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2) if price is mismeasured, so is the dependent variable, but then their formula or the coefficient becomes $(\beta + 1)(\sigma - 1)$, and the implied $\sigma = 1.2$ is even ess credible.

"Aging of lines": Once popular restaurants lose customers over time. We ould bring in new ones and make an adjustment for their superiority. But then, ome time later, the chefs are hired away and the old restaurants regain their hare. Will we come back to the same level? How?

A major finding is that if one allows for the changing mix of import goods his leads to lower estimates of their income elasticity. That makes sense, but ow low "should" the import income elasticity be? Can one really explain ising world trade just by the reduction in transport costs and the rising quality f traded goods? I find the notion that traded goods have higher income elastic- ties quite plausible. The explicit "bias" adjustment to the price index that fol- ows is, however, more problematic. But the advice to collect more data is urely right!

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The Roles of Marketing, Product Quality, and Price Competition in the Growth and Composition of the U.S. Antiulcer Drug Industry

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7.1 Introduction

The introduction of Tagamet into the U.S. market in 1977 marked the beginning of a revolutionary treatment for ulcers and the emergence of a new industry. What distinguished the products of this new industry was their ability to heal ulcers and treat preulcer conditions pharmacologically on an outpatient basis, thereby substituting for traditional, and costly, hospital admissions and surgeries. Tagamet, known medically as an H_2-receptor antagonist, promotes the healing of ulcers by reducing the secretion of acid by the stomach.

A striking feature of the antiulcer market is that it has sustained growth in sales (quantity, not just revenue) for over fifteen years and still shows no sign of slowing. New prescribing habits have clearly diffused to an ever increasing number of physicians. Today there are a total of four H_2-receptor antagonists: Tagamet, Zantac, Pepcid, and Axid. Zantac is now the United States' (and the world's) largest-selling prescription drug, having estimated worldwide sales in 1992 of about $3.5 billion. Moreover, Tagamet is also among the ten top-selling prescription drugs in the United States.[1]

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1. One hundred powerhouse drugs (1993, S1). Incidentally, Tagamet ranks 7th, Pepcid 17th, Prilosec 25th, and Axid 61st in terms of U.S. sales. In terms of world sales, Tagamet is 7th, Pepcid 22d, Prilosec 49th, and Axid 67th.

total industry patient-days, one would implicitly be assuming that the vari- drugs are perfectly substitutable. To circumvent this problem, we employ economic theory of price indexes and calculate the industry price using the ıer-Ideal price index.[14]

n terms of quality, to the extent that product-quality characteristics affect size of the potential market, they should be included in an overall industry and equation. We would expect that the size of the potential patient market ld depend on the specific indications for which the FDA has granted oval. We shall concentrate on one particular indication, GERD, which esented an especially large potential new market, and for which the H_2- gonists first received FDA approval relatively late in the sample. Specifi-, when the FDA granted approval to Glaxo's Zantac for GERD, Zantac llers were permitted to provide specific information to physicians concern- he treatment of GERD. This was significant, for instead of being confined tailing to gastroenterologists who saw ulcer patients, now Zantac detailers made calls on general practitioners who commonly saw patients having D symptoms. This undoubtedly expanded the potential market.

ich reasoning suggests that a dummy variable, say, GERD (taking the of 1 following FDA approval), be employed in the overall industry de- l equation. However, it is worth noting that information concerning the ıcy of drugs for different indications typically diffuses prior to formal approval. The medical community is often aware of results of clinical prior to the FDA's reviewing the clinical-trial data and coming to a final ion concerning approval for a new indication. As a result, a great deal of ribing is done off-label prior to the FDA's granting approval. Thus, it is lear how reliable the GERD dummy variable will be in capturing major ges in the size of the potential patient base.

third set of factors affecting industry demand involves marketing ef- Earlier we noted that, in this industry, the two principal forms of market- forts are minutes of detailing and either pages or deflated dollars of medi- urnal advertising. There are several important issues concerning the ırement of marketing efforts. First, since drug marketing is largely a mat- providing information about the existence and usefulness of the product, pect its impact to be long-lived; once a physician has been informed, it l to see how such information might be destroyed. Indeed, precisely be- of this durability, firms typically expend a particularly large amount of ting effort in the early stages of a new product's life. Hence the impact rketing on sales is likely better measured by the cumulative stock of ting efforts since product launch, rather than simply by the flow of cur-

pecifically, the Fisher-Ideal price index is the geometric mean of the Laspeyres and price indexes, where each of them is computed using updated weights. New products are ated as soon as is feasible (i.e., in the second period of their existence, so that their first e is calculated). For further details concerning the Fisher-Ideal price index, see Diewert 992).

rent monthly expenditures. We will also want to allow for the possibility that this stock of information depreciates or deteriorates over time, although we might expect the depreciation rate to be quite low.

