"USING SURVEY DATA IN INFERENCES ABOUT PURCHASE BEHAVIOUR"

by

Anil GABA*
and
Robert WINKLER**

N° 90/80/TM

* Assistant Professor of Decision Sciences, INSEAD, Boulevard de Constance, Fontainebleau, 77305 Cedex, France.

** Duke University, Durham, NC, U.S.A..

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Anil Gaba
INSEAD
Fontainebleau, France

and

Robert L. Winkler
Duke University
Durham, NC USA

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ABSTRACT

Data from consumer surveys often include errors, and such errors can have a serious effect on inferences about purchase behavior or other activities. In this paper a model is developed for making inferences about purchase behavior based on survey data with possible errors. A likelihood analysis reveals an identification problem, which is avoided when a Bayesian approach is taken. The model is applied with purchase recall data from two previous studies, and the analysis shows that errors can have a significant impact on inferences about purchase behavior. Ignoring such errors leads to point estimates that are systematically too high in many cases and to interval estimates that are unrealistically narrow. The effective amount of information in the survey data is reduced dramatically by the presence of errors. These results have important implications for the use and value of survey data in studies of purchase behavior and in many other areas.

(ERRORS IN SURVEY DATA; BAYESIAN INFERENCE; PURCHASE BEHAVIOR; MARKETING RESEARCH)

1. INTRODUCTION

Data from consumer surveys are gathered and used frequently in marketing research to make inferences about purchase behavior. For example, consumers are often asked whether they have purchased a particular product or brand. It is recongnized in the literature that such data may be in error (e.g., see Peterson and Kerin, 1981). Consumers may intentionally misreport, may not remember their purchases accurately, or may misunderstand survey questions; answers may be recorded or coded incorrectly; and so on. Similar errors may occur in other marketing applications, such as studies of magazine readership (Clancy, Ostlund, and Wyner, 1979) and ad recognition (Singh and Churchill, 1986), as well as in other types of surveys.

Errors in survey data can have a serious effect on inferences about purchase behavior. Suppose we are interested in the proportion of consumers who purchase a given product. If errors in reported purchases lead to a tendency to overstate the incidence of purchases, then the usual estimator (the sample proportion) will be overly optimistic. An inferential model for this situation should formally consider the possibility of errors. In so doing, the model should correct for such tendencies as overstating purchase incidence. It should also reflect the fact that the additional noise (over and above the usual sampling variability in an error-free process) will reduce the precision of estimators of purchase incidence.

The purpose of this paper is to develop a model for making inferences about purchase behavior based on survey data with possible errors. The model, which has two error-rate parameters in addition to the parameter of primary interest, the proportion of consumers who purchase a given product or brand, is a generalization of a model with a single parameter for imperfect sampling from a Bernouli process (Winkler and Gaba, 1990) and an earlier model analyzed under the assumption of known error rates (Winkler, 1985). A likelihood analysis of the model reveals an identification problem, which is avoided when a Bayesian approach is taken.

The inferential model is described in Section 2, with discussions of a likelihood analysis and a Bayesian analysis of the model. Two applications with actual purchase recall data are presented in Section 3. Data from previous studies by Wind and Lerner (1979) and Parfitt (1967) are reexamined, with inferences being made about purchase behavior and errors in reported purchase behavior. A Bayesian analysis is illustrated and the impact of the errors in the data are discussed. Section 4 contains a brief summary and discussion.

2. ERRORS IN PURCHASE BEHAVIOR DATA: AN INFERENTIAL MODEL

Let p represent the proportion of consumers who purchase a given product or brand. If purchases and lack of same are reported and recorded accurately in a survey, then the data follow a Bernouli process with parameter p. However, errors in the data modify this process. Let e_1 denote the probability that a purchaser is erroneously recorded as a nonpurchaser and e_2 denote the probability that a nonpurchaser is mistakenly recorded as a purchaser. If q represents the proportion of consumers recorded as purchasers, we have

$$q = p(1-e_1) + (1-p)e_2 \tag{1}$$

and

$$1-q = pe_1 + (1-p)\,(1-e_2) \tag{2}$$

are recorded as nonpurchasers. The recording (as opposed to the actual status) of purchasers and nonpurchasers follows a Bernoulli process with parameter q instead of parameter p.

A Likelihood Analysis

Suppose that in a random sample of n consumers, r are recorded as purchasers and the remaining n-r as nonpurchasers. The likelihood function is therefore

$$l\,(r,n|p,e_1,e_2) = [p(1-e_1) + (1-p)e_2]^r\,[pe_1 + (1-p)\,(1-e_2)]^{n-r}. \tag{3}$$

If e_1 and e_2 are known, then the maximum likelihood estimate of p is

$$\hat{p} = \begin{cases} 1 & \text{if}[(r/n)-e_2]/(1-e_1-e_2) > 1, \\ [(r/n)-e_2]/(1-e_1-e_2) & \text{if } 0 \le [(r/n)-e_2]/(1-e_1-e_2) \le 1, \\ 0 & \text{if}[(r/n)-e_2]/(1-e_1-e_2) < 0. \end{cases} \quad (4)$$

Note how this differs from r/n, the mle if we ignore the possibility of errors in the data.

But we generally do not know e_1 and e_2 exactly, and we therefore should consider the likelihood as a function of three parameters: p, e_1, and e_2. Unfortunately, the maximum likelihood estimate of (p, e_1, e_2) is not unique. The likelihood function is unable to distinguish among all points (p, e_1, e_2) with the same value of q from (1). As a result of this identification problem, the likelihood attains its maximum value at all points (p, e_1, e_2) such that $p(1-e_1) + (1-p)e_2 = r/n$. For instance, if we observe 40 recorded purchases in a sample of 100 consumers, the likelihood is maximized at an infinity of combinations, including:

$p = .4,\ e_1 = e_2 = 0;$

$p = .2,\ e_1 = .2,\ e_2 = .3;$

$p = 0,\ e_2 = .4$ (e_1 can take on any value);

$p = 1,\ e_1 = .6$ (e_2 can take on any value).

