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by
Wilfried R. VANHONACKER

and

Lydia J. PRICE **

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* Associate Professor of Marketing, INSEAD, Boulevard de Constance, Fontainebleau 77305, France.

** Assistant Professor of Marketing, INSEAD, Boulevard de Constance, Fontainebleau 77305, France.

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Wilfried R. Vanhonacker *

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* Associate and Assistant Professors of Marketing, INSEAD, Boulevard de Constance, 77305 Fontainebleau, France. The authors are thankful to Donald Lehmann and Gerry Tellis for sharing their extensive data-bases.

On the Practical Usefulness of Meta-Analysis Results

ABSTRACT

The natural experiment hypothesis underlying meta-analyses and their extensive designs give rise to many empty or scarcely populated cells. The implications of this improper sampling can be severe when the results are incorporated as prior knowledge in a Bayesian estimation framework. Using existing meta-analyses in marketing and a known recursive framework for updating estimates in linear regression models, the practical limitations of such priors are discussed and illustrated. Some suggestions are provided to alleviate some of the problems in performing meta-analyses.

Key Words: META-ANALYSIS; SAMPLING; BAYESIAN UPDATING.

1. INTRODUCTION

In recent years, researchers have come to acknowledge the need to take stock of the empirical results published over the years and see what knowledge, if any, has been accumulated. A common approach to perform this task has been meta-analysis (Glass, McGaw, and Smith 1981, Hunter, Schmidt, and Jackson 1982). In meta-analysis, independently-executed studies are viewed as imperfect replications of one overall but unplanned experiment. Analysis of variance or linear regression is then used to uncover systematic variation related to study design, data characteristics, etc. Examples in the marketing research literature are Assmus, Farley and Lehmann (1984), Farley, Lehmann, and Ryan (1982), Hite and Fraser (1988), Houston, Peter, and Sawyer (1983), Reilly and Conover (1983), Sultan, Farley, and Lehmann (1988), Churchill, et. al. (1985), Churchill and Peter (1984), and Tellis (1988).

Using the empirical study as a unit of analysis, meta-analysis has been used in two ways (Kemery, Mossholder, and Dunlap 1989). First, it has been used descriptively to summarise results from many studies. Second, meta-analysis has been used inferentially to make statements about sources of variance between study results. Correct inference regarding relationships between variables across contexts (i. e., transportability issue) requires proper sampling. From the perspective of the natural experiment underlying meta-analysis, the question of whether the parameter space has been properly sampled is a relevant and important one. The authors of meta-analyses generally recognise the experimental imperfectness of the design, but seem to implicity suggest that the answer to the question is inconsequential to their results.

One study which explicitly addresses an aspect of sampling is Rust, Farley, and Lehmann (1988). They investigate the potential publication bias. Given the publication criteria adopted by scientific journals, the reported findings are obviously confined to a subspace (Iyengar and Greenhouse 1988, Begg and Berlin 1988). Rust, Farley, and Lehmann (1988) focus on the reliability and validity of generalizations given publication bias as a sampling constraint. Their results suggest, however, that the concern is somewhat unfounded and that publication bias is largely non-existant.

A slightly different answer might arise when one starts building on meta-analysis results, particularly when the variability within the design contains relevant information. One area of recent interest has been in the use of published empirical results in parameter estimation (Vanhonacker 1989a). Updating sample information with known estimates enables stable and efficient estimation with few data points and as such enhances the timeliness of model-based decision making. Sultan, Farley, and Lehmann (1989), Vanhonacker (1989b) and Vanhonacker, Lehmann, and Sultan (1989) contain examples where the meta-analysis results are incorporated as prior information in subsequent estimation. A similar direction is pursued in Montgomery and Srinivasan (1989). Such approaches require the explicit recognition of parameter heterogeneity and, hence, correct representation of that heterogeneity through proper sampling becomes paramount.

This paper addresses the issue of proper sampling in meta-analysis within an empirical Bayesian scheme described in Vanhonacker, Lehmann, and Sultan (1989). Specifically, the information content of empty or scarcely populated cells available for enhancing parameter stability and efficiency is assessed. In doing so, the paper establishes the practical usefulness of meta-analysis results as prior information in light of sparcity of empirical results.

