| | | | (0.123)* | | | (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 | |
| | | | | | | |
| 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 m
* significant at 10%; ** significant at 5%; *** significant at 1%

**Table 7: Robustness of demand analyses to dynamics of patent expiration effects.**

| | ln(price) | ln(samp) | ln(grams) | ln(price) | ln(samp) | ln(grams) | ln(price) | ln(samp) | ln(grams) |
|---|---|---|---|---|---|---|---|---|---|
| Expired for 1 months | 0.041 | 0.395 | | 0.019 | 0.394 | | 0.001 | 0.331 | |
| | (0.036) | (0.209)* | | (0.027) | (0.160)** | | (0.024) | (0.142)** | |
| Expired for 2 months | -0.120 | -0.319 | | | | | | | |
| | (0.036)*** | (0.209) | | | | | | | |
| Expired for 3 months | | | | -0.121 | -0.413 | | | | |
| | | | | (0.028)*** | (0.161)** | | | | |
| Expired for 4 months | | | | | | | -0.127 | -0.426 | |
| | | | | | | | (0.024)*** | (0.141)*** | |
| log total price (sales/gram) | | | -0.817 | | | -0.837 | | | -0.802 |
| | | | (0.544) | | | (0.529) | | | (0.530) |
| Log total samples | | | 0.390 | | | 0.382 | | | 0.395 |
| | | | (0.206)* | | | (0.163)** | | | (0.163)** |
| Time Trend | | Cubic in Month | | | Cubic in Month | | | Cubic in Month | |
| Observations | 2276 | 2276 | 2276 | 2276 | 2276 | 2276 | 2276 | 2276 | 2276 |
| Short-run cost of quantity restriction ($/month) | | $2,300,000 | | | $2,300,000 | | | $2,400,000 | |
| Long-run cost of quantity restriction ($/month) | | $12,900,000 | | | $12,800,000 | | | $13,000,000 | |
| Short-run patent cost ($/month) | | -$700,000 | | | -$1,400,000 | | | -$1,800,000 | |
| Long-run patent cost ($/month) | | $7,100,000 | | | $7,400,000 | | | $6,900,000 | |
| Value to consumers of monopoly marketing (% of revenue) | | 35% | | | 32% | | | 20% | |

Notes: Table reports 3-stage least squares coefficients and standard errors using dummies for months since expiration as instruments for ln(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%