Without any further information about p, e_1, or e_2, many disparate explanations for the sample results seem equally compelling.

The uncertainty introduced by the error parameters can be seen more clearly by rewriting the likelihood function in a mixture form. The likelihood function given in (3) can be expressed as

$$l(r,n|p,e_1,e_2) = \sum_{j=0}^{r} \sum_{t=0}^{n-r} \binom{r}{j} \binom{n-r}{t} p^{n-j-t}(1-p)^{j+t} e_1^{n-r-t}(1-e_1)^{r-j} e_2^{j}(1-e_2)^{t} . \quad (5)$$

Here j can be interpreted as the number of consumers who are really nonpurchasers but are erroneously recorded as purchasers, and t as the number of actual nonpurchasers correctly recorded as nonpurchasers. Thus, j of the r consumers recorded as purchasers are in fact misclassified, as are n-r-t of the n-r recorded as nonpurchasers. Of course, we do not know the values of j and t, and that is precisely what complicates our inferential problem. If we knew j and t, the likelihood would be separable in p, e_1, and e_2 as a product of three Bernoulli likelihoods. Without knowledge of j and t, we lose this separability and wind up with a mixture of products of Bernoulli likelihoods.

A Bayesian Analysis

With errors in purchase behavior data, we would expect to have some relevant prior information. In many cases, for instance, we might view extremely high values of e_1 and e_2 as reasonably unlikely. For example, $(p,e_1,e_2) = (.2,.2,.3)$ and $(.8,.7,.8)$ yield identical likelihoods because they lead to the same value of q, but we might tend to dismiss $(.8,.7,.8)$ because error rates of 70% and 80% seem very unrealistic. A Bayesian analysis enables us to formalize our prior judgements and can provide the information necessary to avoid identification problems that arise in the likelihood analysis. The prior information concerns all three parameters; information about e_1 and e_2 is potentially just as valuable as information about p in our model with errors, because it helps us to disentangle effects due to e_1 and e_2 in attempting to make inferences about p.

Beta distributions are conjugate with respect to sampling from a Bernoulli process and are viewed as satisfactory approximations for a wide variety of types of information concerning a proportion. All three parameters in our model are proportions, and we will assume that the prior density for (p,e_1,e_2) is a product of beta densities:

$$\begin{aligned} f(p,e_1,e_2) &= f_\beta(p|\alpha,\beta)\, f_\beta(e_1|\alpha_1,\beta_1)\, f_\beta(e_2|\alpha_2,\beta_2) \\ &\propto p^{\alpha-1}(1-p)^{\beta-1}\, e_1^{\alpha_1-1}(1-e_1)^{\beta_1-1}\, e_2^{\alpha_2-1}(1-e_2)^{\beta_2-1}, \end{aligned} \tag{6}$$

with α, β, α_1, β_1, α_2 and $\beta_2 > 0$. Assuming that p, e_1, and e_2 are independent a priori does not seem unreasonable in this situation.

Multiplying the prior density and the likelihood and normalizing as required by Bayes' theorem yields a posterior density that can be expressed as a mixture:

$$f(p,e_1,e_2|r,n) = \sum_{j=0}^{r}\sum_{t=0}^{n-r} w_{jt}\, f_\beta(p|\alpha+n-j-t,\ \beta+j+t)\, f_\beta(e_1|\alpha_1+n-r-t,\ \beta_1+r-j)\, f_\beta(e_2|\alpha_2+j,\ \beta_2+t), \tag{7}$$

where

$$w_{jt} = a_{jt} / \sum_{j=0}^{r} \sum_{t}^{n-r} a_{jt}$$

and

$$a_{jt} = \binom{r}{j}\binom{n-r}{t} \frac{\Gamma(\alpha+n-j-t)\,\Gamma(\beta+j+t)\,\Gamma(\alpha_1+n-r-t)\,\Gamma(\beta_1+r-j)\,\Gamma(\alpha_2+j)\,\Gamma(\beta_2+t)}{\Gamma(n+\alpha+\beta)\,\Gamma(\alpha_1+\beta_1+n-t-j)\,\Gamma(\alpha_2+\beta_2+j+t)}$$

The posterior density is a mixture of products of beta distributions. The weight w_{jt} is the posterior probability that j of the r recorded as purchasers are nonpurchasers and t of the n-r recorded as nonpurchasers are nonpurchasers. Thus, we take the possible posterior distributions under exact knowledge about misclassifications and weight them by the probabilities of the different possible combinations of misclassifications.

Since the primary objective is to make inferences about purchase behavior, the marginal posterior distribution of p is of particular interest. Integrating the joint posterior density with respect to e_1 and e_2, we get

$$f(p|r,n) = \sum_{j=0}^{r} \sum_{t=0}^{n-r} w_{jt}\, f_\beta(p|\alpha+n-j-t,\ \beta+j+t)\ .$$

This can be reexpressed as

$$f(p|r,n) = \sum_{s=0}^{n} v_s\, f_\beta(p|\alpha+n-s,\ \beta+s), \tag{8}$$

where

$$v_s = \sum_{(j,t)\ \ni j+t=s} w_{jt}$$

is the posterior probability that there are really s nonpurchasers in the sample. The posterior mean of p is

$$E(p|r,n) = \sum_{s=0}^{n} v_s \left(\frac{\alpha+n-s}{\alpha+\beta+n}\right);$$

and the posterior variance can be found from E(p|r,n) and

$$E(p^2|r,n) = \sum_{s=0}^{n} v_s \frac{(\alpha+n-s+1)(\alpha+n-s)}{(\alpha+\beta+n+1)(\alpha+\beta+n)}\ .$$

The entire posterior density f(p|r,n) provides the full representation of uncertainty about p following the sample, and in a given situation f(p|r,n) can, of course, be graphed. Note that the Bayesian model produces not just an estimate of p, but a full distribution of p.