2. BASIC METHODOLOGY

1. Review and Discussion

In a meta-analysis, parameter estimates of past studies are the dependent observations. The literature is searched for empirical values on a parameter of interest. Tellis (1988), for example, accumulated 422 price-response estimates. A set of variables are defined subsequently which might explain systematic differences in these estimates across studies. Those independent variables are viewed as the design variables of the natural experiment. In other words, the estimates of the past studies are viewed as sample points within the "imperfect" experiment whose design is defined by the independent measures. These independent variables can contain design characteristics of the original studies (such as, e.g., time period of observation, estimation method used, model specification), data characteristics (such as, e.g., data interval, sample size, national setting), and other variables. Interpreted alternatively, these variables specify design cells and identify to which cell each of the past estimates belongs.

Whether the analysis is performed with ANOVA (as in, e.g., Assmus, Farley, and Lehmann 1984) or regression (as in, e.g., Tellis 1988), a basic linear model underlies the methodology which can be expressed as (using matrix algebra notation)

$$\hat{\beta} = Zc + \varepsilon \qquad (1)$$

where $\hat{\beta}$ is a column vector which contains the parameter estimates of the previous studies, Z is a design matrix, c is the parameter vector, and ε is a vector of disturbances. The columns of matrix Z correspond to the design variables identified to capture systematic variation in the published estimates. Accordingly, each row contains the design profile of the past study whose parameter estimate is in the corresponding position in vector $\hat{\beta}$. That profile vector also identifies the cell of the natural experiment to which that study belongs. Hence, grouping of the studies on profile similarity gives a quick reading of sampling frequencies.

The disturbance term ε has a complex structure as it recognizes two error components: one is the error of the estimate (i.e., $\hat{\beta}_i - \beta_i$ for all i); the other is the sampling errors of the individual studies relative to the cell means (i.e., $\beta_i - \bar{\beta}_j$ for all i and j) where j denotes the cell to which past study i belongs) which characterises the random coefficient assumption implicit in meta-analysis. Note that the systematic variance captured by Z is the systematic variance in those cell means ; in other words, the cell means are a linear combination of the columns in Z. The statistical properties of ε were derived and discussed in Vanhonacker, Lehmann, and Sultan (1989). For the purpose of this discussion, it suffices to know that $E(\varepsilon) = 0$ and $E(\varepsilon\varepsilon') = \Delta$ where E denotes the expectation operator. When the meta-analysis focuses on a single parameter (as is commonly the case), Δ is a diagonal variance-covariance matrix. With these disturbance characteristics, Generalised Least Squares (GLS) estimates can be obtained for c as $\hat{c} = (Z'\Delta^{-1}Z)^{-1} Z'\Delta^{-1}\hat{\beta}$. These estimates measure the extent to which the selected design variables contained in the columns of Z describe the systematic variance in the parameter estimates of the past studies.

The $\hat{c}$ estimate can now be used in formulating a prior on the parameter of interest in a new study. Suppose y_o and X_o contain, respectively, the sales and sales predictor observations in a new market response model. One of the columns in X_o might, for example, contain advertising observations. If a meta-analysis was done on the advertising response parameter (as the advertising elasticity in Assmus, Farley, and Lehmann 1984), then $\hat{c}$ of the analysis could be used to provide a prior value for the advertising response parameter in the new sales response study. Specifically, the prior $b_o = z_o\hat{c}$ could be obtained where z_o is a row vector which describes the profile of the new study in terms of the design variables contained in Z.[1]

Prior $b_o = z_o\hat{c}$ can be written as $b_o = D\hat{\beta}$ where $D = (Z'\Delta^{-1}Z)^{-1}Z'\Delta^{-1}$. Vanhonacker, Lehmann, and Sultan (1989) show that this prior can be expressed further as

$$b_o = z_o \, De \, \beta_o + z_o \, D \, \bar{\beta}_\Delta + u \qquad (2)$$

where e denotes a vector containing all ones, $\bar{\beta}_\Delta$ denotes a vector containing the difference between the cell mean corresponding to a specific past study and the mean of the cell to which the new study belongs (hence, for past studies whose profile is identical to z_o, the corresponding entries in $\bar{\beta}_\Delta$ are zeros), and u denotes a disturbance term. Prior (2) can be incorporated in an expanded system as