**Figure 1: Distribution of quantity changes by molecule, from patent expiration to one month after expiration**
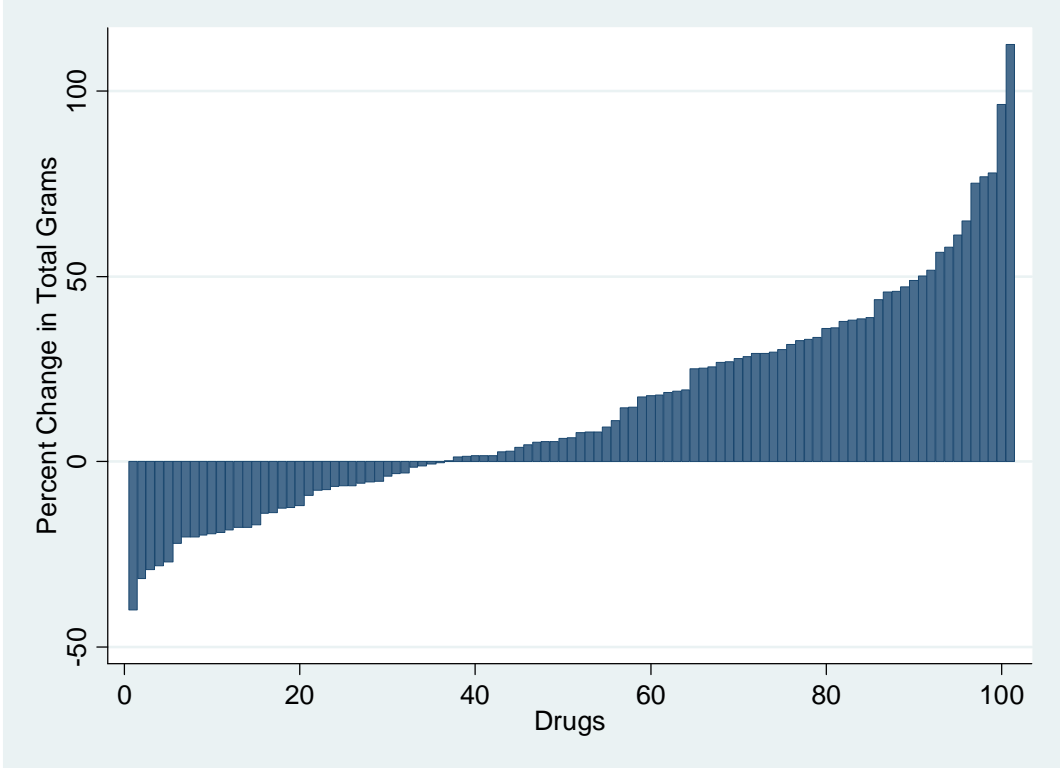
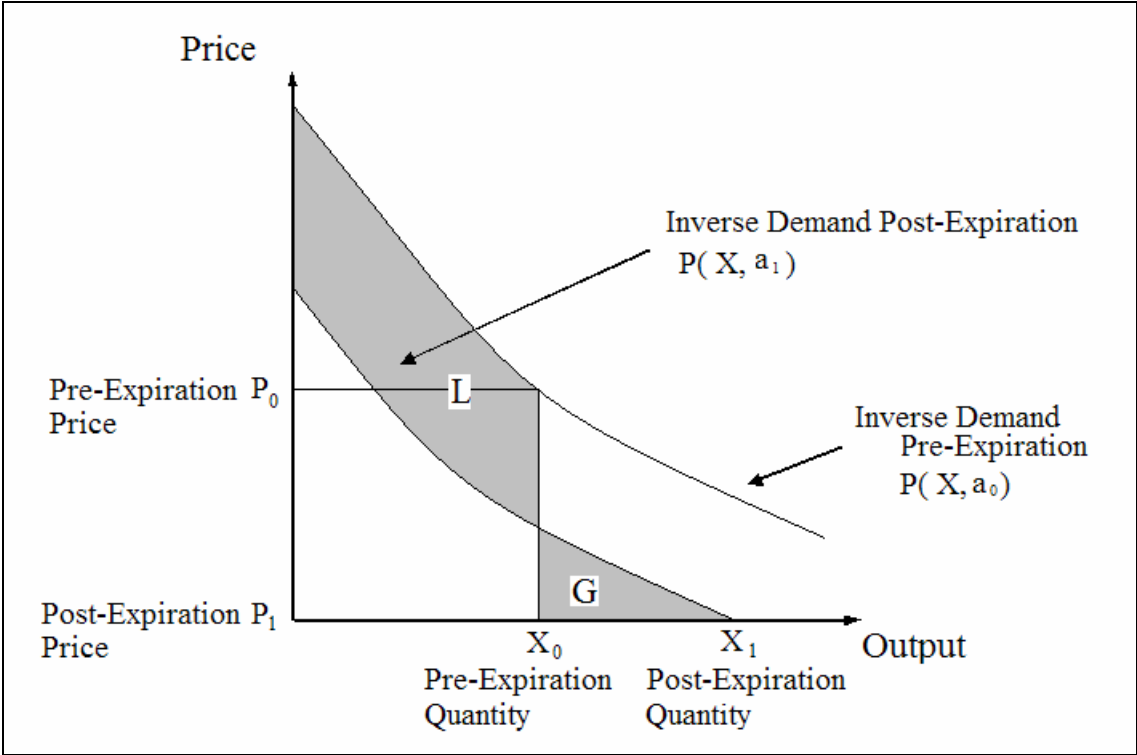**Figure 2: Gross Welfare Effects of Patent Expiration**

