Intellectual Property and Marketing*

Darius Lakdawalla†

RAND

Tomas Philipson‡

The University of Chicago

Richard Wang

Astrazeneca

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† Corresponding author. Address: RAND, 1776 Main Street Santa Monica, CA 90407. (Tel) 310-393-0411. Email: darius@rand.org.

‡ Address: Harris School of Public Policy, University of Chicago, Rm. 179, 1155 E. 60th St., Chicago, IL 60637. (Tel) 773-702-9128. Email: t-philipson@uchicago.edu.

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ABSTRACT

In awarding intellectual property rights, society often faces a trade-off between higher R&D, and the cheaper provision of inventions. For example, patents are generally believed by economists to be second-best methods of stimulating R&D, because they reward it at the expense of granting ex post monopoly power. However, this analysis has so far failed to appreciate the ambiguous effects monopoly power has on efficient outcomes, particularly in the context of newly discovered products. To be sure, monopoly restricts output inefficiently, but this effect has to be balanced against the stronger incentives monopolists have to disseminate information about their product. Since information is often under-provided by a competitive market, monopoly thus improves efficiency along this dimension. This is particularly important in the pharmaceutical industry, which invests heavily in advertising to patients and doctors. As a result, we analyze theoretically the impact of intellectual property on the efficient degree of advertising, and vice-versa. In addition, we analyze empirically the net impact of monopoly in the pharmaceutical industry. We find that, in the short-run (one year), patent expiration has a net zero effect on efficiency, but in the long-run, patent monopolies have social costs, but they are smaller than previously believed.

A. INTRODUCTION

Intellectual property spurs innovation by raising the rewards to the discovery of a new product, but it does so by granting an inefficient monopoly after the innovation has been discovered. There is thus a trade-off between ex ante and ex post efficiency. In the case of the pharmaceutical industry, this trade-off creates a politically charged conflict between current and future patients, and one that has profound implications for the health and health care of the US population, as well as the distribution of resources across resources. Today's elderly suffer harms from restricted access to drugs sold by monopolists, but they may not reap the benefits of today's innovation until their children or grandchildren become elderly themselves.

According to standard arguments, the benefits of R&D induced by a patent must be weighed against the reduced output after the discovery induced by the monopoly power the patent grants. In this classical analysis, when a patent expires, the increased competition reduces price and raises output. However, in Figure **Error! Reference source not found.**, we depict the change in quantity that occurs in the month immediately following a patent expiration, for US pharmaceutical products between 1990 and 1997. The figure shows the percentage decline and growth in prescriptions filled during the month before and the month after expiration.[1] For about 40% of drugs, output actually falls after patent expiration, and expands only modestly for many others. This surprising finding suggests that intellectual property generates incentives for quantity

[1] More detail on the data is given in the empirical analysis.

provision that are more complex than theories of price-competition would suggest. In particular, we will argue that while monopolists have incentives to restrict quantity, they also have more incentive to promote their product through advertising, which has the opposite effect on quantity. The data above suggests a monopolist's incentive to restrict quantity through higher prices may not be the only, or even the dominant, factor in pharmaceutical markets. Thus, we argue that the classical analysis of IP must be extended to include not only price-competition, but also non-price competition, here centered on marketing and advertising.

This paper provides a theoretical and empirical analysis of the relationship between IP and non-price competition in terms of marketing. Section 2 first analyzes the impact intellectual property design has on the efficient degree of advertising and then reverse impact advertising has on the efficient design of intellectual property. Section 3 the test for the implications of IP on quantity using data on patent-expirations from the US pharmaceutical markets during 1990-2003.

The drug industry is a natural one in which to analyze the relationship between R&D and marketing, two forms of behavior that our research suggests are more related than commonly thought. In addition to spending a vast amount of resources on R&D, the drug industry also is engaged in heavy marketing of drugs that have been developed. The US pharmaceutical industry spends about 20% of sales on marketing and advertising compared to about 16% of sales on R&D. This makes them among the highest industries in both dimensions compared to the average industry in the US as 2% and 3% of GDP gets allocated to advertising and R&D respectively. In particular, 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. The increased level of drug marketing has lead many observers to claim that advertising raises prices, and hence

drug spending, beyond desirable levels and that such marketing expenses could be better used if allocated to R&D investments. However, our analysis suggests R&D and marketing are complements rather than substitutes, that marketing raises profits and access, which in turn raises R&D.

The project relates to much previous work on the topics on advertising and intellectual property. However, such previous analyses analyze two topics separately rather than jointly as here. In the economic analysis of advertising, Kaldor (1949) gives a good early analysis of advertising that discusses both positive and normative economic issues. 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). Analytically, our emphasis on the complementarity between advertising and goods advertised is closely related in several respects to Spence's (1976) important analysis of product quality. There are also summary treatments of advertising in Tirole (1988), Shapiro (1982) and Schmalensee (1996). Examples of previous empirical studies on advertising of pharmaceuticals include Rosenthal et al (2002) and Bhattacharya and Vogt (2003), though with different objectives in mind than our analysis. In the economic analysis of intellectual property, an equally long-standing literature tackles the appropriate methods of generating the efficient amount of R&D, but without discussing marketing and advertising. There is a large literature analyzing the effects and desirability of public interventions affecting the speed of technological change such as 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).

Although both advertising and IP are well-analyzed separately in these strands of analyses, the combined allocation problem of how to appropriately address marketing

and R&D incentives jointly seems less understood. More importantly, this seems to have led to substantial confusion and disagreement about appropriate policy solutions for many important issues that implicitly seem to involve this joint allocation problem, particularly the marketing of pharmaceuticals to the elderly in the US.

B. Theoretical Analysis

Let *x* denote the quantity of output, a the amount of advertising, *p(a,x)* the inverse demand curve, and *c(x,a)* the cost curve. Let $\pi(x,a) = p(a,x)x - c(a,x)$ and $s(x,a) = \int_0^x [p(a,q) - p(a,x)]dq$ denote the producer- and consumer surplus for a given level of output and advertising. Social surplus *W(x,a)* is defined by:

$$W(x,a) = s(x,a) + \pi(x,a) \tag{1}$$

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 level of R&D maximizes expected payoffs for the innovator. Given an ex post prize z, therefore, the innovator will invest in research $r(z)$ according to:

$$r(z) = \arg\max_r m(r)z - r \tag{2}$$

As *m(r)* is increasing and concave, *r(z)* is single-valued and increasing. Expected social surplus depends on R&D, output, and advertising, according to:

$$EW(r,x,a) = m(r)W(x,a) - r \tag{3}$$

The *first-best* allocation *(r*, x*, a*)* maximizes expected surplus and is characterized by the first-order necessary conditions:

$$\begin{aligned} EW_x &= mW_x = 0 \\ EW_a &= mW_a = 0 \\ EW_r &= m_r W - 1 = 0 \end{aligned} \tag{4}$$

Clearly, the advertising and output levels that are optimal ex ante are also optimal ex post, so that:

$$(x^*, a^*) = \arg\max_{x,a} W(x,a) \tag{5}$$

Optimal R&D is achieved if the innovator receives the optimal level of ex-post welfare in profit: $r^* = r(W(x^*, a^*))$.

B.1 The Impact of Advertising on the Optimal Design of Intellectual Property

We now use the framework above to explore how advertising influences the efficient design of patents. For a given patent length τ, ex-post welfare and profits are

$$\begin{aligned} W(\tau) &= W_B(\tau) + W_A(\tau) \\ \pi(\tau) &= \pi_B(\tau) + \pi_A(\tau) \end{aligned} \tag{6}$$

$W_B(\tau)$ *and* $W_A(\tau)$ denote the present value of social welfare before- and after- expiration, respectively, and similarly for $\pi_B(\tau)$ and $\pi_A(\tau)$. Assume that monopoly before patent expiration and competition after expiration induces the aggregate amounts of output and advertising denoted $h_M(x_M, a_M)$ and $h_C(x_C, a_C)$, respectively. This implies that the pre- and post-expiration levels of welfare and profits are

$$\begin{aligned} W_B(\tau) &= v(\tau) W(h_M) \\ W_A(\tau) &= [v(\infty) - v(\tau)] W(h_C) \\ \pi_B(\tau) &= v(\tau) \pi(h_M) \\ \pi_A(\tau) &= [v(\infty) - v(\tau)] \pi(h_C) \end{aligned} \tag{7}$$

Here, $\beta \in (0,1]$ is the discount factor and $v(\tau) = \dfrac{1-\beta\tau}{1-\beta}$ is the present value at date zero of an annuity that pays one dollar for τ years. The amount of R&D induced by a given

patent length is $r(\tau) = r(v(\tau)\pi(h_M))$. Naturally, this implies R&D rises with IP protection; $r_\tau > 0$. The ex-ante optimal patent length maximizes dynamic expected welfare:

$$EW(\tau) = m(r(\tau))W(\tau) - r(\tau) \tag{8}$$

An interior optimum satisfies the first-order necessary condition:

$$r_\tau[m_r W - 1] = m(-W_\tau) \tag{9}$$

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, *mrW* -1, which consists of the marginal social gain of extra R&D less its marginal cost. For an optimal patent life, this marginal benefit of an extension must equal the marginal cost of the extension represented by extending monopoly power an additional year (on the right-hand side). This trade-off occurs because a longer patent life lowers the surplus received but raises the chance of receiving it. Patents do not generate the first-best allocations because they reward innovation with inefficient monopoly power and social surplus is larger than the profits motivating R&D.