$$\begin{bmatrix} y_o \\ b_o^* \end{bmatrix} = \begin{bmatrix} X_{o1} \\ 0 \end{bmatrix} \beta_1 + \begin{bmatrix} x_{o2} \\ z_o De \end{bmatrix} \beta_o + \begin{bmatrix} u_o \\ u \end{bmatrix} \tag{3}$$

with $X_o = \left[X_{o1} \mid x_{o2} \right]$

where x_{o2} is a column vector containing the observations on the predictor whose corresponding parameter has been investigated in a meta-analysis, and

$$b_o^* = b_o - z_o D\bar{\beta}_\Delta \tag{4}$$

An updated estimate of β_o can be obtained using GLS on (3).

2. What information is contained in b_o^* ?

The prior value b_o^* incorporated in (3) is based on the expression

$$b_o^* = z_o D\, e\, \beta_o + u.$$

Accordingly, b_o^* is an adjustment over b_o. Since $D\bar{\beta}_\Delta$ can be interpreted as a least squares estimate of the design matrix Z on $\bar{\beta}_\Delta$, the predicted value b_o is adjusted for differences in cell means. It is actually adjusted in the direction of the mean of the cell to which the new study belongs. When Z contains a constant (i.e., an intercept term or the first-column entries are all equal to one), the expected value of b_o^* is equal to that mean if $\hat{c}$ is an unbiased estimate of c (The proof is given in Appendix 1). Moreover, since $z_o De$ equals 1 in that instance, the expanded system in (3) becomes a straightforward Goldberger-Theil estimator (see, e.g. Rao and Yamada 1988) where the prior is the mean of the cell to which the new study belongs. This result is intuitive as the relevant information is confined to that cell. Nevertheless, this has not been fully recognised in previous studies.

This result raises serious questions in relation to the scarcity issue charaterizing unplanned natural experiments. First, is $\hat{c}$ an unbiased estimate of c? Second, what does one do when the new study belongs to an empty cell? One would be hard pressed to show that $\hat{c}$ is an unbiased estimate of c. With empty cells and scarcely populated cells (and, hence, the likelihood of improper sampling within these cells), it is almost certain that some biases will occur. Note that by applying a coding scheme in the design matrix Z such that all entries in z_o are zeros except the intercept, the biases become less relevant. Specifically, biases in the grand mean (the estimated intercept term in $\hat{c}$) would be the only ones carried over into the prior (see expression 1-2 in Appendix 1).

The second question relates to which prior values to use when the cell to which the new study belongs is empty. In this instance, b_o^* in (4) cannot be computed and alternative ways to derive a prior value will have to be pursued. One approach, advocated in Sultan, Farley, and Lehmann (1989), is to use the predicted value $b_o = z_o\hat{c}$ and incorporate that value into the traditional Goldberger-Theil representation

$$\begin{bmatrix} y_o \\ b_o \end{bmatrix} = \begin{bmatrix} X_{o1} \\ 0 \end{bmatrix} \beta_1 + \begin{bmatrix} x_{o2} \\ 1 \end{bmatrix} \beta_o + \begin{bmatrix} u_o \\ v \end{bmatrix} \qquad (5)$$

where v is a disturbance term. This is a recursive representation of a typical Bayes estimator and an updated estimate for β_o can then be derived using GLS on (5).

Given that $\hat{c}$ is likely to be biased as discussed above, the prior value $b_o = z_o\hat{c}$ will be biased and that bias will be carried over into the updated estimate. To the extent that the bias is significant, this approach might not be advisable and alternative approaches have to be devised. The approach suggested here is to reduce the design until at least one past study is in the corresponding cell and then proceed with (3). This approach not only addresses the second question directly but also provides at the same time potential for reducing the bias in $\hat{c}$.

There are two ways to reduce the design of a meta-analysis. One way is to recode the design variables in such a way as to collapse some levels. Looking at the coding schemes in Assmus, Farley, and Lehmann (1984) and Tellis

(1988), this has already been done to some extent, although with different objectives in mind. The other way is to delete some of the design variables. (i.e., reduce number of columns in Z). This is the approach suggested here in reducing the design. One theoretical issue in favor of this type of reduction is that because of the orthogonality of the design variables, deleting one or more variables will not bias the c estimates of the remaining design variables. Further justification for such a reduction is provided in the framework of an empirical illustration. One has to keep in mind, however, that reduction and recursive estimation following (3) will not necessarily eliminate the bias in $\hat{c}$. Incorporating the mean of the corresponding cell as prior into (3) will confine the bias to the sampling characteristics within the cell to which the new study belongs; those sampling characteristics might be enhanced through design reduction. Hence there is potential for improvement, but it is not guaranteed.