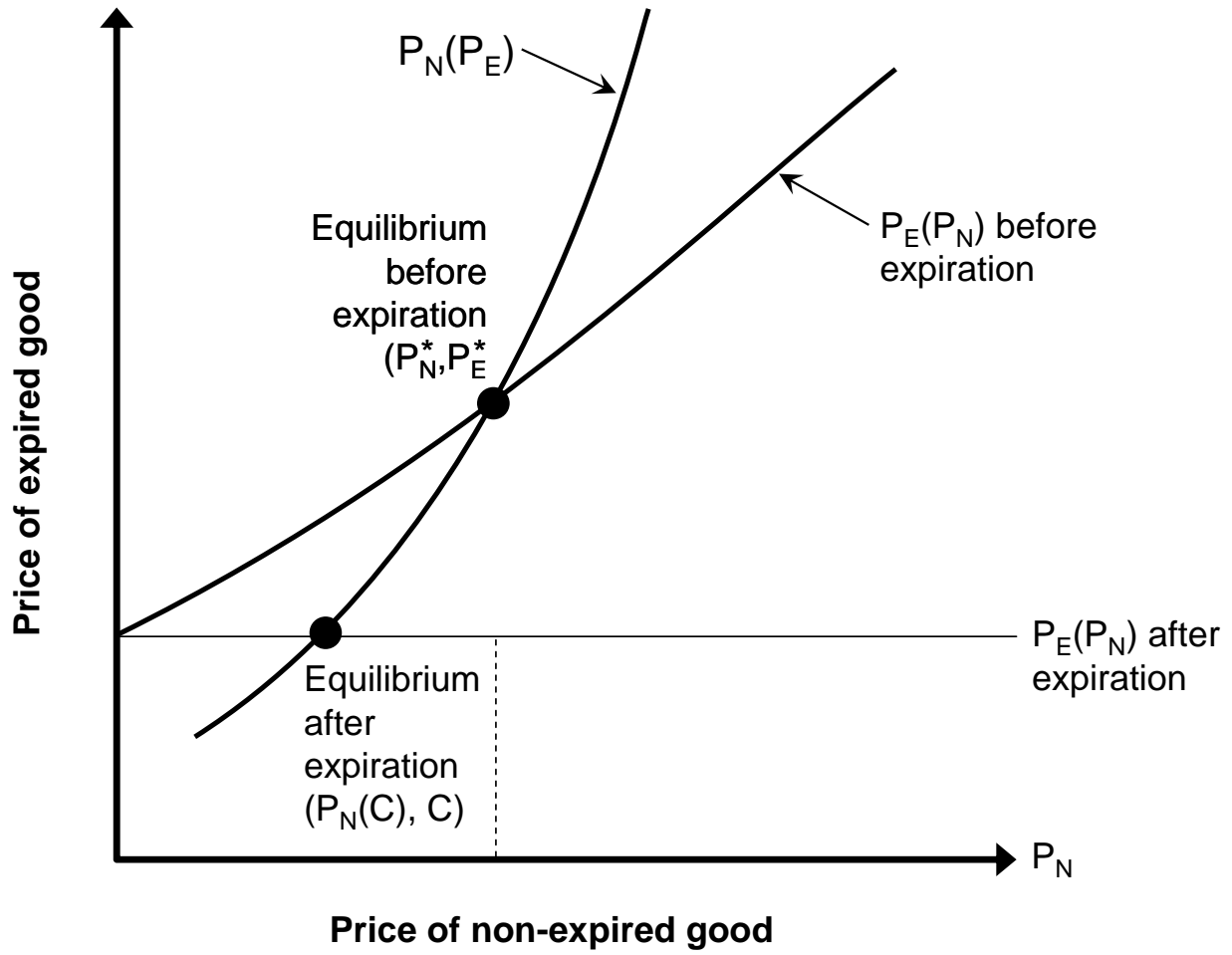**Figure 3: Pricing Before and After Expiration**