We therefore employ the well-known perpetual-inventory method. Let M_t be the *stock* of marketing effort at the end of month t (as measured by the stocks of journal advertising and detailing minutes), let δ be the monthly rate of depreciation of this stock, and let m_t be the flow of marketing effort during time period t. Define M_t as the depreciation-adjusted stock of marketing effort carried over from the last month $(1 - \delta)M_{t-1}$, plus new marketing efforts during months t (m_t), that is

$$(1) \qquad M_t = (1 - \delta)\, M_{t-1} + m_t = \sum_{\tau=1}^{t} (1 - \delta)^{t-\tau} m_\tau.$$

We construct separate stock measures for detailing and for journal advertising. Unlike the typical case for capital-stock accounting, we have no problem wth establishing benchmark or "starting values" since we know that prior to August 1977, the Tagamet journal (and detailing) stocks were zero. To implement equation (1), one must however assume rates of depreciation for each of these stocks. As discussed below, we will use the historical data on marketing and sales to estimate δ econometrically, rather than assume its value a priori.

The other major issue in measuring the effects of marketing efforts entails an innovation of this paper. Other authors have suggested that advertising be modeled as having two simultaneous effects in the market: overall advertising by all firms affecting overall market demand, and relative levels of advertising among firms affecting the individual firms' market shares.[15] We take this modeling one step further here by hypothesizing that firms may choose to direct their marketing efforts to emphasize one of the two effects more than the other. Although the degree to which firms' marketing efforts are directed, say, at overall market expansion cannot be directly observed from data on quantities of marketing done by firms, we now propose a method for estimating this effect econometrically.

To clarify this concept, we discuss it in the context of the antiulcer drug market. When SmithKline marketed Tagamet from its introduction in 1977 until the entry of Zantac in 1983, they did not worry about competing for market share in the H_2-antagonist market, for patent status conferred on them a temporary monopoly position. From this monopoly position, the goal of marketing for SmithKline was to convince more and more physicians of the utility of H_2-antagonists in treating ulcer patients. They, and no other firm, reaped the rewards of having expended efforts on diffusing information on H_2-antagonists to physicians, since they held 100 percent market share. However, once Zan-

15. See, for example, Schmalensee (1972). There is a considerable body of literature on a related, but distinct, approach that decomposes advertising into its "information" and "persuasive" components. For examples in the context of the pharmaceutical industry, see Leffler (1981) and Hurwitz and Caves (1988).

e 7.2 focus only on relative quantities (market shares), but leave fixed the of total industry demand at, say, $\overline{Q}$; denote these price elasticities by e_{jj}^*. tal-price elasticity also captures the impact of a product's price change on industry demand; denote such a price elasticity by e_{jj} (no asterisk). As been shown by, inter alia, Berndt and Wood (1979), the relationship be- n e_{jj}^* and e_{jj} is as follows:

$$\varepsilon_{jj} = \varepsilon_{jj}^* \Big|_{Q=\overline{Q}} + \left(\frac{\partial \ln Q_j}{\partial \ln Q}\right)\left(\frac{\partial \ln Q}{\partial \ln P}\right)\left(\frac{\partial \ln P}{\partial \ln P_j}\right),$$

e Q_j is the quantity demanded of product j, Q is total industry demand, P is industry price. The first partial derivative in equation (10) can be ned to equal unity (other things being equal, demand for product j grows roportionally with market demand, i.e., according to its market share), the second partial derivative is the industry- or market-price elasticity nated values of which are given in table 7.1). The last partial derivative uation (10) indicates the impact of a change in product j's price on the ll industry price index; it can be approximated by the revenue share of ct j in total industry revenues.