We can also, if desired, make inferences about e_1 and e_2. Their marginal posterior densities are

$$f(e_1|r,n) = \sum_{j=0}^{r} \sum_{t=0}^{n-r} w_{jt} f_\beta(e_1|\alpha_1+n-r-t,\ \beta_1+r-j) \tag{9}$$

and

$$f(e_2|r,n) = \sum_{j=0}^{r} \sum_{t=0}^{n-r} w_{jt} f_\beta(e_2|\alpha_2+j,\ \beta_2+t)\ . \tag{10}$$

In summary, the chance of errors in purchase behavior data can be allowed for in a model of the data-generating process. However, a likelihood analysis of this model reveals an identification problem caused by an inability of the likelihood function to distinguish the relative effects of the error parameters from the primary parameter of interest, the proportion of consumers who purchase the product. Prior information can help us sort out these effects. The Bayesian model presented here uses beta prior distributions for the parameters, although in practice the analysis could proceed with any choice of prior distributions. The model enables us to make probabilistic inferences about the proportion of purchasers and about the error parameters.

3. APPLICATIONS WITH ACTUAL PURCHASE RECALL DATA

In this section we reexamine purchase recall data from two previous studies and consider inferences about purchase behavior and errors in reported purchase behavior. The first study, by Wind and Lerner (1979), collected both survey-based purchase data and diary records of purchase behavior from the same respondents. Using the diary records to validate the survey data, we can directly estimate the parameters of our model for the situation investigated by Wind and Lerner: purchases of brands of margarine. The second study, by Parfitt (1967), also involves both diary panel records and purchase recall data for one sample, and in addition purchase recall data alone are available for a second (matched) sample. In this case, we will use our model to make inferences about actual purchase behavior for the second sample. We focus on two of the products for which Parfitt collected data, instant coffee and dentifrice.

Estimates Based on the Wind-Lerner Data

Wind and Lerner (1979) used 450 respondents selected from a national subsample of a MRCA diary panel. For each respondent, margarine purchase data recorded in the household purchase diaries for June-November 1976 and survey data regarding reported margarine purchases were obtained. These data are of particular interest for our purposes because of the availability of the diary data to validate the reported purchases. This allows us to estimate the error parameters directly from the data, a luxury not generally available.

Wind and Lerner report, for each of seven brands of margarine, the proportions of respondents who purchased the brand (1) among those who reported in the survey that they purchased the brand and (2) among those who reported in the survey that they did not purchase the brand. Also, the proportion of respondents reporting purchases was given.

For each brand of margarine, let

x = proportion who purchased brand among those who reported not purchasing brand,

y = proportion who purchased brand among those who reported purchasing brand,

and b = proportion who reported purchasing the brand.

From these values, joint proportions for the four combinations of purchase behavior (purchased, did not purchase) with recall (reported purchasing, reported not purchasing) can be determined, as can the sample proportions corresponding to p, e_1, and e_2. The estimates of p, e_1, and e_2 are

$$\hat{p} = x(1-b) + yb,$$

$$\hat{e}_1 = x(1-b)/[x(1-b) + yb] \, ,$$

and $$\hat{e}_2 = b(1-y)/[(1-x)(1-b) + (1-y)b] \, .$$

The values of x, y, and b from the Wind-Lerner data and the resulting estimates $\widehat{p}$, $\hat{e}_1$, and $\hat{e}_2$ are reported by brand in Table 1. With respect to a comparison of purchase behavior and purchase recall, note that $\widehat{p}$ is below b for all brands, considerably so in some cases. The ratio of $\widehat{p}$ to b varies from .33 (for Mazola) to .85 (for Parkay). This is consistent with previous claims (e.g., Wells, 1961, 1963; Sudman, 1964a, 1964b; Sudman and Ferber, 1978) and is related to the higher estimates for e_2 (ranging from .23 to .56) than for e_1 (ranging from .11 to .32). These error rates indicate that nonpurchasers report purchasing more frequently than purchasers report not purchasing. Moreover, they suggest that the incidence of errors in the survey data is quite high; we are not talking about error rates in the neighborhood of 5-10%, but of much higher rates. These numbers make a careful analysis taking account of such errors particularly important in studies of purchase behavior.

<u>Inferences from the Parfitt Data</u>

Parfitt (1967) collected both interview purchase claims and diary data concerning purchase behavior for twelve consumer products from a sample of housewives from the Attwood Consumer Panel in Great Britain. In addition, interview purchase claims (but not diary data) were obtained from a matched sample of non-panel housewives. The data from the panel allow us to estimate the error parameters directly from the data, as with the Wind-Lerner data, and they can form a basis for prior distributions to be used in making inferences from the non-panel data.

We focus on two products, instant coffee and dentifrice. The joint and marginal proportions of interview claims (purchase/no) and panel records (buyers/non-buyers) are shown in Table 2. Based on this sample, estimates of p and b are $\widehat{p} = .57$ and $\widehat{b} = .76$ for instant coffee, $\widehat{p} = .62$ and $\widehat{b} = .71$ for dentifrice. Once again, we find that the recalled purchase incidence is higher than the recorded purchase incidence.

Estimates of error rates can be calculated from Table 2. For instant coffee,

$\hat{e}_1 = .02/.57 = .04$ and $\hat{e}_2 = .21/.43 = .49$;

for dentifrice,

$\hat{e}_1 = .05/.62 = .08$ and $\hat{e}_2 = .14/.38 = .37$.

There are differences between the two products, but in both cases nonpurchasers are reported as purchasers much more often than vice versa. The estimates of e_1 are lower than for the Wind-Lerner margarine data (which involved purchases of specific brands within a product line, as opposed to purchases of a product), but the estimates of e_2 are comparable.

Next, we consider the data from the matched sample of non-panel housewives. For instant coffee, r = 724 of n = 940 claimed they purchased instant coffee. From (1), the likelihood function is

$$l(r{=}724,\ n{=}940|p,e_1,e_2) = [p(1-e_1) + (1-p)e_2]^{724}\,[pe_1 + (1-p)(1-e_2)]^{216} .$$

If we treat the estimated error rates from the panel data as certainty equivalents, the maximum likelihood estimate of p for non-panel housewives is, from (4),

$$\hat{p} = [(724/940)-.49]\,/\,(1-.035-.49) = .59$$

On the other hand, if we do not assume that e_1 and e_2 are known, then the maximum value of the likelihood function is attained at all triples (p,e_1,e_2) satisfying $p(1-e_1) + (1-p)e_2 = 724/940$. The surface representing this set of maximum likelihood estimates for instant coffee is shown in Figure 1. This illustrates how tradeoffs among the three parameters can lead to the same (maximum) likelihood and therby points out the difficulties with a likelihood analysis.