B.1.1 *The Welfare Effects of Patent Expiration*

The marginal cost of patent expiration depended on the effect of patent extension on ex-post welfare, $\frac{dW}{d\tau}$, which is directly related to the welfare effect of patent expiration. The effect of patent expiration on welfare and profits satisfies:

$$\begin{aligned} \frac{dW}{d\tau} &= \frac{dv}{d\tau}[W_M - W_C] \\ \frac{d\pi}{d\tau} &= \frac{dv}{d\tau}[\pi_m - \pi_C] \end{aligned} \tag{10}$$

Patent length increases profits, because profits under patent exceed those earned under competition.

Without advertising, longer patents reduce welfare by extending the duration of monopoly and the higher prices they imply. From an ex post perspective, therefore, optimal patent length is zero under classical analysis. However, when we consider non-price competition such as marketing, W_τ becomes larger and may even become positive. If $W_\tau > 0$, optimal patent length is infinite, because patents are costless.

More generally, standard analysis of patents ignores advertising and is focused on price implications alone. In the classic analysis of patents, market output is an indicator of social welfare in the sense that growth or contraction in output, at constant advertising, corresponds to a rise or fall in welfare:

$$W_C > W_M \ \ if\ and\ only\ if\ x_C > x_M \tag{11}$$

When non-price competition such as advertising is feasible, patent expirations affect both price and advertising, so that output does not continue to serve as an unambiguous measure of welfare. Consider when the two allocations h_M and h_C involve a monopoly that advertises more at higher prices:

$$a_M \geq a_C, p_M \geq p_C \tag{12}$$

Then the resulting impact on aggregate output is indeterminate. There are two opposing forces operating on market output after expiration; one is the reduction in price and the other is a reduction in marketing. These opposing effects will determine whether the market power created by patents is as harmful as often claimed and whether, as a consequence, the optimal design of patents differs when taking into account both pricing and advertising. Generally, output may expand while welfare is lowered or may contract while welfare is raised, and output may be constant while efficiency is raised or lowered.

Surprisingly, it seems that output changes nevertheless are valuable to infer an asymmetric direction of welfare. We conjecture that for any well-behaved preferences and costs, i.e. inverse demand curve *p(x,a)* and cost curve *c(x,a), a reduction in output is sufficient but not necessary for a reduction in (gross) welfare*. The result can be easily illustrated by Figure 2 that shows the change in gross surplus, not netting out advertising spending. Region G and L show the respective gain and loss in social surplus attributable to a reduction in advertising and price. However, region G only exists if output rises with the reduction in advertising and price. Therefore, if output contracts upon expiration, welfare is decreased, while if output expands welfare may be decreased or increased.

The result contrasts with the classic assessment of the welfare effects of patent expirations that considers only price reductions, in which case an increase in output is not only sufficient but also necessary for a gain in social welfare. This has the important implication that output gains after the patent expires may be incorrectly interpreted to imply that the patent induced a welfare gain, when it in fact induced a welfare loss. If this was the case, then the optimal patent life may be infinite even when patent expiration induces output growth.

An additional important reason why non-price measures such as advertising may alter standard efficiency arguments about patents is that they can be *discriminated* more easily than price. 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, however, it is more easily implemented than traditional forms of price-discrimination. Thus, advertising may act to lower the inefficiencies associated with patents and hence lower the marginal cost of patent extension. This is because patent-inefficiency is created by the inability of the

monopolist to price discriminate. Discriminatory advertising may lower or even remove the dead-weight losses associated with patent monopolies.

B.1.2 *Optimal Patent Length*

How does advertising affect social welfare and profits, and consequently optimal patent length?[2] Clearly, this depends on how it affects the marginal benefit and cost of patent extension. The marginal benefit is determined by the degree to which a patent extension stimulates R&D and the net social gain in more R&D spending. The size of the marginal cost of an extension is determined by how much ex post welfare is reduced from an additional year of a patent.

To examine the impact of advertising on optimal patent life, first consider the effect on the marginal benefit of an additional year of patent life. The marginal benefit of patent extension is the product of two components: the marginal increase in R&D induced by patent length r_τ, multiplied by the degree of social under-investment in R&D $m_r W - 1$. Our analysis will establish the conditions under which advertising raises the overall net benefit of patent extension.

The ex post marginal cost of patent extension is its impact on ex post welfare, $\frac{dW}{d\tau} = \frac{dv}{d\tau}\left[W(h_C) - W(h_M)\right]$. The impact of advertising on the marginal cost of patent-extension is thus influenced by whether it raises or lowers ex-post welfare. However, as R&D rises with advertising, the chance of discovery, m, rises with advertising thus raising the *expected* marginal cost of patent extension.

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[2] Note that traditional envelope conditions do not apply here because the optimal choice is second-best, determined by the expected profits facing the firm undertaking the R&D, not expected welfare.

We therefore conjecture that advertising incentives have an ambiguous effect on both the marginal cost and benefit of patent extension because productivity effects (*m*) may operate against ex-post welfare effects (*W* and π).

However, there are certain identifiable conditions under which we can say optimal patent protection is increased or decreased by advertising. The first involves a clear predicted increase of the optimal patent life when the marginal cost of patent extension is negative under advertising, that is, the patent confers ex-post welfare gains, $\frac{dW}{d\tau} > 0$. As long as there is any marginal benefit of patent extension, the lack of a cost implies the patent should be infinite.

The second case concerns a clear predicted decrease of the optimal patent life when the marginal benefit of patent extension is zero under advertising, as may occur when advertising induces zero profits, perhaps due to the competitive effects of advertising in raising the elasticity of demand across products. In this case patent extensions do not confer additional R&D; r_τ =0. As long as there is a marginal cost of patent extension, the lack of a benefit implies the patent length should be zero.

B.2 The Impact of Intellectual Property on the Efficient Degree of Advertising

The previous analysis considered the effect of marketing on intellectual property. This section considers the reverse: the effect of IP on optimal advertising. Previous treatments of advertising only concern the static effects on welfare, *W*, and may therefore be incomplete. This occurs if dynamic welfare, EW, behaves differently than static welfare. This may occur if advertising affects profits and hence R&D incentives. Advertising may lower welfare ex-post but raise expected welfare when profits rise to encourage R&D. In general, the static analysis concerns only overall effects on ex-post

welfare, while the dynamic welfare effects depend on the *incidence* of advertising—how it affects producers and consumers separately.

Consider an intervention that changes welfare and profits from their ex-post overall levels (W,π) to a new set of levels (W^*,π^*) due to a change in incentives to advertise. Analysis that is solely static in nature examines only the difference between W and W^*. A fuller analysis of advertising that incorporates dynamic welfare and R&D effects would, in contrast, evaluate the difference between $EW(W,\pi)$ and $EW(W^*,\pi^*)$. As static welfare consists of consumer and producer surplus, $W = s + \pi$, the tradeoff between the two when dynamic welfare is constant:

$$\frac{ds}{d\pi} = -\frac{dEW_{\pi}}{dEW_{s}} = -1 - \frac{r_{\tau}\left[m_{r}W - 1\right]}{m} \tag{13}$$

The first term, -1, is the tradeoff between consumer and producer surplus keeping ex-post welfare constant. However, this tradeoff is tilted towards producer surplus (profits) according to the extent to which profits generate additional social welfare through more R&D, $r_{\tau}[m_{r}W - 1]$. This welfare is then discounted by its chance of occurring, $\frac{1}{m}$. Even with other models of the R&D process, the general point remains that the dynamic tradeoff is the static tradeoff corrected for a R&D effect.

Figure 3 depicts what determines the direction of the change in dynamic welfare resulting from a change in producer and consumer welfare due to a change in advertising incentives away from initial levels (s,π). The steeper line represents combinations of surpluses that keep classic ex-post welfare the same and thus has a unit slope. The less steep line depicts the combinations that keep dynamic welfare constant when profit changes affects R&D.

When a change in advertising incentives has the same effect on both producer and consumer welfare (they both fall or rise), then clearly dynamic welfare is changed in the same direction as classic ex-post welfare. In the figure, both static and dynamic welfare are higher in the first and fourth quadrant around the initial surplus levels (s,π). When consumer surplus falls by more than profits rise by advertising regulations, the situation is deemed inefficient by classic analysis, but may be dynamically efficient. This would be true for the new levels of producer and consumer surplus in region A in the figure. Conversely, when ex-post consumer surplus rises more than profits fall by advertising regulations, this would be considered efficient by classical analysis, but it may involve dynamically inefficient change. This would be true for new levels in region B in the figure. The figure illustrates that classic welfare calculations can produce quantitatively incorrect results, but also that their *qualitative* conclusions may be inaccurate; the *sign* of the static and dynamic welfare impacts may differ. Classical analysis of the effects of advertising regulations may thus be misguided when advertising raises profits and hence the incentive to engage in R&D. This occurs only if the regulations affect profitability and classic ex-post welfare differentially. In that case, ex-post profits can be raised to overturn a given reduction in classic welfare or profits can be reduced to overturn a gain in classic welfare.