3. EMPIRICAL ILLUSTRATIONS

1. Representation and Priors

The original data bases underlying the meta-analysis on advertising elasticities by Assmus, Farley, and Lehmann (1984) and the meta-analysis on price elasticities by Tellis (1988) were obtained to illustrate some of the concerns and issues raised above. Furthermore, they provide an opportunity to illustrate some of the practical suggestions in a rich empirical framework.

The meta-analysis reported in Assmus, Farley, and Lehmann (1984) incorporated 128 advertising elasticity estimates and 25 design variables. Using their original coding scheme, the regression results are shown in Table 1. That table also contains the results for a reduced design and the profile vector (z_o) of a new data set. The reduced design was obtained by deleting the least statistically significant variables in the original (full) design. The stopping rule was such that the cell to which the new data set belonged had one prior observation. In other words, the reduced design was such that design matrix Z had at least one row identical to z_o. The meta-analysis reported in Tellis (1988) incorporated 422 price parameter estimates and 21 design variables. The regression results using the original coding scheme are contained in Table 2.[2] Again, a reduced design was estimated using the same approach as discussed above. Overall, the results are in line with what was reported in the original studies. There are some minor deviations which are likely to be a direct result of the coding scheme and/or the sample used. For example, Tellis (1988) confined himself to 368 "usuable" results where the estimates in Table 2 are based on 421 prior estimates (i.e., one prior study of the entire data base was dropped because the price response parameter was missing). For the substantive interpretation of the results in Tables 1 and 2, the reader can refer to the original publications.

TABLE 1

META-ANALYSIS REGRESSION RESULTS: SHORT-TERM ADVERTISING ELASTICITY

Variable	Original Assmus, Farley, Lehmann (1984) Design		Reduced Design		Design Profile (z_o) New Data Set	
	Parameter Estimates	(Standard Error)	Parameter Estimates	(Standard Error)	(1)[a]	(2)[b]
Intercept	0.3790	(0.1699)	0.3432	(0.0554)	1	1
Dependent	-0.0039	(0.1011)	0.0517	(0.0538)	1	1
Variable	0.1203	(0.1046)	0.0517	(0.0597)	0	0
Advertising	-0.0986	(0.1184)			1	
Variable	-0.0140	(0.0647)			0	
Mature Product	-0.0146	(0.0884)			1	
Carry Over	-0.2471	(0.0747)	-0.1773	(0.0432)	1	1
Other Variables	-0.0338	(0.1027)			-1	
Price	-0.0198	(0.0849)			1	
Exogenous Variables	-0.0791	(0.0542)	-0.0729	(0.0098)	-1	-1
Estimation	-0.1361	(0.0681)	-0.0570	(0.0400)	1	1
Method	0.0622	(0.1044)			0	
	0.0857	(0.1269)			0	
Pooled Data	-0.1386	(0.0785)	-0.0768	(0.0088)	-1	-1
Multiplicative Model	-0.1565	(0.1073)	-0.1242	(0.0390)	1	1
Media Aggregated	-0.1517	(0.1285)	-0.0282	(0.0351)	1	1
TV Advertising	-0.0626	(0.0655)			-1	
Frequently Purchased	0.0230	(0.0619)			1	
Product	-0.0419	(0.0736)			1	
Category	0.0264	(0.0616)			-1	
	-0.0429	(0.1024)			-1	
National	-0.0709	(0.0888)	-0.0741	(0.0512)	1	1
Setting	0.1620	(0.1983)	0.2670	(0.0745)	0	0
Brand Level	0.0305	(0.1078)			1	
Temporal	-0.0226	(0.1215)			0	
Aggregation	-0.1271	(0.0811)			1	

[a] Original (full) design profile.

[b] Reduced design profile.