The Bayesian model presented in Section 2 can formally represent our uncertainty about p, e_1, and e_2. For example, suppose that our prior distribution is a product of beta distributions, as in (6), with $\alpha = 11$, $\beta = 9$, $\alpha_1 = 2$, $\beta_1 = 48$, $\alpha_2 = 10$, and $\beta_2 = 10$. The prior means of p, e_1, and e_2 (.55, .04, and .50, respectively) are close to the estimates obtained from the panel data, and the prior standard deviations of .11, .03, and .11 reflect a fair degree of a priori uncertainty about p and e_2 with less uncertainty about e_1.

The resulting marginal posterior distribution for p following the non-panel sample with r = 724 and n = 940 is shown in Figure 2. For reference, the marginal prior distribution is also shown, as is the posterior distribution of p assuming an error-free process (e1=e2=0). The latter distribution is what would result from a typical analysis ignoring the possibility of errors in the data.

From Figure 2, we see that the posterior distribution has changed from the prior distribution somewhat, but not nearly as much as in the case of a model without errors. The errors represent a considerable source of noise in the data that greatly reduces the impact of the data in terms of the information that is provided about p. The prior distribution admits values of p from roughly .25 to .85. After a sample of 940 housewives, we still fell that p could be as low as .30 or as high as .75. The shift from the prior standard deviation of .11 to the posterior standard deviation of .08 is roughly equivalent to the shift that would be expected from a sample of size 16 if the sampling could be done without error. In this case, then, the sample of 940 housewives is roughly equivalent in impact to a sample of 16 housewives with all possible errors eliminated. If the errors were mistankenly ignored in the model, the posterior standard deviation would be smaller by a factor of about six, providing spurious accuracy.

Note from Figure 2 that the posterior distributions with and without errors in the model do not just differ in terms of how spread out they are. There is also a large difference in location, with a posterior mean of .56 for the model with errors and .77 for the model ignoring the errors. The latter model does not allow for the overreporting of purchase incidence that we observed in the Wind-Lerner and Parfitt panel data. Ignoring the errors can lead to grossly misleading results in terms of both the location and the spread of the posterior distribution.

For dentifrice, the matched sample of n=927 non-panel housewives yielded r=686 claimed purchasers. Considering the panel data on dentifrice purchases, we took a product of beta distributions with $\alpha = 12$, $\beta = 8$, $\alpha_1 = 4$, $\beta_1 = 46$, $\alpha_2 = 8$, $\beta_2 = 12$ as our prior distribution. The marginal posterior distribution for p is shown in Figure 3 along with the prior distribution and the posterior distribution under the unrealistic assumption of error-free data. As in the case of instant coffee, the posterior distributions for the two models differ considerably in both location and spread. Ignoring the possible errors yields a posterior mean that is too high and a false sense of security because of a standard deviation that is too low. The noise once again reduces the effective sample size; for dentifrice, the shift from prior to posterior as a result of the sample of 927 is equivalent to a shift that would be expected from a sample of size 21 from a process with error-free reporting.

To investigate the sensitivity of inferences about p to the choice of a prior distribution, we have conducted the analysis under a variety of prior distributions for p, e_1, and e_2. Posterior distributions for selected prior distributions are shown in Figure 4 for instant coffee and in Figure 5 for dentifrice. Some summary measures are given in Table 3. For each product, the five posterior distributions correspond to the following prior distributions:

1. the base case (the prior distribution already used in the analysis discussed earlier);
2. the base case except for a reduced standard deviation for $e_{2;}$
3. the base case except for an increased standard deviation for e_2;
4. the base case except for a diffuse (unform) prior for p;
5. diffuse (uniform) priors for all three parameters.

The last choice is included because of the common practice of including an analysis with a diffuse prior distribution in order "to let the data speak for themselves." In Figures 4 and 5, the posterior densities corresponding to a diffuse prior are almost uniform and are symmetric about p = .5. In this situation, unfortunately, such a prior leaves us with the identification problem discussed earlier, and the posterior mean of p is fixed at .50 regardless of the data because of the symmetry of the likelihood function. As a result, this prior distribution is unreasonnable here and will not be discussed further.

Considering the other four prior distributions for each product, we see from Table 3 and Figures 4 and 5 that the posterior mean of p is relatively insensitive to variations in the prior. The posterior standard deviation is more sensitive, however, increasing when p is diffuse a priori (as would be expected) and decreasing when the prior standard deviation of e_2 is reduced. The latter result occurs because reduced uncertainty about e_2 means that less information is wasted trying to disentangle p and e_2. Note that the case with a reduced prior standard deviation of .05 (from a base case of .11) for e_2 yields equivalent noise-free sample sizes for p of 53 (instant coffee) and 56 (dentifrice). These are on the order of three times larger than the equivalent sample sizes in the base case, but are still only about 6% of the actual sample sizes. In the other direction, approximately doubling the prior standard deviation of e_2 leads to equivalent sample sizes of less than 1% of the actual sample size.

The primary focus in this situation is on p, but we can also consider marginal posterior distributions of the error parameters. In our examples, these posterior distributions are very close to the corresponding prior distributions. For the base case with instant coffee, the difference between posterior and prior mean is zero for e_1 and .01 for e_2, and the ratio of posterior to prior standard deviation is .96 for e_1 and .76 for e_2. The results for dentifrice are similar, and these results are quite robust to reasonable variations in the prior parameters.