These tradeoffs concern the overall ex-post producer and consumer welfare as represented by the present value of annual flows of the two variables pre- and post-patent expiration. As overall welfare is related to annual welfare levels according to:

$$\begin{aligned} s &= s_B + s_A = v s_M + \left[\frac{1}{\beta} - v\right] s_C \\ \pi &= \pi_B + \pi_A = v \pi_M + \left[\frac{1}{\beta} - v\right] \pi_C \end{aligned} \tag{14}$$

it follows that $\frac{ds}{ds_M} = \frac{d\pi}{d\pi_M}$ and $\frac{ds}{ds_C} = \frac{d\pi}{d\pi_C}$. This implies that the tradeoff between the annual flows under competition and monopoly respectively both equal the tradeoff discussed above, $\frac{ds_C}{d\pi_C} = \frac{ds_M}{d\pi_M} = \frac{ds}{d\pi}$. Therefore, for a classical analysis that determined that changes in advertising raised classic welfare under competitive conditions, or that it lowered classic welfare under conditions of market power, the corresponding offsets in profits to overturn such welfare analysis could be obtained are as before.

C. Empirical Analysis

We use data on pharmaceutical patent expirations and advertising to quantify the competing effects of monopoly—quantity-restriction, and advertising-promotion. To do so, we estimate the demand for pharmaceuticals as a function of price, along with the effect of patent expiration on price. With these estimates, we can determine the effect of patent expiration on prices, and on advertising, and the effects of both these changes on the quantity of the drug consumed. This allows us to compare the two competing effects.

C.1 Data

The IMS Generic Spectra database contains data on 65 molecules. For each one, it reports 6 years of monthly data, which span 3 years prior to and 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 are estimated by IMS as total revenues from the drug divided by grams of the drug sold. 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 monopolist, rather than the price paid by insured or uninsured consumers. We also have three measures of advertising: monthly expenditures on medical journal advertisements, monthly visits to doctors by the company's sales representatives (called "detailing visits" in the parlance of the industry), and the number of drug samples dispensed by representatives to doctors. We also have data on the number of competitors who produce a generic form of the molecule, applicable when the molecule is no longer on patent.

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 so on for the branded and generic prices. In estimating market demand, we use total market prices and quantities.

Table 2 reports a breakdown of the 65 included molecules by therapeutic class and advertising status. We call a drug "advertised" if it reports some advertising activity in each of the three advertising categories we have, and vice-versa. Unadvertised drugs account for about 28% of the molecules, but less than 10% of total revenues. Not surprisingly, advertising effort is much higher for heavily used drugs. We will focus most of our attention on the advertised drugs, since they account for the vast majority of revenues, and since they are much less likely to suffer from missing data.

C.2 Patent Expiration and Changes in Quantity

An initial examination of the data reveals some interesting patterns that suggest the interplay of quantity-restriction and advertising effects. Figure **Error! Reference source not found.** demonstrates that for 40% of drugs, the total market quantity consumed falls 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 1 shows that the same type of pattern obtains at a longer window also, comparing the month prior to expiration to one year after expiration.

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 drugs are 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 centered among the group of advertised drugs. The non-advertised drugs tend to behave according to the standard theory of monopoly. Compare Figures 5 and 6, which show trends, respectively, for advertised and non-advertised drugs. Trends for the non-

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 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 non-advertised drugs, where the incentive to advertise is weak or absent, patent expiration eliminates the incentive to restrict quantity but has no other effects. In the case of an advertised drug, however, the patent expiration has competing effects, which can lead to ambiguous changes in total market quantity.

C.3 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. This jump is most pronounced and longest-lived in the case of journal advertising, and much smaller (indeed, almost negligible) in the case of detailing visits and samples dispensed.

The nature of these three types of advertising activities differs considerably. We focus primarily on journal advertising, because it best represents the dispensation of information about the drug to physicians, and little else. Since our theory applies to advertising insofar as it dispenses information, it is most directly applicable to journal advertising. In contrast, detailing visits dispense information, but they also provide perq's and gifts to individual physicians. In addition, from the point of view of measurement, attributing a detailing visit to a particular drug is much more difficult than

attributing journal advertising expenditures. Finally, samples dispensed provide consumers with information about the drug, if they take the samples, but they can also work to crowd out purchases of the drug directly, in the short-term.

C.4 Identifying the Demand for Drugs

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

Motivated by this general idea, we pursue two distinct but related strategies for identifying the demand for drugs:

1. Identify dips or bumps in price and advertising around the date of patent expiration. These short-run changes are used to calculate demand elasticities;
2. Identify trend breaks in price and advertising. These changes are used to calculate demand elasticities.

We call these strategies "the expiration window" strategy, and "the trend break" strategy, respectively. To lay out our approaches, we first present estimates of quantity demanded as a function of price, without considering advertising. As we show later, this turns out to be a reasonable way to approximate the price effects, and it is a pedagogically useful first step in explaining the larger strategy. We explain each strategy in turn.

C.4.1 *Expiration Window Strategy*

Formally, this strategy involves estimating the following first- and second-stage equations via Instrumental Variables:

$$\ln(P_{dm}) = \alpha_0 + \alpha_1 Expired_{dm} + \phi_d + \gamma_{6-month} + \eta_{dm} \quad (15)$$

$$\ln(Q_{dm}) = \kappa + \varepsilon_D \ln(P_{dm}) + \phi_d + \gamma_{6-month} + \varepsilon_{dm} \quad (16)$$

For each drug d, and month m, we use data on price P_{dm}, and quantity in grams Q_{dm}. The model includes a drug fixed-effect, ϕ_d, and a dummy for a 6-month interval of time, $\gamma_{6-month}$. The set of 6-month intervals is centered around the date of patent expiration, so that one of the identified intervals spans two months prior to expiration, and three months following expiration, with the month of expiration in the middle.

To identify the elasticity of demand, this strategy uses the change in the market price and quantity of the drug between the three-month period immediately prior to expiration and the three-month period immediately after expiration. The estimated price elasticity of demand is given by the average (across all drugs) of $\frac{\%\Delta Q}{\%\Delta P}$, where changes are calculated from the earlier three-month interval to the immediate post-expiration period.

This point is illustrated graphically in Figure 10. The 6-month interval dummies slice up the entire period into 6-month windows. As a result, the "Expiration" variable computes the effect of expiration within a 6-month window. This amounts to comparing the three months immediately prior to expiration to the three months immediately following it. The identifying assumption is that changes immediately adjacent to the month of expiration are driven by the effect of expiration on prices (and, later, advertising), but not by unobserved changes in demand.

C.4.2 *Trend Break Strategy*

The "expiration window" strategy uses changes in price and quantity immediately adjacent to the month of expiration. An alternative approach is to fit trends in price and quantity, and identify trend breaks that occur at expiration. This approach uses all the months of data in constructing the trend and its associated break, but it focuses on the apparent shocks to the trend that accompany patent expiration.

Formally, this strategy involves estimating the following first- and second-stage equations via Instrumental Variables:

$$\ln(P_{dm}) = \alpha_0 + \alpha_1 Expired_{dm} + \phi_d + MonthPoly + \eta_{dm} \quad (17)$$

$$\ln(Q_{dm}) = \beta_0 + \varepsilon_D \ln(P_{dm}) + \phi_d + MonthPoly + \varepsilon_{dm} \quad (18)$$

The only formal change required by this strategy is the use of a polynomial in month $MonthPoly$ instead of a dummy for an interval of time. The expiration variable identifies the break in the polynomial trend that occurs at expiration for price and quantity. These trend breaks, which imply percentage changes in quantity and price, are then used to estimate a demand elasticity. This approach is depicted graphically in Figure 11. A common polynomial time trend is fitted for percentage changes over time in the prices and quantities of each drug. Aberrations in that trend at the date of expiration are attributed to the expiration itself. These are assumed independent of unobserved changes in demand and used to estimate movement along the demand curve.

C.5 The Effects of Quantity-Restriction by Monopolists

The results of these estimation strategies are given in Table 3. The table reports IV coefficients, along with FGLS standard errors. It reports the first- and second-stage results for 4 versions of the model. The first two models employ the 6-month time interval fixed-effect, while the last two employ a cubic in month. The models also differ in their measurement of expiration: some use the first month after expiration as the beginning of the off-patent period, while others use the second month.

The standard errors for the IV price-elasticity estimates are somewhat large, due to the presence of drug fixed-effects. They range from approximately –1 to approximately –2.5. While these estimates vary quite a bit, it is striking that the interval [1.09,1.37] is the

only one to lie within one standard deviation of all four estimates. The immediate effect of patent expiration is to lower prices by four to seven percent. Therefore, if the price elasticity lies within the interval given above, patent expiration raises the quantity of drugs sold by approximately 4 to 9 percent.

