



Studies in Income and Wealth
Volume 58

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The Economics of New Goods

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National Bureau of Economic Research
Conference on Research in Income and Wealth



The University of Chicago Press

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

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

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

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7

The Roles of Market Quality, and Price in the Growth and of the U.S. Anticancer Drug Industry

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7.1 Introduction

The introduction of Tagamet into the U.S. marketing of a revolutionary treatment for ulcers and the try. What distinguished the products of this new heal ulcers and treat preulcer conditions pharmaceutical basis, thereby substituting for traditional, and cosmetic surgeries. Tagamet, known medically as an H_2 -re the healing of ulcers by reducing the secretion of

A striking feature of the anticancer market is the sales (quantity, not just revenue) for over fifteen years of slowing. New prescribing habits have clearly reduced the number of physicians. Today there are a total of five Tagamet, Zantac, Pepcid, and Axid. Zantac is now world's) largest-selling prescription drug, having in 1992 of about \$3.5 billion. Moreover, Tagamet selling prescription drugs in the United States.¹

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Financial support from the Alfred P. Sloan Foundation is data support of Stephen C. Chappell, Nancy Duckwitz, and Rita and Joan Curran, Marjorie Donnelly, Phyllis Rausch, Ditas R Lowe at Merck & Co. The authors have also benefited from the Amit Alon, Ittai Harel, Michele Lombardi, and Bonnie Scou Bresnahan, Stan Finkelstein, M.D., Valerie Suslow, and Stephen

1. One hundred powerhouse drugs (1993, \$1). Incidentally, Prilosec 25th, and Axid 61st in terms of U.S. sales. In terms of

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

In terms of quality, to the extent that product-quality characteristics affect the size of the potential market, they should be included in an overall industry demand equation. We would expect that the size of the potential patient market would depend on the specific indications for which the FDA has granted approval. We shall concentrate on one particular indication, GERD, which represented an especially large potential new market, and for which the H₂-antagonists first received FDA approval relatively late in the sample. Specifically, when the FDA granted approval to Glaxo's Zantac for GERD, Zantac detailers were permitted to provide specific information to physicians concerning the treatment of GERD. This was significant, for instead of being confined to detailing to gastroenterologists who saw ulcer patients, now Zantac detailers also made calls on general practitioners who commonly saw patients having GERD symptoms. This undoubtedly expanded the potential market.

Such reasoning suggests that a dummy variable, say, GERD (taking the value of 1 following FDA approval), be employed in the overall industry demand equation. However, it is worth noting that information concerning the efficacy of drugs for different indications typically diffuses prior to formal FDA approval. The medical community is often aware of results of clinical trials prior to the FDA's reviewing the clinical-trial data and coming to a final decision concerning approval for a new indication. As a result, a great deal of prescribing is done off-label prior to the FDA's granting approval. Thus, it is not clear how reliable the GERD dummy variable will be in capturing major changes in the size of the potential patient base.

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

14. Specifically, the Fisher-Ideal price index is the geometric mean of the Laspeyres and Paasche price indexes, where each of them is computed using updated weights. New products are incorporated as soon as is feasible (i.e., in the second period of their existence, so that their first difference is calculated). For further details concerning the Fisher-Ideal price index, see Diewert (1981, 1992).

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

We therefore employ the well-known perpetual-inventory model for the *stock* of marketing effort at the end of month t (the sum of journal advertising and detailing minutes), let δ be the rate of depreciation of this stock, and let m_t be the flow of marketing effort in 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 effort in months t (m_t), that is

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

We construct separate stock measures for detailing and advertising. Unlike the typical case for capital-stock accounting, we do not establish a benchmark or "starting values" since we begin our sample in 1977, the Tagamet journal (and detailing) stocks were zero. In equation (1), one must however assume rates of depreciation for the stocks. As discussed below, we will use the historical data on sales to estimate δ econometrically, rather than assume a value.

The other major issue in measuring the effects of marketing is addressed in an innovation of this paper. Other authors have suggested that marketing is modeled as having two simultaneous effects in the market: one by all firms affecting overall market demand, and another by individual firms affecting the individual firms' market shares. We are modeling one step further here by hypothesizing that firms' marketing efforts to emphasize one of the two effects. Although the degree to which firms' marketing efforts affect overall market expansion cannot be directly observed, the effect of marketing done by firms, we now propose a method to estimate and test it econometrically.

To clarify this concept, we discuss it in the context of the Tagamet market. When SmithKline marketed Tagamet from 1977 until the entry of Zantac in 1983, they did not worry about their market share in the H₂-antagonist market, for patent secured a temporary monopoly position. From this monopoly position, their marketing for SmithKline was to convince more and more physicians of the benefits of H₂-antagonists in treating ulcer patients. They, and not the patients, reaped the rewards of having expended efforts on diffusing information about the drug to physicians, since they held 100 percent market share.

15. See, for example, Schmalensee (1972). There is a considerable, but distinct, approach that decomposes advertising into its components. For examples in the context of the pharmaceutical

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

$$(10) \quad \varepsilon_{jj} = \varepsilon_{jj}^* \Big|_{Q=\bar{Q}} + \left(\frac{\partial \ln Q_j}{\partial \ln Q} \right) \left(\frac{\partial \ln Q}{\partial \ln P} \right) \left(\frac{\partial \ln P}{\partial \ln P_j} \right),$$

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

Alternative OLS and 2SLS estimates of e_{jj}^* are given in table 7.2, while NLS and NL-2SLS estimates of the industry-price elasticity are presented in table 7.1. For the two-product market, 1993 drugstore revenue shares for Tagamet and Zantac are approximately 0.25 and 0.75. For the four-product market, these shares are approximately 0.19 (Tagamet), 0.60 (Zantac), 0.12 (Pepcid), and 0.09 (Axid). Together, these relationships imply that in the two-product context, the 2SLS estimates of the total own-price demand elasticities for Tagamet and Zantac are approximately -1.154 and -1.690 , respectively, while in the four-product market, the 2SLS estimated total own-price demand elasticity is -0.909 for Tagamet, -1.153 for Zantac, -0.820 for Pepcid, and -0.799 for Axid. Note that while these point estimates imply that some of the demand elasticities are less than one in absolute magnitude, the associated standard errors may well imply that reasonable confidence intervals include values of one and above (in absolute value).