Figure 3: Pricing Before and After Expiration

$P_N(P_E)$

$P_E(P_N)$ before expiration

Equilibrium before expiration $(P_N^*, P_E^*)$

$P_E(P_N)$ after expiration

Price of expired good

Equilibrium after expiration $(P_N(C), C)$

$P_N$

**Price of non-expired good**

**Figure 4:  Trends in price and quantity for the average drug.**
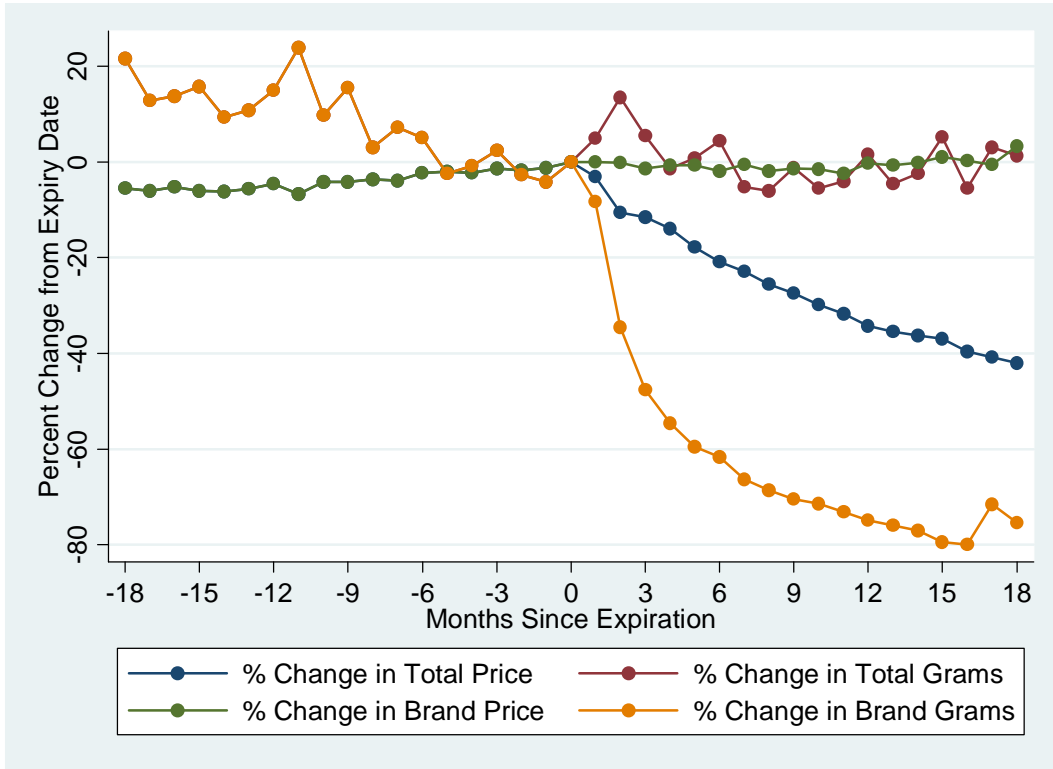
**Figure 5: Mean trends in price and quantity for fully advertised drugs.**
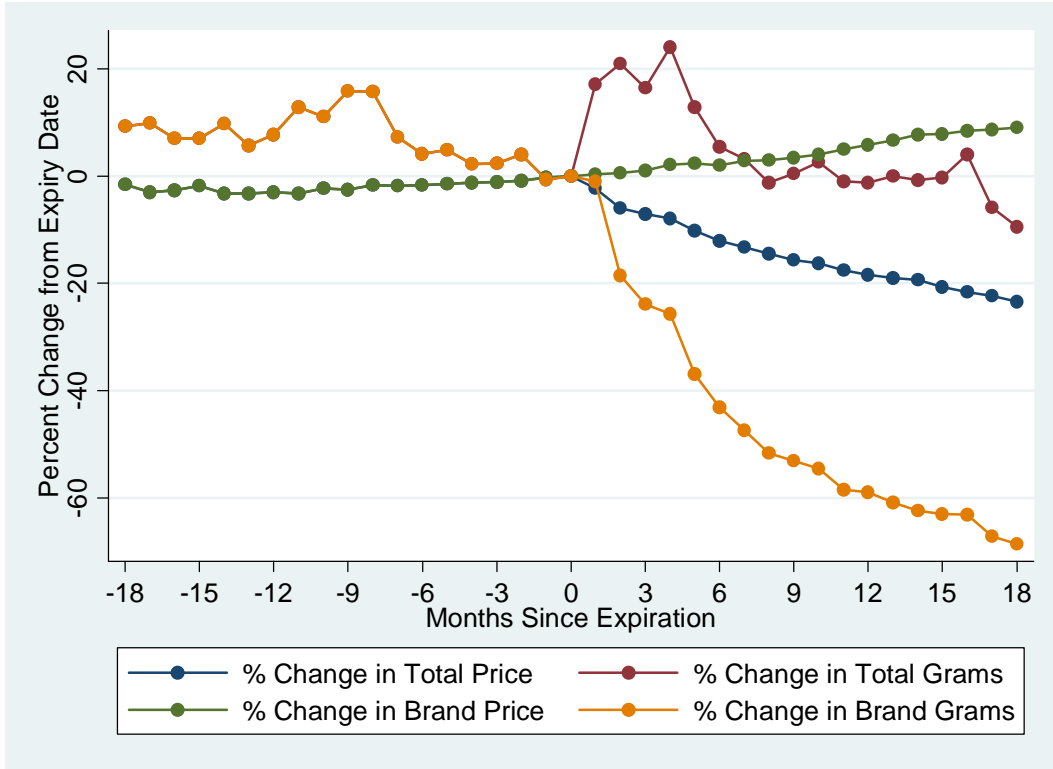
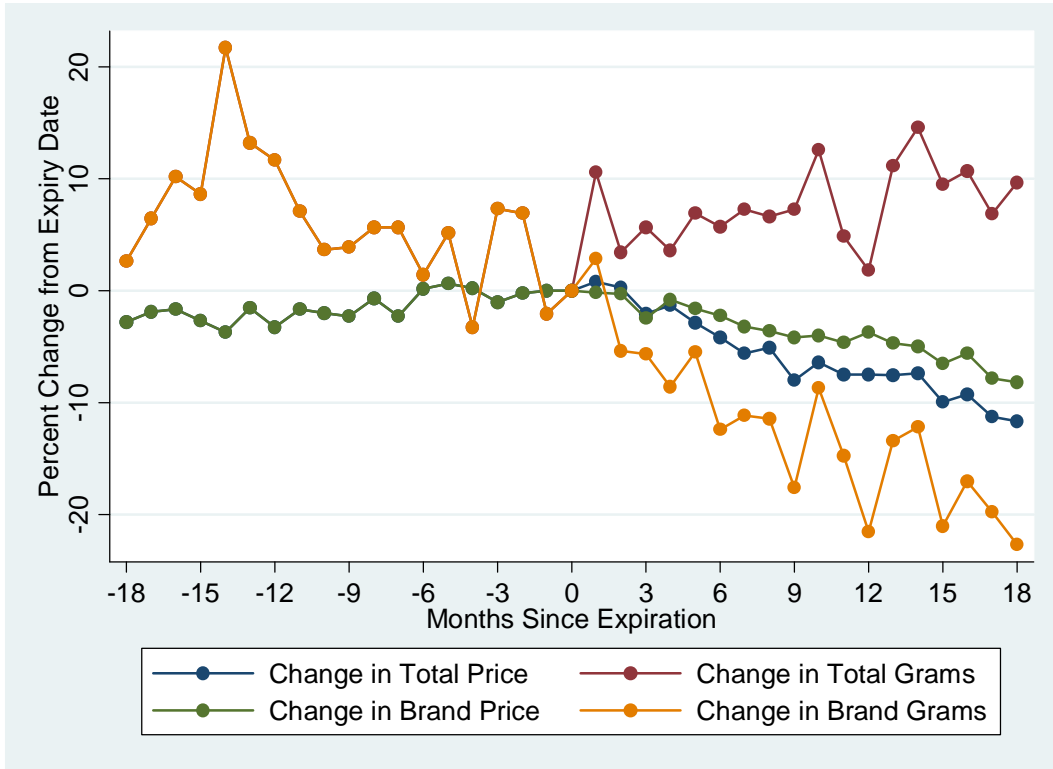**Figure 6: Mean trends in price and quantity for drugs not fully advertised.**