Economic theory can help pin down the elasticities further. 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.[3] This implies that the demand elasticity at expiration is predicted to be approximately –1.1. This lies within the interval we delineated above. This analysis also helps us quantify the long-run effect of patent expiration. Over a short period of time, price falls by about 5 to 7 percent, but in the long-run, it falls by 80 to 90 percent. Given the likely demand elasticities, patent expiration raises quantity by more than 90 percent, all else equal (including advertising incentives).

C.6 The Effects of Advertising-Promotion

To identify the effects of advertising, we must extend the strategies given above. Unobserved changes in demand are likely to affect the incentive to advertise. As a result, advertising cannot be regarded as an exogenous variable in demand estimation, and we need an additional source of identifying variation to estimate the effects of both price changes and advertising effort.

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[3] This is based on our analysis of MIDAS data on long-run generic prices.

C.6.1 *Extending the Identification Strategies*

We obtain additional identifying variation by extending the strategies presented above. Earlier, we used 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 in part to the vagaries of the FDA approval process. If expiration has lagged effects, we can obtain more identifying variation. We adapt the expiration window strategy by considering 12-month intervals, rather than the tighter 6-month windows, and using three instruments — the month after expiration, four months after expiration, and seven months after expiration. Formally, this is implemented by the following model:

$$\ln(P_{dm}) = \alpha_0 + \alpha_1 Expired_{dm} + \alpha_2 Expired\_4_{dm} + \alpha_3 Expired\_7_{dm} + \phi_d + \gamma_{year} + \eta_{dm} \quad (19)$$

$$Adv_{dm} = \alpha_0 + \alpha_1 Expired_{dm} + \alpha_2 Expired\_4_{dm} + \alpha_3 Expired\_7_{dm} + \phi_d + \gamma_{year} + \eta_{dm} \quad (20)$$

$$\ln(Q_{dm}) = \kappa + \varepsilon_D \ln(P_{dm}) + \varepsilon_A Adv_{dm} + \phi_d + \gamma_{year} + \varepsilon_{dm} \quad (21)$$

The variable Adv_{dm} is a measure of advertising. The dummy variables $Expired\_4$ and $Expired\_7$ denote, respectively, the fourth month after expiration, and the seventh month after expiration. The variable γ_{year} represents a 12-month interval. These intervals are arrayed such that one interval begins two full months after expiration and ends 9 full months after expiration. This alignment is depicted graphically in Figure 12.

In measuring advertising, we will focus on journal advertisement spending, as this is the closest measure of information dissemination that we have. As a result, we have two endogenous regressors and three instruments, leaving us with an overidentified model.

This allows us to test the overidentifying restriction, along with estimating the relevant demand elasticities.

In a similar manner, we extend the "trend break" strategy to allow for trend breaks just after patent expiration, as well as four months after, and seven months after. Formally, this requires estimating the pair of equations:

$$\ln(P_{dm}) = \alpha_0 + \alpha_1 Expired_{dm} + \alpha_2 Expired\_4_{dm} + \alpha_3 Expired\_7_{dm} + \phi_d + MonthPoly + \eta_{dm} \quad (22)$$

$$Adv_{dm} = \alpha_0 + \alpha_1 Expired_{dm} + \alpha_2 Expired\_4_{dm} + \alpha_3 Expired\_7_{dm} + \phi_d + MonthPoly + \eta_{dm} \quad (23)$$

$$\ln(Q_{dm}) = \beta_0 + \varepsilon_D \ln(P_{dm}) + \varepsilon_A Adv_{dm} + \phi_d + MonthPoly + \varepsilon_{dm} \quad (24)$$

This once again provides us with three instruments to identify two endogenous regressors and test an overidentifying restriction.

C.6.2 *Results*

The results of extending the expiration window strategy are given in Table 4. The table shows the results of two different specifications. In the first, we exclude all drug-months with zero journal advertising spending and estimate the effect of log advertising. In the second, we use all the data, but instead estimate the effect of advertising dollars in levels; we then compute the implied elasticity at the mean values of advertising and quantity. These two approaches yield similar advertising elasticities, of 0.22 and 0.28. These are statistically indistinguishable. The price elasticity estimates are again within one standard deviation of the interval [1.09,1.37].

Using these estimates, we can compute the combined effect of patent expirations on price and advertising, in the initial 9-months after patent expiration. Price falls by about 6.5%. Journal advertising falls by about 44% (the absolute decline of $17,730 in advertising spending corresponds to the same percentage decline). These estimates

imply that quantity rises by 7.1% to 8.9% due to the price reduction, but that quantity falls by 9.7% to 12.3% due to the increase in advertising. These effects are quantitatively similar, suggesting that in the short-run, the total effect of patent expiration on quantity is approximately zero.

We can estimate the combined long-run effects of advertising and quantity-restriction by turning to the theory of monopoly. This implies that the ratio of the advertising elasticity ε_A to the price elasticity ε_D should be approximately equal to the share of sales spent on advertising. In the pharmaceutical industry, this is approximately 20%. Since theory implies the demand elasticity at the point of expiration ought to be approximately 1.1, this implies an advertising elasticity of 0.22. In the long-run, advertising falls to zero, while price falls by 80% to 90%. Therefore, the long-run effect of patent expiration is the sum of: a 90% increase in quantity due to price reduction, and a 22% decrease in quantity due to the reduction in advertising. In the long-run, the advertising effect is about one-fifth the size of the price effect. On balance, patent expiration raises quantity, but the size of the effect is smaller due to advertising. Moreover, in the short-run, the effects are approximately the same size. The presence of the offsetting reduction in advertising incentive delays the ability of patent expirations to increase the quantity of drugs sold.

D. Conclusion

Patents are generally believed by economists to be second-best methods of stimulating R&D as they do so by rewarding the R&D by ex-post inefficient monopoly power. However, previous analysis of intellectual property has focused only on its impact on price-competition ignoring non-price competition such as marketing. We analyzed the impact intellectual property design has on the efficient degree of advertising and, vice versa, the impact advertising has on the efficient design of intellectual property. We empirically analyze the efficiency impact of intellectual property by use of patent-expirations in the US pharmaceutical markets during the period 1990-2003. Such expirations displayed the interesting pattern that for a majority of drugs there are output *reductions* rather than expansions after the patent expires. The increased competition induced by patent-expirations seems to reduce, as opposed to expand, output because advertising is reduced more than price is when patents expire. Our theoretical and empirical analysis casts doubt on the common claim that patents are second-best methods to stimulate innovation in the area of pharmaceuticals. If output falls when patents expire, and access is thus reduced to under-utilized medicines, then traditional harms of intellectual property, only considering price-competition, seems overstated.

The paper suggests several avenues of future research. First, our analysis seems to easily generalize to other forms of non-price competition. If the monopoly power induced by patents has additional effects beyond standard price-competition, those effects may offset or exaggerate the traditional harms of patents induced by less price competition. In particular, since advertising when viewed as a compliment to the good advertised has many features similar to general quality provision, quality and price competition should be analyzed more generally in relation to IP.

Second, using patent-expirations as exogenously induced competition may prove useful to test theories of market structure or estimate demand parameters in other markets. For example, our data with sharp declines in advertising following patent-expiration directly support an often debated claim in the industrial organization literature; that increased competition reduces advertising. Other predictions about the effects of market structure on industry conduct may well be useful to test with patent expiration behavior.

Third, our findings may alter the interpretation of previous studies that have estimated substantial gains from generic entry upon patent expiration as they only consider the gains from price reductions, not the changes in welfare from changes in non-price measures such as advertising. In particular, these studies always find welfare gains from generic entry as prices come down after patents expire. However, our data certainly suggest that valuing only price reductions leads to an upward bias of generic entry on welfare.

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Table 1: Monthly Molecule-Level Variables Available in IMS Generic

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.

[1]Revenues are collected at the retail level, but then "adjusted" to reflect wholesale revenues using margin formulas deemed appropriate by IMS.

Table 2: Types of molecules represented in IMS Generic

	Number of Drugs		
2-digit USC Category	Unadvertised	Advertised	TOTAL
Analgesics		3	3
Anesthetics	2		2
Anti-arthritics		5	5
Hemostat modifiers		2	2
Antihistamines		1	1
Anti-infectives	1	2	3
Anti-malarials		1	1
Neurological Treatments	2	2	4
Gastro-Intestinal Drugs		3	3
Beta-Blockers		2	2
Anti-neoplasm	3	1	4
Ace-Inhibitors	3	8	11
Anti-hyperlipidemic		2	2
Dermatologicals		1	1
Diabetes Therapy		2	2
Diuretics	1	1	2
Hormones	1	2	3
Musculoskeletal	1		1
Opthalmic		3	3
Psychotherapeutics	3	2	5
Sedatives		2	2
Tuberculosis Therapy	1		1
Anti-viral		1	1
Immunologic		1	1
TOTAL	18	47	65

Table 3: Estimated Demand Elasticities for Drugs.