ernative OLS and 2SLS estimates of e_{jj}^* are given in table 7.2, while NLS IL-2SLS estimates of the industry-price elasticity are presented in table or the two-product market, 1993 drugstore revenue shares for Tagamet antac are approximately 0.25 and 0.75. For the four-product market, shares are approximately 0.19 (Tagamet), 0.60 (Zantac), 0.12 (Pepcid), 09 (Axid). Together, these relationships imply that in the two-product t, the 2SLS estimates of the total own-price demand elasticities for Taga- d Zantac are approximately -1.154 and -1.690, respectively, while in r-product market, the 2SLS estimated total own-price demand elasticity 909 for Tagamet, -1.153 for Zantac, -0.820 for Pepcid, and -0.799 id. Note that while these point estimates imply that some of the demand ities are less than one in absolute magnitude, the associated standard may well imply that reasonable confidence intervals include values of d above (in absolute value).

Concluding Remarks

is paper we have attempted to explain the phenomenal growth of the gonist antiulcer drug industry in the United States, as well as changes narket shares garnered by the various products over time. Although we amined the roles of product quality, order of entry, and price, we have particular attention on the role of various marketing efforts. Our ork and results can be summarized as follows.

marketing efforts such as detailing and medical journal advertising g-lived impacts. Thus, in explaining current-period sales, a stock of

cumulative detailing or cumulative medical journal advertising is a more appropriate measure of marketing impacts than are current monthly expenditures. In the context of industry demand, we distinguish investments of firms in these marketing activities by the industry structure prevailing when the expenditures originally occurred. In a monopoly market structure, all marketing expenditures are market-expanding, for the monopolist has 100 percent market share. In a market structure with k products, however, marketing activities become more rivalrous, and as k becomes large, we expect relatively little "spillover" of a firm's marketing efforts in affecting industry demand. We have hypothesized, therefore, that in terms of affecting *industry* demand, the relative effects of marketing expenditures originally made when k products were in the market will tend to decline as k increases. In other words, we hypothesize that the effectiveness of marketing in generating industry sales depends on market structure in a systematic manner.

In our empirical analysis of the antiulcer drug market, we obtained considerable but not quite unanimous support for this hypothesis. In particular, normalizing the impact of a monopolist's marketing investments on current sales to unity, we estimated the impact in a duopoly to be 0.6, in a three-product industry to be 0.8, and in a four-product market to be 0.5; these last three numbers are all statistically significantly different from unity (implying that we reject the hypothesis that the effectiveness of marketing efforts is independent of market structure), and from zero (indicating that we reject the hypothesis that once there is competition, the only impact of marketing is on market share, and there is none on overall market size). Thus our results suggest that in the antiulcer drug market there is clear evidence of spillovers, and that these spillovers are considerably less than 100 percent effective. Moreover, for the most part, these spillovers decline as the number of products in the industry increases.

Second, we find that at the industry level, both cumulative minutes of detailing and cumulative pages of medical journal advertising affect sales; typical estimates of these elasticities are 0.5 and 0.2, respectively. At the market-share level, relative sales of products are also positively related to relative cumulative minutes of detailing; this elasticity is typically in the range of 0.7 to 0.9. Together these results imply that the marketing efforts of firms in the antiulcer drug market had substantial effects, in terms of affecting both market shares and the size of the overall industry.

Third, a somewhat unexpected result we obtained is that at the industry level, the rate of depreciation of stocks of both minutes of detailing and medical journal advertising was estimated to be zero. We believe that this result reflects the fact that market-expanding marketing primarily involves informing physicians about the usefulness of this class of drugs, and that once a physician begins prescribing these drugs, he or she is not likely to forget about their existence and stop prescribing them. By contrast, at the level of market shares a rather different picture emerges. In particular, in the four-product market

gamet, Zantac, Pepcid, and Axid), we find that the market-share impact of stock of detailing minutes deteriorated at an annual rate of around 40 per-t, reflecting perhaps a more rivalrous content of marketing efforts.