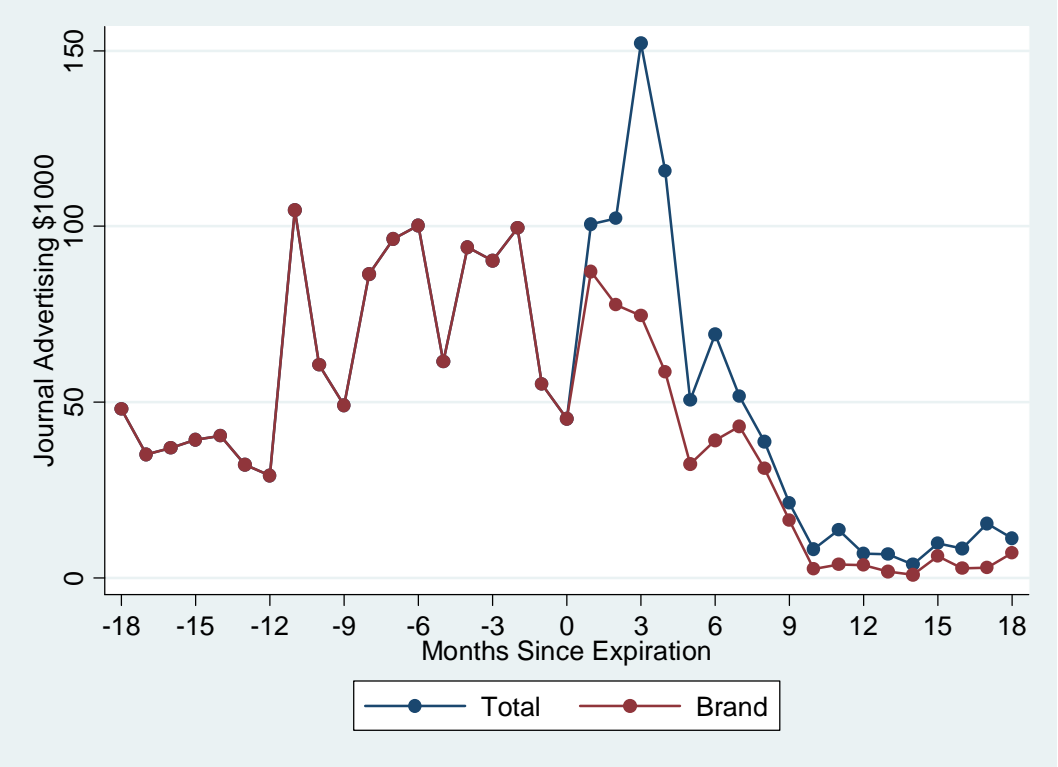**Figure 7:  Mean monthly spending on journal advertising.**