TABLE 2

META-ANALYSIS REGRESSION RESULTS : PRICE ELASTICITY

Variable	Original Tellis (1988) Design		Reduced Design		Design Profile (Z_o) New Data Set	
	Parameter Estimates	(Standard Error)	Parameter Estimates	(Standard Error)	Data Set 2 (1)[a]	(2)[b]
Intercept	-7.3426	(5.2448)	-3.1403	(4.0463)	1	1
Quality	-3.0202	(1.8112)	-2.2420	(1.6740)	0	0
Distribution	-0.5241	(1.5319)			0	
Advertising	2.5397	(1.6258)	2.1453	(1.2220)	1	1
Promotion	2.5069	(2.2994)			0	
Other Variables	-2.2103	(1.3876)	-1.1091	(1.1952)	0	0
Lag Dependent	-0.8036	(1.2693)			1	
Lag Independent	0.6473	(2.1850)			0	
Functional Form	0.1253	(0.4291)			1	
Dependent Variable Definition	0.6413	(0.5170)			0	
Price Variable Definition	0.2862	(0.5046)			0	
Estimation Method	-0.2688	(0.4874)			1	
Durable	3.4431	(1.9884)	3.5850	(1.7761)	0	0
Product Class	-0.7371	(0.3192)	-0.6466	(0.2589)	1	1
Product Life Cycle	-0.1267	(0.9168)			3	
National Setting	-0.3443	(1.1405)			1	
Data Interval	1.0126	(0.5560)	0.5795	(0.3941)	3	3
Data Type	-4.1428	(0.8362)	-3.8226	(0.6797)	2	2
Elasticity	6.9851	(1.8734)	4.8267	(1.4964)	1	1
Data Source	2.6727	(1.2453)	2.3882	(0.9769)	2	2
Data Level	2.0123	(2.6002)			1	

[a] Original (full) design profile.

[b] Reduced design profile.

Summary statistics of the samples are shown in Table 3. The representation results clearly illustrate the problem of empty cells. For both meta-analyses the large majority of cells did not have any prior estimates. Even after reduction, many cells remain empty. For the remaining cells, the distribution is rather uneven (see Appendix 2). For example, in Tellis (1988)'s data base, there are 52 prior estimates (12% of the total sample) which belong to the same cell. This might be a result of a "researcher" bias. Most applied researchers favor certain model specifications and estimation methods. Hence, their estimates (even from different publication sources) might end up in identical cells. Actually, in the Tellis (1988) data base, 28% of all price response estimates come out of Lambin (1976). All 52 estimates in that highly populated cell come out of that subset.

The prior values derived for the price and advertising elasticities are shown in Table 4. Two sets of results are shown. The first set are the predicted priors $z_o\hat{c}$, using the design profile z_o for the new data set and the $\hat{c}$ estimate. For the full design, these predictions are for empty cells (see Table 3). The advertising elasticity value of -0.3051 and the price elasticity of 1.8835 have no face validity. This clearly illustrates the biases discussesd above. For the reduced design, the advertising elasticity prior of 0.0839 is intuitively reasonable, but the price elasticity prior is still positive. Relative to the corresponding advertising elasticity results, only a single prior estimate belongs to the cell to which both new data set belongs (see Table 3); hence, the predicted prior is driven primarily by sample information not immediately relevant. Moreover, biases are at work and could be attributed to many different origins, including the uneven distribution over and underrepresentation of the various cells in the design. The b_o^* values of 0.0325 for the advertising elasticity and -2.3360 for the price elasticity have the correct sign and seem intuitively reasonable.

TABLE 3
REPRESENTATION AND SUMMARY STATISTICS

	Short-Term Advertising Elasticity (Assmus, Farley, & Lehmann 1984)	Price Elasticity (Tellis 1988)
Sample: * Size	128	421
* Mean	0.2224	-1.7600
Representation:		
* Total Number of Cells		
- Original Design	2.6542×10^{6}	1.8208×10^{10}
- Reduced Design	1152	26880
* Number of Cells with at Least One Observation (Range of Membership)		
- Original Design	43 (1 - 26)	209 (1 - 15)
- Reduced Design	27 (1 - 28)	96 (1 - 52)
* Number of Equal Group Members (Group Variance)		
- New Data Set: . Original Design	0	0
. Reduced Design	2(0.000012)[a]	1

[a] Sample variance within the cell.