The remarkable growth in the market share of Zantac over time can be par-ly explained, then, by the very substantial marketing efforts undertaken by xo. However, pricing policies also had an impact. Zantac gained share over amet in part because the price premium commanded by Zantac declined n about 56 percent in 1983 to only 25 percent in 1993. Our estimates of ıstry-price elasticities range from about -0.7 to -0.9, while estimates of s-price elasticities between any pair of the four products are about 0.7.

nother set of important factors affecting sales of antiulcer drugs concerns luct-quality attributes. At the industry level, the evidence suggests that the of the market was enlarged considerably when the FDA granted approval he GERD indication—a condition that occurs in a relatively large popula-

At the market-share level, we find that when a product had a GERD-oval advantage relative to other products, its market share increased. Thus her reason why Zantac fared so well in the marketplace is that for quite time it was the only product that had received FDA approval for the ment of GERD. Another variable affecting market share significantly is umber of adverse interactions with other drugs reported to the FDA. On ıccount Tagamet fared relatively badly (by 1993, Tagamet had twelve drug ıctions, Zantac and Axid had only one, and Pepcid had none). Thus Zan-so enjoyed advantages from this product-quality characteristic. An unex-d result we obtained, however, was that dosing frequency did not appear ect market shares in a statistically significant manner.

ıally, we found that, as in many other markets, order-of-entry effects are substantial. In particular, holding constant price, marketing efforts, and ct quality relative to the nth product, the $(n + 1)$th entrant can expect forty percent lower sales.

results of this paper are of considerable interest in the current health-eform debate. Critics of the pharmaceutical industry have argued that detailing is merely aimed at market share and is socially wasteful. Some uggested placing ceilings on the marketing activities of pharmaceutical but our findings demonstrate that this could have negative social welfare ts. The findings in this paper suggest that marketing efforts also play a nportant role in the diffusion of information to physicians, although the to which this is true probably declines somewhat as the number of prod-a market increases. Moreover, our results suggest that in order to over-pioneer-product advantages, later entrants have found it necessary to se more intensively. An implication of these results is that if all pharma-l firms were constrained in their marketing activities, it is possible that efits would accrue primarily to the pioneer firms, at the expense of later s who would be prevented from trying to overcome pioneer-product ad-

vantages. Thus, such a policy could have anticompetitive impacts, although it would be consistent with a patent system that rewards innovation.

The research reported in this paper should be extended in a number of ways. First, although the industry and market-share equations are plausible and provide important initial evidence on the roles of marketing, price, and product-quality competition in the antiulcer market, the underlying models could be modified in a number of useful ways. The most obvious extension is to reformulate the models within an explicitly dynamic diffusion framework, such as those involving the Gompertz, logistic, or other more general diffusion-curve formulations. In such a framework, marketing and pricing policies might not only affect the long-run or equilibrium level of demand, but they might also affect the speed at which a long-run equilibrium level is approached.

As second useful extension would involve incorporating data on direct-to-consumer marketing. In 1988 SmithKline experimented with a "Tommy Tummy" television advertising campaign that was aimed directly at consumers but did not mention Tagamet by name. More recently, Glaxo has advertised in magazines and on television, suggesting that patients with heartburn and acid discomfort should see their physicians. These ads are sponsored by the Glaxo Research Institute and, consistent with FDA regulations on direct-to-consumer advertising, do not mention the Zantac product by name unless the requisite warning and other product information is also fully disclosed. Since these advertisements typically do not mention products' names, their impact is more likely to be on industry demand than on market share. Moreover, direct-to-consumer advertising may change the physician-patient information-sharing relationship, and therefore could modify the diffusion process. It would be useful to examine whether such effects have actually occurred, and by extension, how effective is direct-to-consumer marketing in the antiulcer marketplace.

Third, and perhaps most importantly, the findings of this paper suggest interesting topics in the theory of industrial organization. What is the optimal marketing strategy for firms when there are spillovers and marketing activities have long-lived impacts? What is the correspondingly optimal pricing behavior? How does this optimal behavior vary with market structure? How is the optimal behavior affected by federal tax provisions that allow the expensing (rather than amortizing) of long-lived marketing investments? What are the implications for social welfare?

Obviously, much remains to be done. We believe we have demonstrated quite clearly that marketing efforts are very important in understanding the diffusion and economic success of new products. Product quality and pricing behavior have also been shown to play important roles in the diffusion process. We hope the results of this paper contribute to this and other related research projects that enrich our understanding of the economics of new products.