7.6 Concluding Remarks

In this paper we have attempted to explain the phenomenal growth of the H_2 -antagonist antiulcer drug industry in the United States, as well as changes in the market shares garnered by the various products over time. Although we have examined the roles of product quality, order of entry, and price, we have focused particular attention on the role of various marketing efforts. Our framework and results can be summarized as follows.

First, marketing efforts such as detailing and medical journal advertising have long-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-period expenditures. In the context of industry demand, we distinguish between the effects of these marketing activities by the industry structure in which they originally occurred. In a monopoly market, marketing expenditures are market-expanding, for the monopolist's market share. In a market structure with k products, however, marketing expenditures become more rivalrous, and as k becomes large, we expect the "over" of a firm's marketing efforts in affecting industry demand is hypothesized, therefore, that in terms of affecting industry demand, the effects of marketing expenditures originally made in a monopoly market will tend to decline as k increases. In other words, the effectiveness of marketing in generating industry demand declines in a systematic manner.

In our empirical analysis of the antiulcer drug market, we found considerable but not quite unanimous support for this hypothesis. In estimating the impact of a monopolist's marketing expenditures on industry demand, to unity, we estimated the impact in a duopoly market to be 0.8, and in a four-product market to be 0.4. These numbers are all statistically significantly different from unity. We reject the hypothesis that the effectiveness of marketing is independent of market structure, and from zero (indicating no effect). The analysis that once there is competition, the only impact of marketing is on market share, and there is none on overall market size). In the antiulcer drug market there is clear evidence of spillovers; in fact, spillovers are considerably less than 100 percent. In most part, these spillovers decline as the number of products increases.

Second, we find that at the industry level, both current and cumulative pages of medical journal advertising have significant estimates of these elasticities are 0.5 and 0.2, respectively. At the product level, relative sales of products are also positively affected by minutes of detailing; this elasticity is typically between 0.1 and 0.2. Together these results imply that the marketing efforts in the antiulcer drug market had substantial effects, in terms of increasing sales and the size of the overall industry.

Third, a somewhat unexpected result we observed is that, at the industry level, the rate of depreciation of stocks of both current and cumulative medical journal advertising was estimated to be zero. This reflects the fact that market-expanding marketing efforts lead physicians to begin prescribing these drugs, he or she is more likely to exist and stop prescribing them. By contrast, in a monopoly market a rather different picture emerges. In particular,

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

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

Another set of important factors affecting sales of antiulcer drugs concerns product-quality attributes. At the industry level, the evidence suggests that the size of the market was enlarged considerably when the FDA granted approval for the GERD indication—a condition that occurs in a relatively large population. At the market-share level, we find that when a product had a GERD-approval advantage relative to other products, its market share increased. Thus another reason why Zantac fared so well in the marketplace is that for quite some time it was the only product that had received FDA approval for the treatment of GERD. Another variable affecting market share significantly is the number of adverse interactions with other drugs reported to the FDA. On this account Tagamet fared relatively badly (by 1993, Tagamet had twelve drug interactions, Zantac and Axid had only one, and Pepcid had none). Thus Zantac also enjoyed advantages from this product-quality characteristic. An unexpected result we obtained, however, was that dosing frequency did not appear to affect market shares in a statistically significant manner.

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

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

vantages. Thus, such a policy could have anticonglomerate implications that would be consistent with a patent system that rewards innovation.

The research reported in this paper should be extended. First, although the industry and market-share equilibrium models provide important initial evidence on the roles of marketing and product quality competition in the antiulcer market, the models need to be modified in a number of useful ways. The models need to be reformulated within an explicitly dynamic framework, as those involving the Gompertz, logistic, or S-curve formulations. In such a framework, marketing efforts would not only affect the long-run or equilibrium level of sales, but also affect the speed at which a long-run equilibrium is reached.

A second useful extension would involve incorporating direct-to-consumer marketing. In 1988 SmithKline Beecham's "Tummy" television advertising campaign that was widely discussed but did not mention Tagamet by name. More recent advertising in magazines and on television, suggesting that patients with heartburn should see their physicians. These advertisements are from the Research Institute and, consistent with FDA regulations, do not mention the Zantac product name. Product warning and other product information is also found in advertisements typically do not mention product names. It is likely to be on industry demand than on market demand. Direct-to-consumer advertising may change the physician-patient relationship, and therefore could modify the market equilibrium. It is useful to examine whether such effects have occurred. In addition, how effective is direct-to-consumer marketing?

Third, and perhaps most importantly, the findings raise interesting topics in the theory of industrial organization. What is the marketing strategy for firms when there are spillover benefits from long-lived impacts? What is the corresponding optimal behavior? How does this optimal behavior vary with market structure? What is the optimal behavior affected by federal tax provisions (such as amortizing) of long-lived marketing investments? What are the implications for social welfare?

Obviously, much remains to be done. We hope the results of this paper contribute to the understanding of the quite clearly that marketing efforts are very important in the diffusion and economic success of new products. We hope the results of this paper contribute to the understanding of the projects that enrich our understanding of the e-