Our analyses indicate the importance of prior information in making inferences from survey data when we expect that errors are present in the data. At a basic level, the typical fallback position of a diffuse prior is not viable here because of the identification problem. With non-diffuse priors, posterior point estimates may not be highly sensitive to variations in the prior, but the degree of uncertainty surrounding such estimates does seem to be reasonably sensitive. As for the error rates, even substantial samples in our examples cause only minor revisions in the distributions of e_1 and e_2. To the extent that new data do not prove very informative about the error rates, the prior distribution takes on added importance. Furthermore, in our examples some prior data regarding the error parameters were available; in actual applications such data often will not be available, placing an even greater burden on subjective judgements concerning the error rates and the proportion of interest. Some might say that this is unfortunate, but it is better to assess a prior distribution carefully and do a formal analysis (including sensitivity analysis) than just to resort to hand-waving.

4. SUMMARY AND DISCUSSION

Errors in purchase recall data and other self-reported purchase data can be caused by respondents themselves (through intentional or accidental misrepresentation) or by other sources (mistakes in recording, coding, etc.). Evidence, including the data sets analyzed here, indicates that the frequency of such errors can be substantial. In this paper, we have presented a model for making inferences about purchase behavior based on survey data with possible errors and have illustrated the model by applying it to purchase data from previous studies. The model enables us to take into account the impact of errors in a formal manner when making inferences about the proportion of consumers who purchase a given product or brand. The output of primary interest from the model is a posterior distribution of this proportion. Of course, summary measures of this posterior distribution can be used to generate point and interval estimates if so desired. In addition, posterior distributions of error rates can be determined.

The analysis of purchase data presented in Section 4 shows that errors can have a significant impact on inferences about purchase behavior. Using standard procedures that ignore such errors can result in misleading inferences in terms of both the location and dispersion of probability distributions of the proportion of consumers purchasing a product or brand. This translates into point estimates that are systematically too high or low (depending on the relative size of the two error rates) and interval estimates that are unrealistically narrow. Another implication of errors is that the effective amount of information in the survey data can be reduced dramatically; in our examples surveys of over 900 consumers led to estimates with precision comparable to that attainable from error-free samples of around 20 consumers.

Our results have important implications for the use of survey data to make inferences about purchase behavior. One obvious suggestion is to make every effort to reduce the error rates in order to prevent loss of information. Some ideas along this line are reviewed in Peterson and Kerin (1981). There is probably a limit to the degree to which errors are likely to be reduced, however. Therefore, it is important to consider the error rates in making inferences, using models such as the one presented here. The necessary prior distributions of error rates may be difficult to assess, but attempting to do so formally seems preferable to mere hand-waving about the potential influence of errors on inferences in a given situation. Moreover, since errors effectively lead to considerable loss of information, they should be taken into account in the design of surveys to gather purchase data. Errors cause drastic reductions in the value of information without corresponding reductions in its costs. Put another way, much larger samples are needed to achieve a given level of precision than in the case of an error-free process.

The data in this paper involve purchase behavior. Surveys are used for a wide variety of issues in marketing; in Section 1 we noted magazine readership and at recognition as two examples. The model developed here could be used in other situations such as these, of course. Moreover, it could be extended to deal with other factors such as nonresponse by bringing in parameters such as the probabilities of nonresponse for a person who has purchased the product and for a person who has not purchased the product. The omnipresence of errors and other factors such as nonresponse in survey data makes it important to include such factors in formal inferential and predictive analyses of survey data in marketing and elsewhere.

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Table 1. Proportions from Wind-Lerner data and estimates of p, e_1 and e_2 by brand.

Brand	x	y	b	$\hat{p}$	$\hat{e}_1$	$\hat{e}_2$
Bluebonnet	.20	.60	.72	.49	.11	.56
Chiffon	.14	.36	.44	.24	.32	.37
Fleischmann	.10	.50	.54	.32	.15	.39
Imperial	.14	.34	.56	.25	.24	.49
Mazola	.06	.27	.45	.15	.21	.39
Mrs. Filbert's	.10	.56	.38	.27	.23	.23
Parkay	.39	.63	.65	.55	.25	.53

Table 2. Proportions for instant coffee and dentifrice from Parfitt panel data.

Instant Coffee (n=940)

		Panel Records: Buyers	Panel Records: Non-Buyers	
Interview Claims	Purchased	.55	.21	.76
	No	.02	.22	.24
		.57	.43	

Dentifrice (n=927)

		Panel Records: Buyers	Panel Records: Non-Buyers	
Interview Claims	Purchased	.57	.14	.71
	No	.05	.24	.29
		.62	.38	

Figure 1. Maximum likelihood surface for instant coffee example (r=724, n=940).