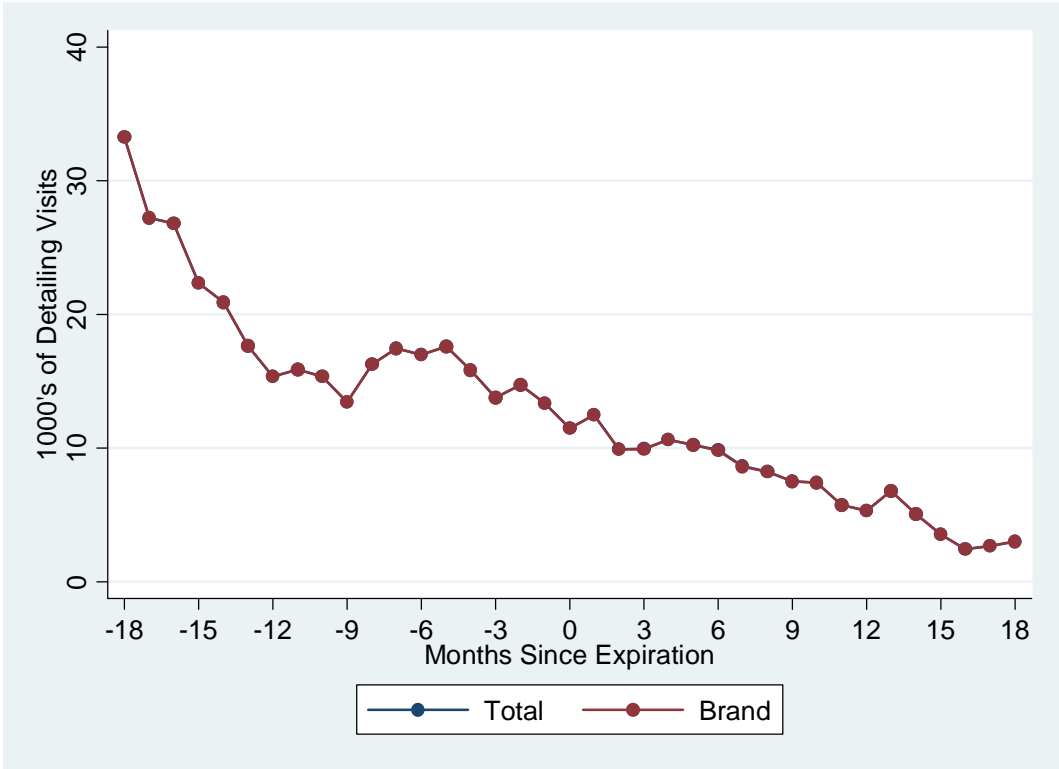**Figure 8:  Mean monthly visits by pharmaceutical company representatives.**

**Figure 9:** **Mean monthly samples dispensed by pharmaceutical company**