	Model 1		Model 2		Model 3		Model 4	
	ln(p)	ln(gms)	ln(p)	ln(gms)	ln(p)	ln(gms)	ln(p)	ln(gms)
Patent Expired for At Least One Month	-0.037 (0.021)*				-0.056 (0.026)**			
Patent Expired for At Least Two Months			-0.069 (0.021)***				-0.068 (0.028)**	
Ln Price		-2.460 (1.371)*		-0.964 (0.406)**		-2.086 (1.003)**		-1.478 (0.680)**
Time Trend	Cubic				Half-Year Fixed Effects			
Observations	2928	2928	2928	2928	2928	2928	2928	2928

Notes: All models include molecule-specific fixed effects. 3-stage least squares standard errors appear in parentheses. Based on the 47 drugs reporting some journal, detailing, and sample advertising.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Effects of Price and Advertising on Pharmaceutical Demand, Using "Expiration Window" Estimation Method.

	Model 1			Model 2		
	ln(p)	ln(journal)	ln(gms)	ln(p)	Journal	ln(gms)
Patent Expired for	-0.090	0.058		-0.056	1.295	
At Least One Month	(0.027)***	(0.160)		(0.026)**	(0.917)	
Patent Expired for	-0.064	-0.343		-0.065	-1.896	
At Least 4 Months	(0.023)***	(0.116)***		(0.026)**	(0.657)***	
Patent Expired for	-0.064	-0.435		-0.063	-1.773	
At Least 7 Months	(0.023)***	(0.136)***		(0.026)**	(0.763)**	
Ln Price			-0.948			-0.784
			(0.550)*			(0.466)*
Total Journal						0.054
Advertising ($10K)						(0.025)**
[Implied Elasticity]						[0.22]
Ln Journal Advertising			0.283			
			(0.131)**			
Time Trend			Year Fixed-Effects			
Observations	1327	1327	1327	2928	2928	2928

Notes: All models include drug-specific fixed-effects. 3-stage least squares standard errors appear in parentheses. Based on the 47 drugs reporting some journal, detailing, and sample advertising.

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Effects of Price and Advertising on Pharmaceutical Demand, Using "Trend Break" Estimation Method

	Model 1			Model 2		
	ln(p)	ln(journal)	ln(gms)	ln(p)	Journal	ln(gms)
Patent Expired for At Least One Month	-0.046 (0.023)**	0.207 (0.142)		-0.012 (0.023)	1.394 (0.785)*	
Patent Expired for At Least 4 Months	-0.046 (0.023)**	-0.312 (0.136)**		-0.047 (0.026)*	-1.608 (0.638)**	
Patent Expired for At Least 7 Months	-0.083 (0.021)***	-0.723 (0.131)***		-0.097 (0.023)***	-2.351 (0.715)***	
Ln Price			-0.920 (0.539)*			-1.403 (0.965)
Total Journal Advertising ($10K) [Implied Elasticity]						0.068 (0.037)* [0.27]
Ln Journal Advertising			0.196 (0.072)***			
Time Trend			Cubic in Month			
Observations	1327	1327	1327	2928	2928	2928

Notes: All models include drug-specific fixed-effects. 3-stage least squares standard errors appear in parentheses. Based on the 47 drugs reporting some journal, detailing, and sample advertising.