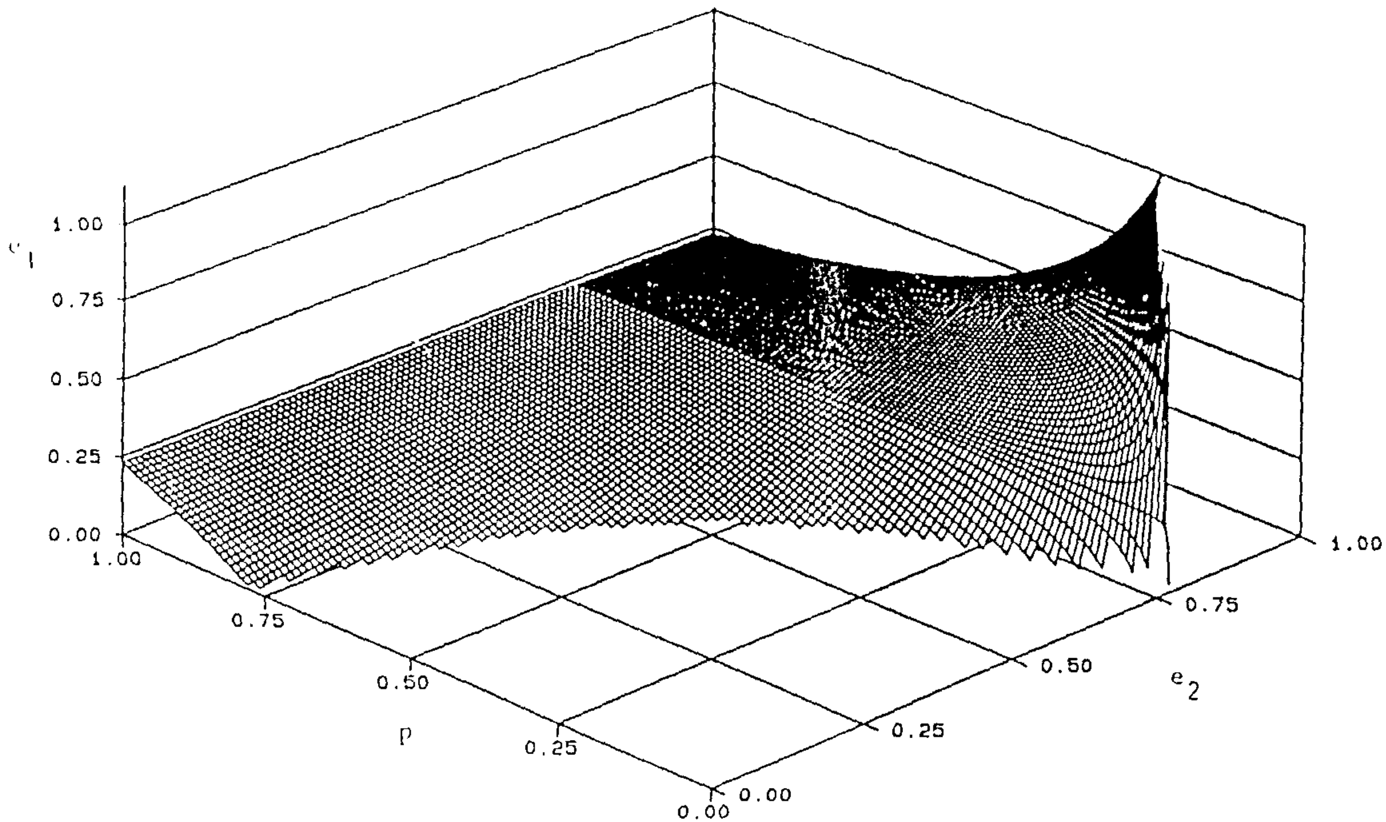


Figure 2. Prior and posterior densities for p in instant coffee example (α=11, β=9, α_1=2, β_1=48, α_2=10, β_2=10, r=724, n=940).

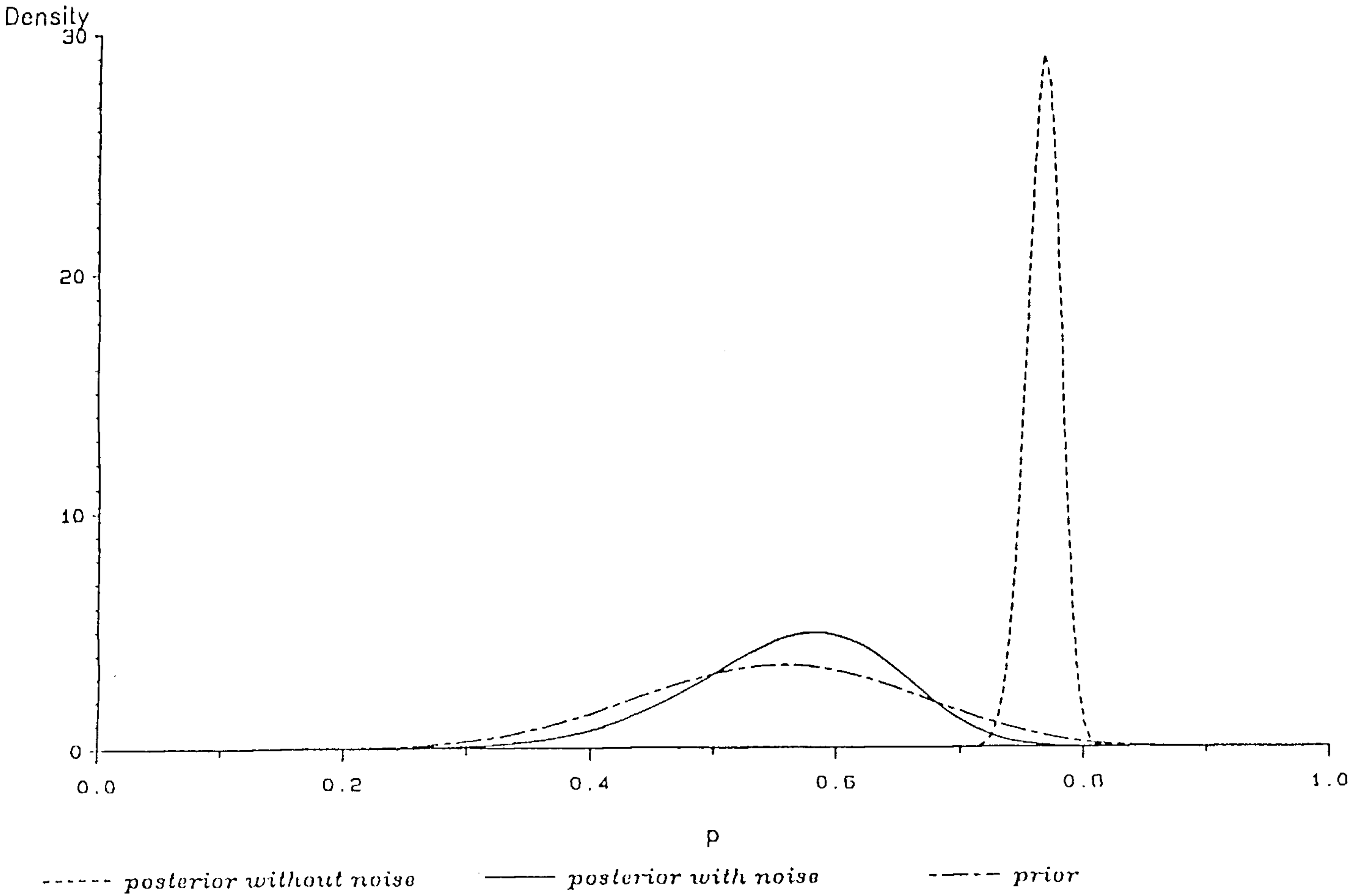


Figure 3. Prior and posterior densities for p in dentifrice example ($\alpha=12$, $\beta=8$, $\alpha_1=4$, $\beta_1=46$, $\alpha_2=8$, $\beta_2=12$, $r=686$, $n=927$).