* 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

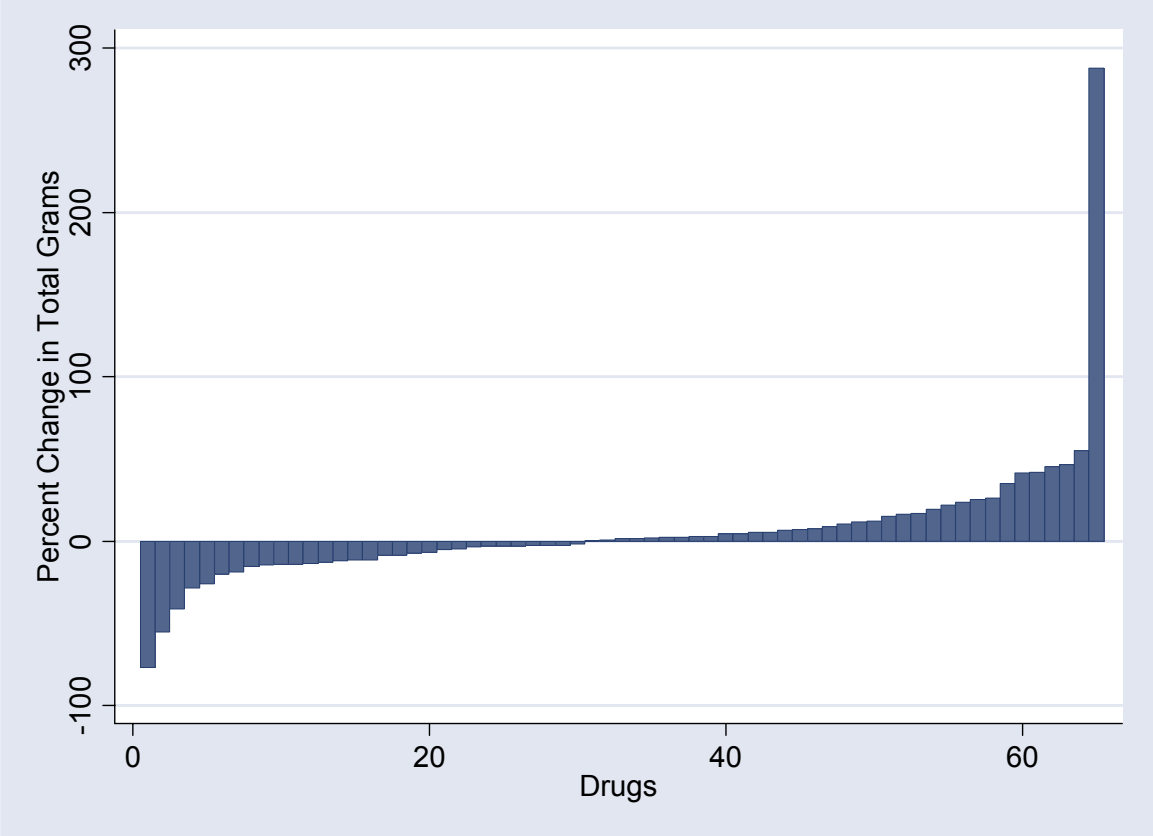

Figure 2: Gross Welfare Effects of Patent Expiration

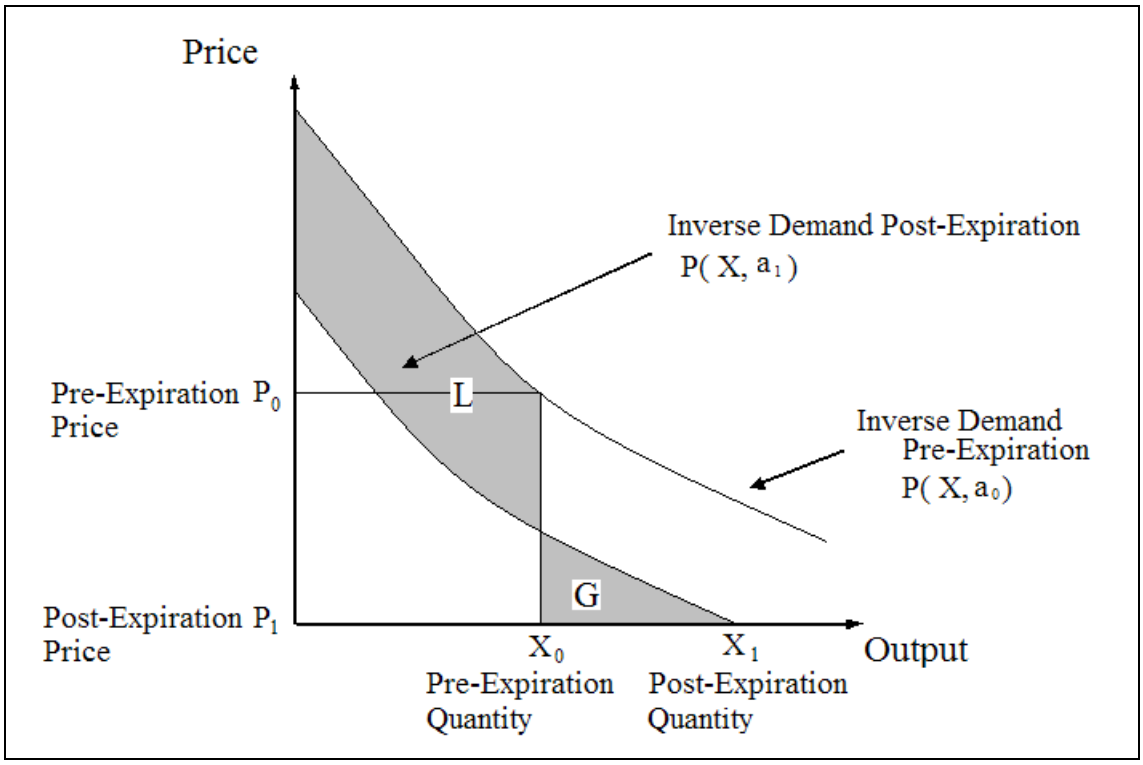

Figure 3: Static vs Dynamic Welfare Changes

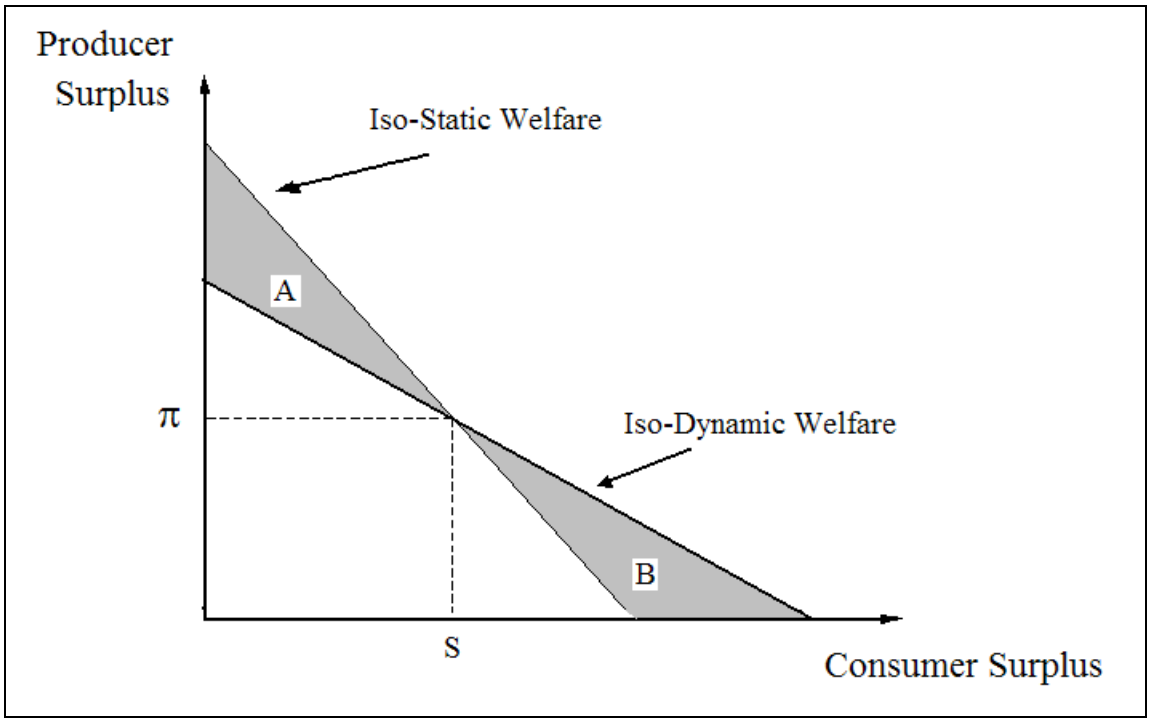

Figure 4: Trends in price and quantity for the average drug.

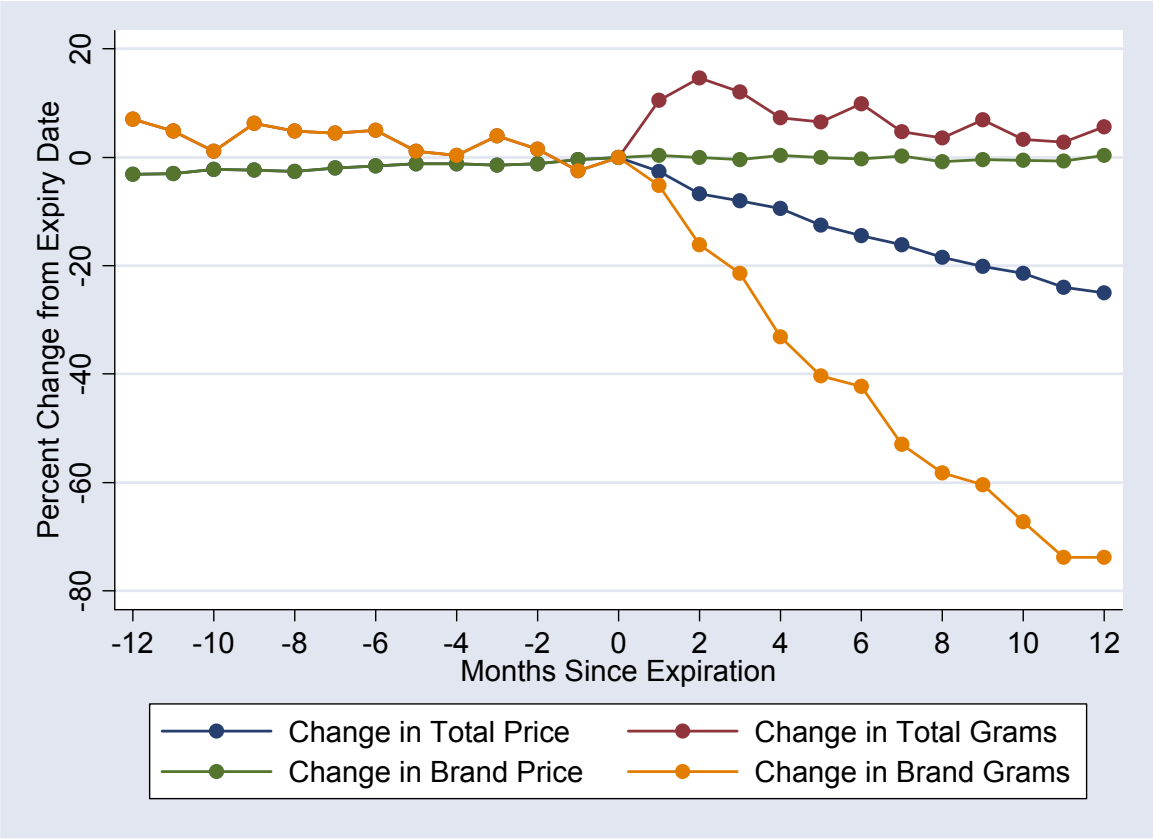

Figure 5: Trends in price and quantity for the mean advertised drug.

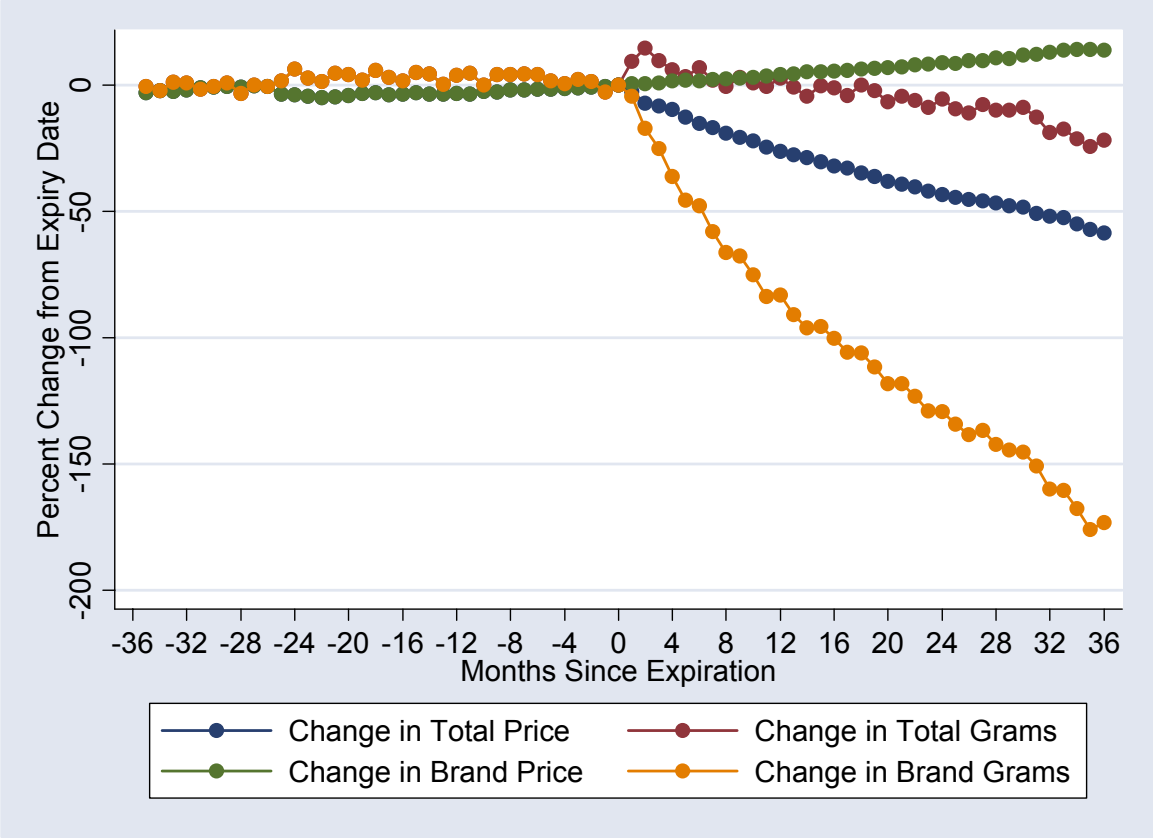

Figure 6: Trends in price and quantity for the mean non-advertised drug.