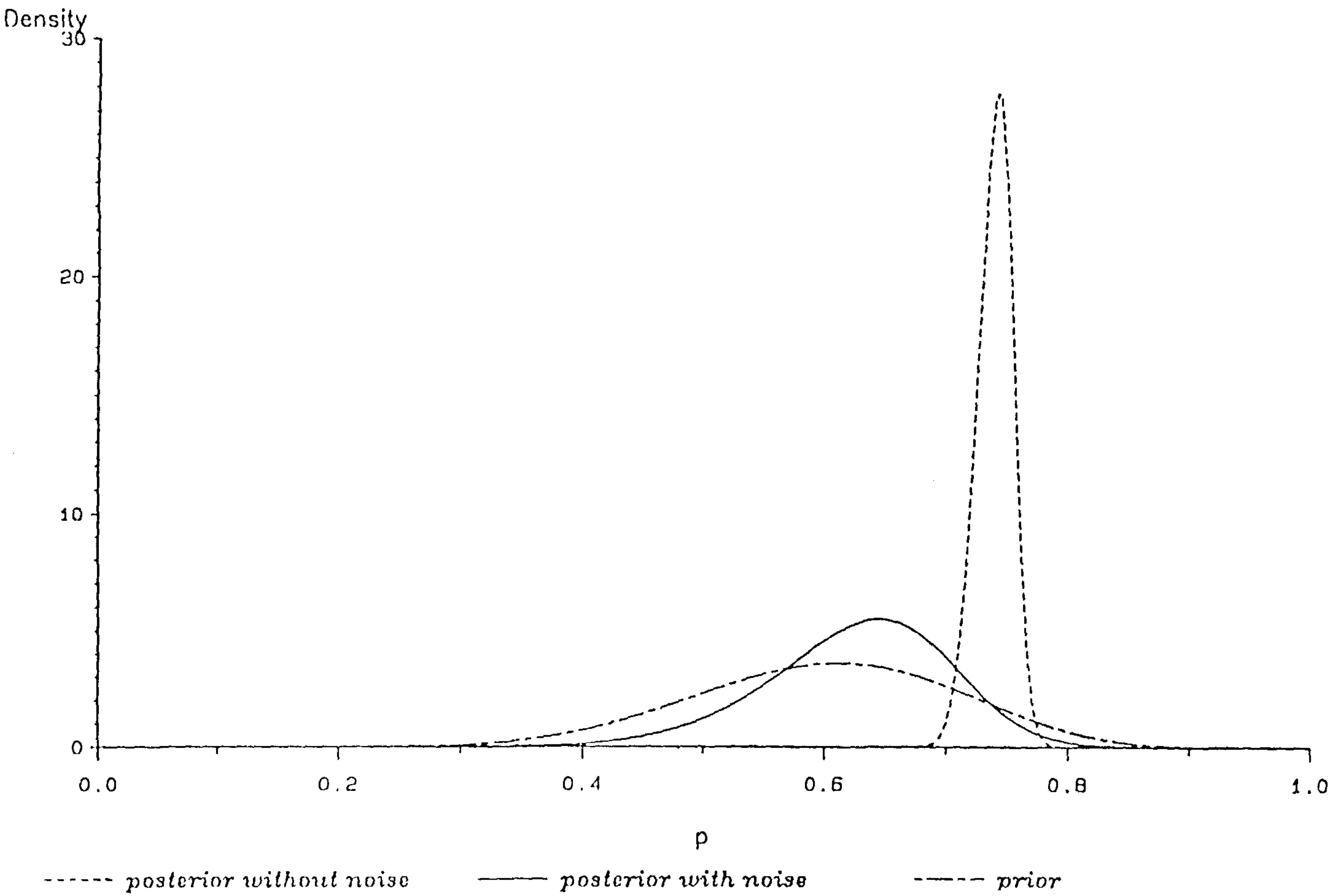


Figure 4. Posterior densities corresponding to selected prior distributions in instant coffee example.

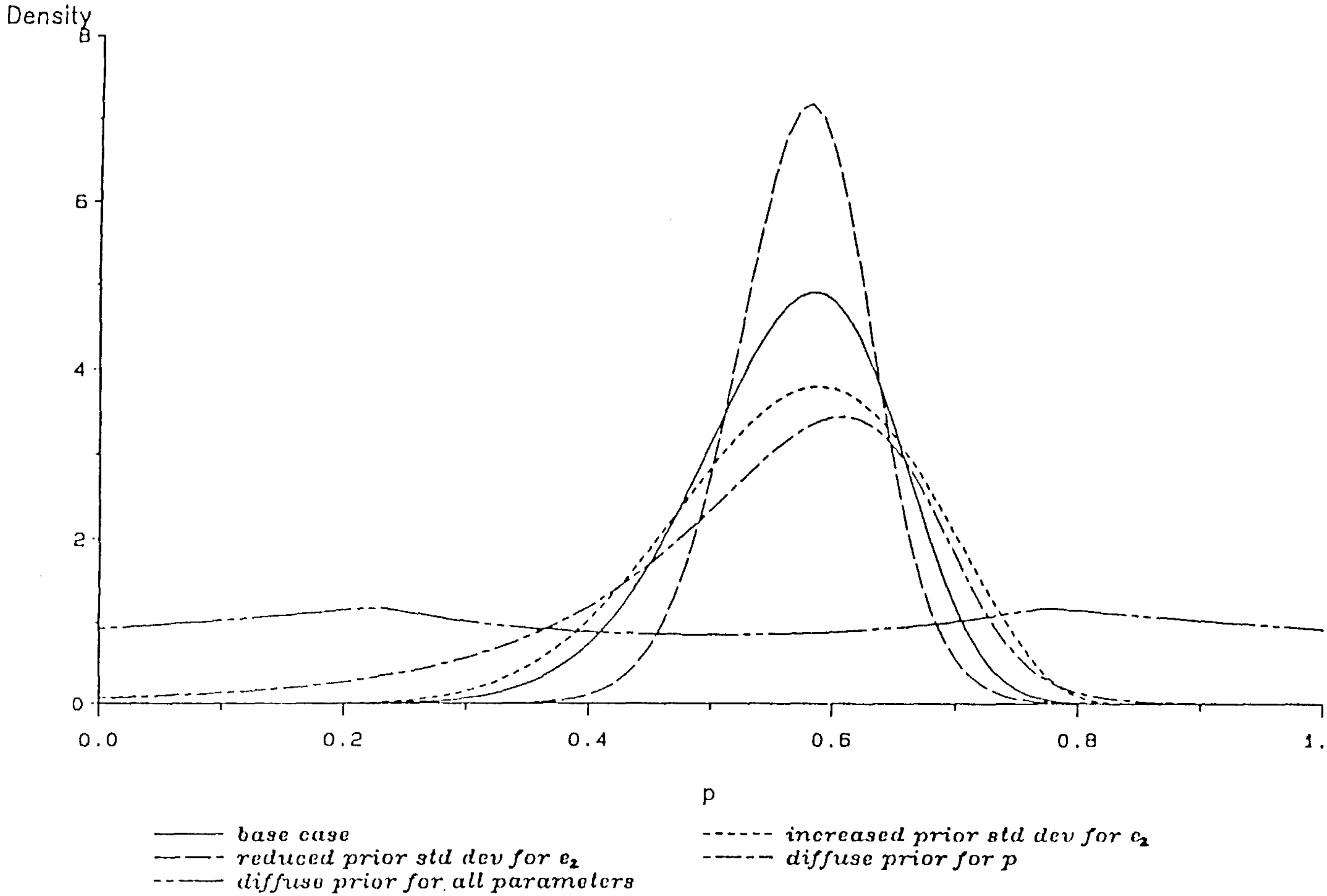
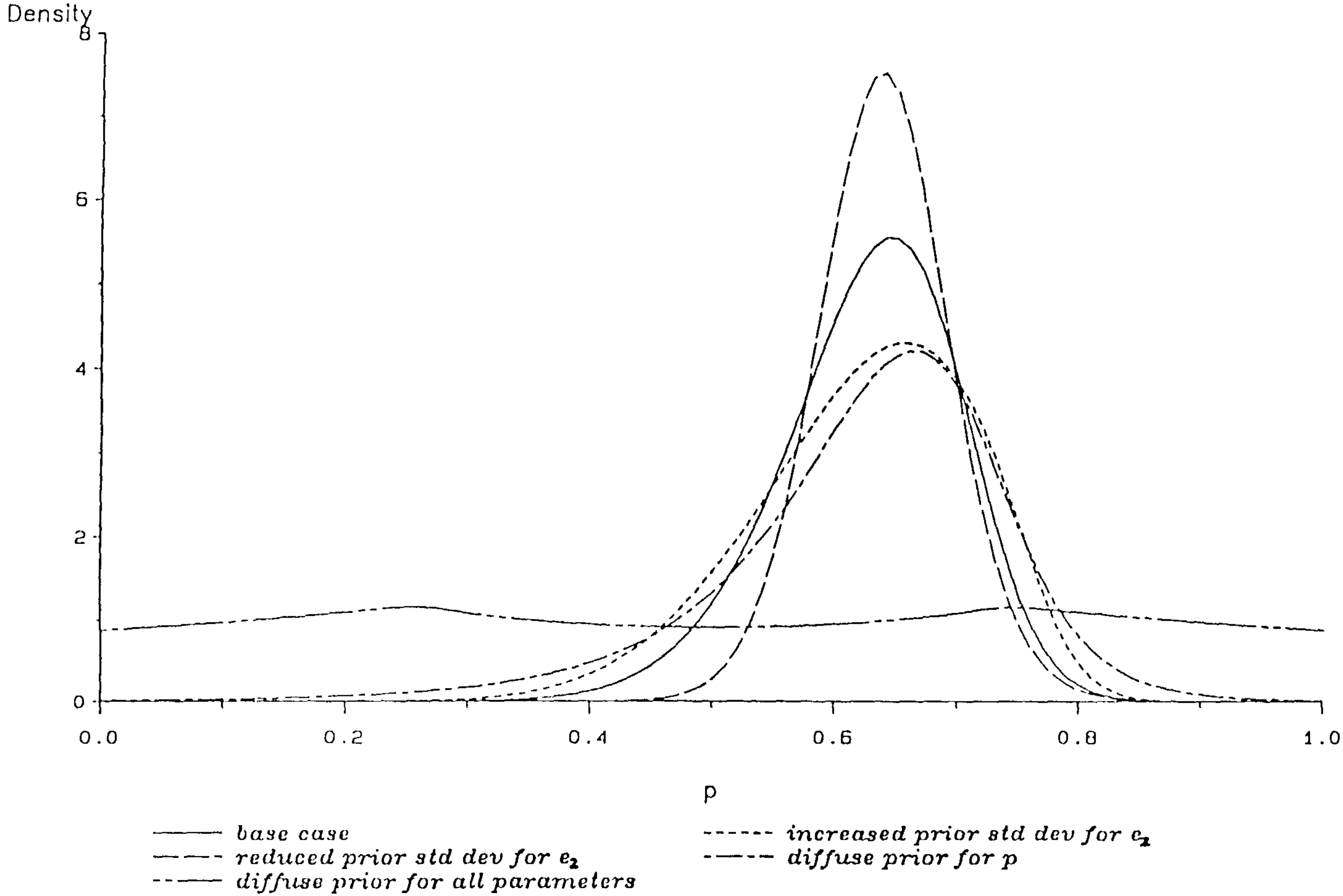


Figure 5. Posterior densities corresponding to selected prior distributions in dentifrice example.



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