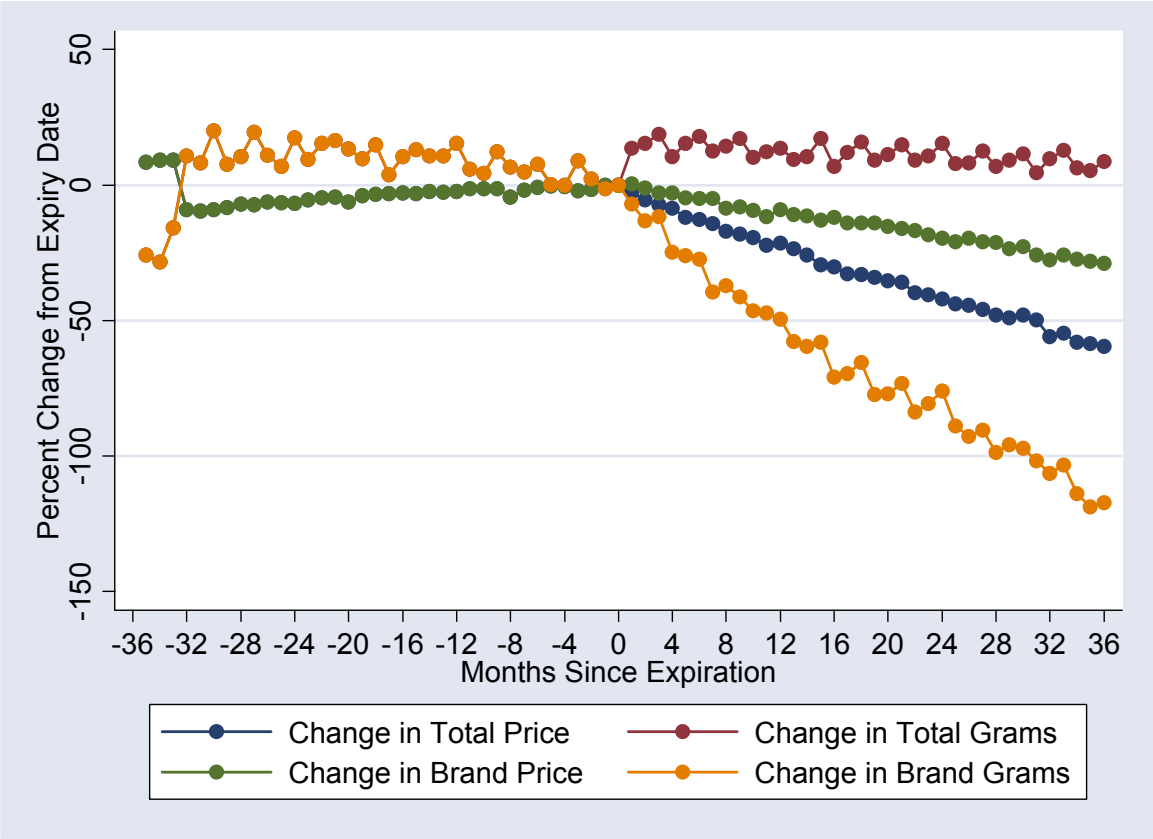

Figure 7: Mean monthly spending on journal advertising.

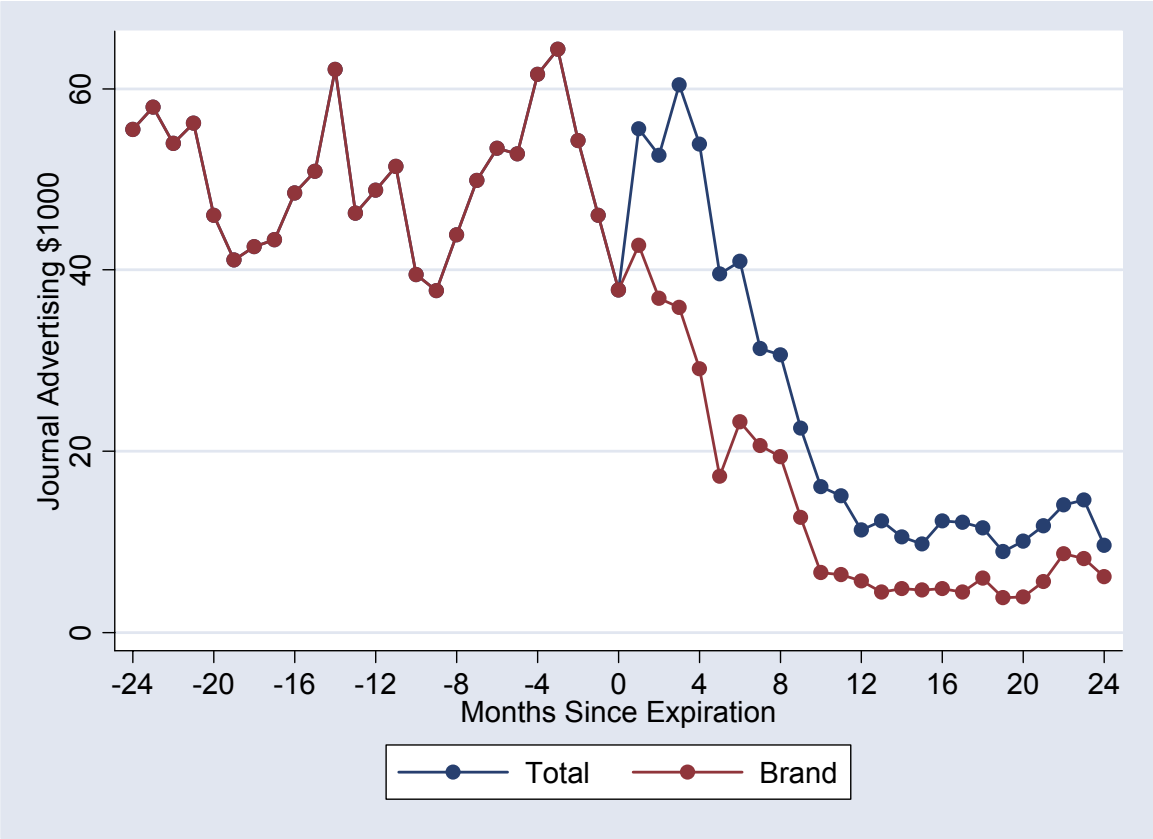

Figure 8: Mean monthly visits by pharmaceutical company representatives.

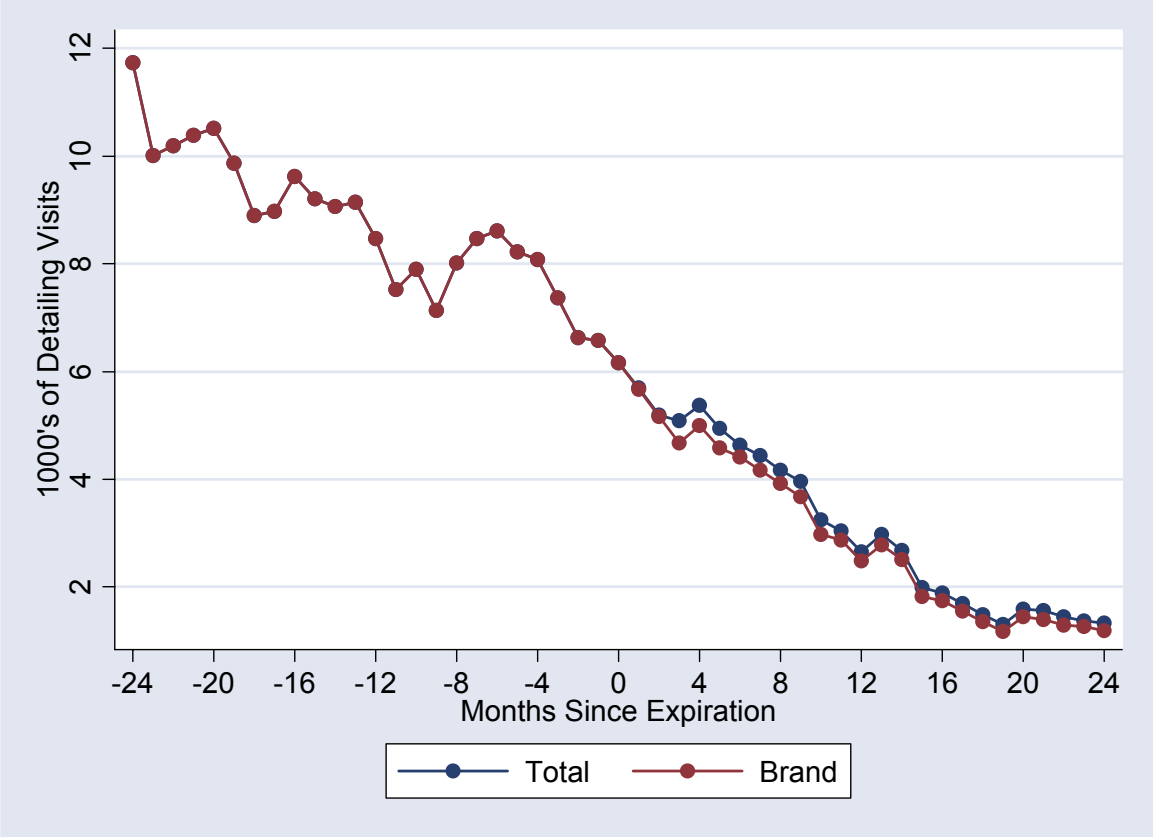

Figure 9: Mean monthly samples dispensed by pharmaceutical company

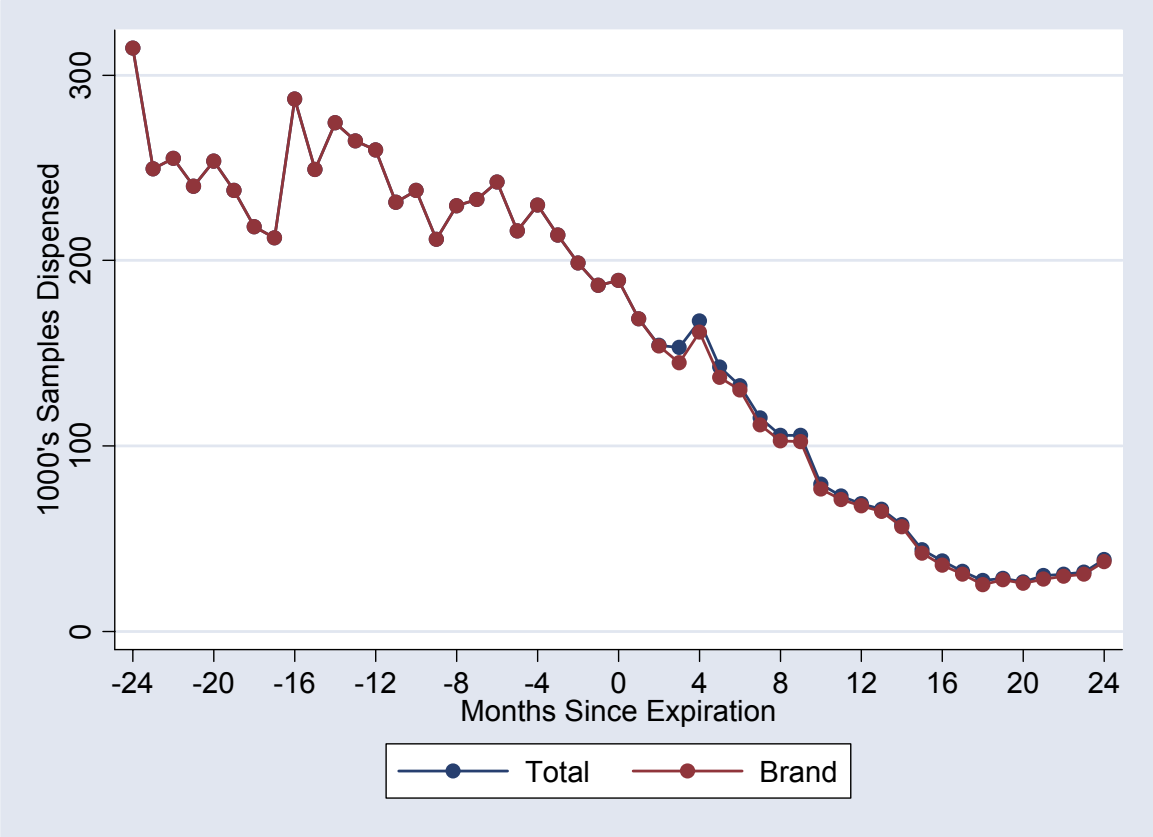

Figure 10: Graphical Depiction of "Expiration Window" Identification Strategy.

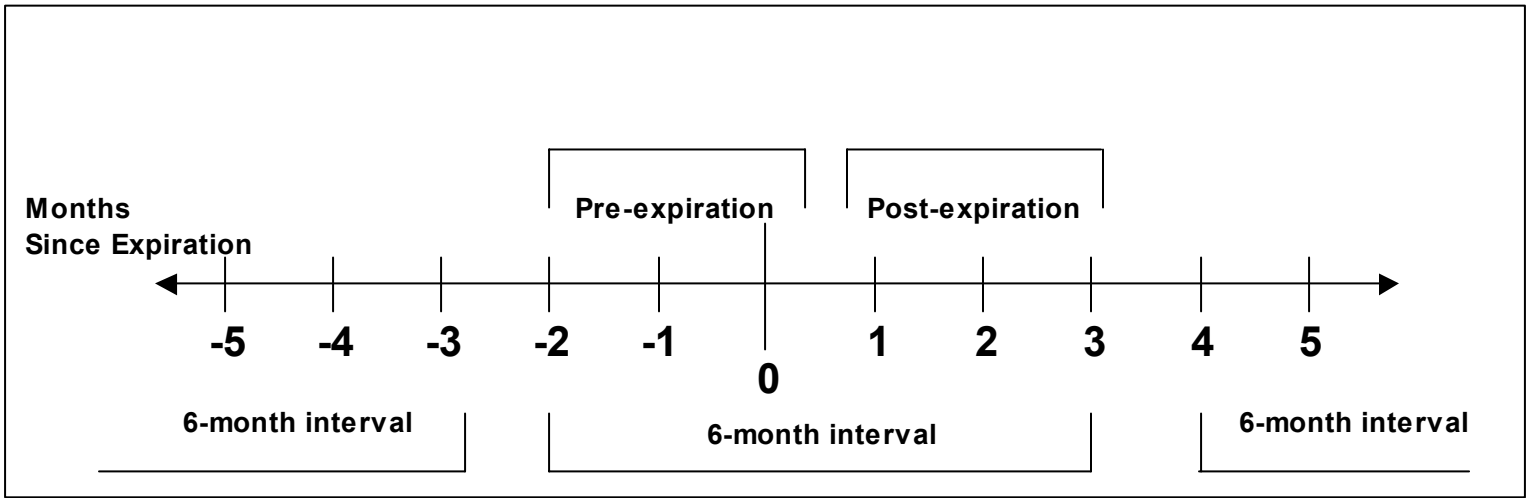

Figure 11: Graphical Depiction of "Trend Break" Identification Strategy

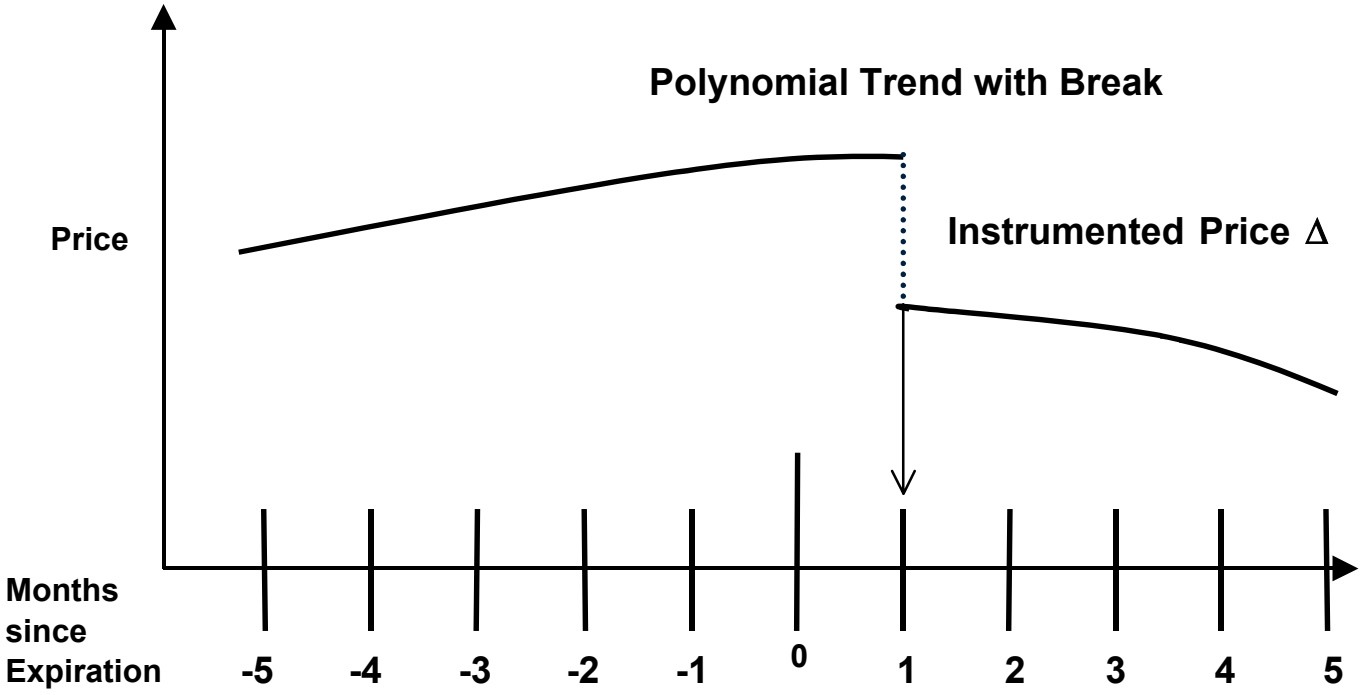

Figure 12: Graphical Depiction of "Expiration Window" Identification Strategy with Lagged Effects.