TABLE 4

META-ANALYSIS PRIORS

	Advertising Elasticity (Assmus, Farley & Lehmann 1984)	Price Elasticity (Tellis 1988)
* Regression Predictions $(b_o)^a$:		
- Full design	-0.3051	1.8835
- Reduced design	0.0839	2.0548
* Corrected Prior $(b_o^*)^b$:	0.0325	-2.3360

[a] $b_o = z_o \hat{c}$.

[b] $b_o^* = b_o - z_o\, D\, \bar{\beta}_\Delta$ as in (4).

These priors play a critical role in the recursive estimation. They are the anchoring points from which sample information will be added to adjust the estimates in a particular direction. Hence, irrespective of whether they are biased or not, they will impact the recursive estimate particularly when sample information is limited. The recursive estimator does not improve or correct on the statistical properties of the prior; it is simply considered a starting point. Given the dubious value of some of the prior estimates (particularly these predicted from the meta-analysis regression), misleading estimates will be derived until the sample information has totally discounted the prior. If the variability is substantial in the sample information, this might never happen This is illustrated extensively below. Moreover, just considering the prior values, the empirical evidence is already in favor of design reduction and estimation recursively according to (3) (i.e., confining prior information to the cell to which the new study belongs).

2. Recursive Estimation

The recursive estimation results are contained in Table 5. Augmenting the sample one observation at a time, two sets of advertising elasticity and price elasticity estimates are shown. The first set are the sample estimates. No prior information is incorporated at all and these estimates, particularly for large sample sizes (i.e., long-run), function as bench marks for the updated estimates. The objective of the recursive estimation methodology is to enhance parameter stability and convergence of the estimates towards that long-run value. The second set of estimates are the recursive estimates incorporating meta-analysis priors (b_o^*) on both elasticities. Hence, these results were derived from the simultaneous updating of both parameters using priors based on two independently executed meta-analyses.

For price-elasticity, the updated estimates remain locked around the prior value irrespective of the number of sample observations incorporated. As the inefficient sample observation estimates indicate (i.e., large estimated variances), the sample observations contain little

TABLE 5

ELASTICITY ESTIMATES FOR NEW DATA SET [a]

Number of Sample Observations	Parameter Estimates (Estimated Variance) Based on			
	Sample Observations[b]		Meta-Analysis Prior b_o^* on Both Parameters	
	Advertising	Price	Advertising	Price
5	0.2310(0.00)	1.7210(7.48)	0.0707(0.01)	-5.3107(0.02)
6	0.1530(0.01)	- 3.4815(12.80)	0.0639(0.00)	-5.3096(0.01)
7	0.1521(0.01)	- 3.4374(5.39)	0.0666(0.00)	-5.3081(0.01)
8	0.1544(0.00)	- 3.4914(4.67)	0.0672(0.00)	-5.3032(0.02)
9	0.1549(0.00)	- 4.0184(4.70)	0.0662(0.00)	-5.3030(0.02)
10	0.1520(0.00)	- 4.1684(4.05)	0.0650(0.00)	-5.3067(0.02)
11	0.0950(0.01)	- 3.5544(6.43)	0.0511(0.00)	-5.3080(0.02)
12	0.0462(0.01)	- 1.6317(10.70)	0.0383(0.00)	-5.3088(0.02)
13	0.0457(0.01)	- 3.5097(11.00)	0.0351(0.00)	-5.3059(0.02)
14	0.0554(0.01)	- 3.5970(9.87)	0.0390(0.00)	-5.3055(0.02)
15	0.0635(0.01)	- 4.2443(7.81)	0.0422(0.00)	-5.3032(0.02)
16	0.0582(0.01)	- 1.3461(5.05)	0.0431(0.00)	-5.3026(0.02)
17	0.0645(0.01)	- 1.0044(4.21)	0.0475(0.00	-5.3002(0.02)
18	0.0548(0.00)	- 1.0553(3.78)	0.0558(0.00)	-5.3000(0.02)
19	0.0566(0.00)	- 1.0573(3.53)	0.0592(0.00)	-5.3006(0.02)
20	0.0610(0.00)	- 1.2296(3.26)	0.0605(0.00)	-2.3341(0.00)

[a] Multiplicative sales response model with predictors advertising share, relat price, and lagged market share.

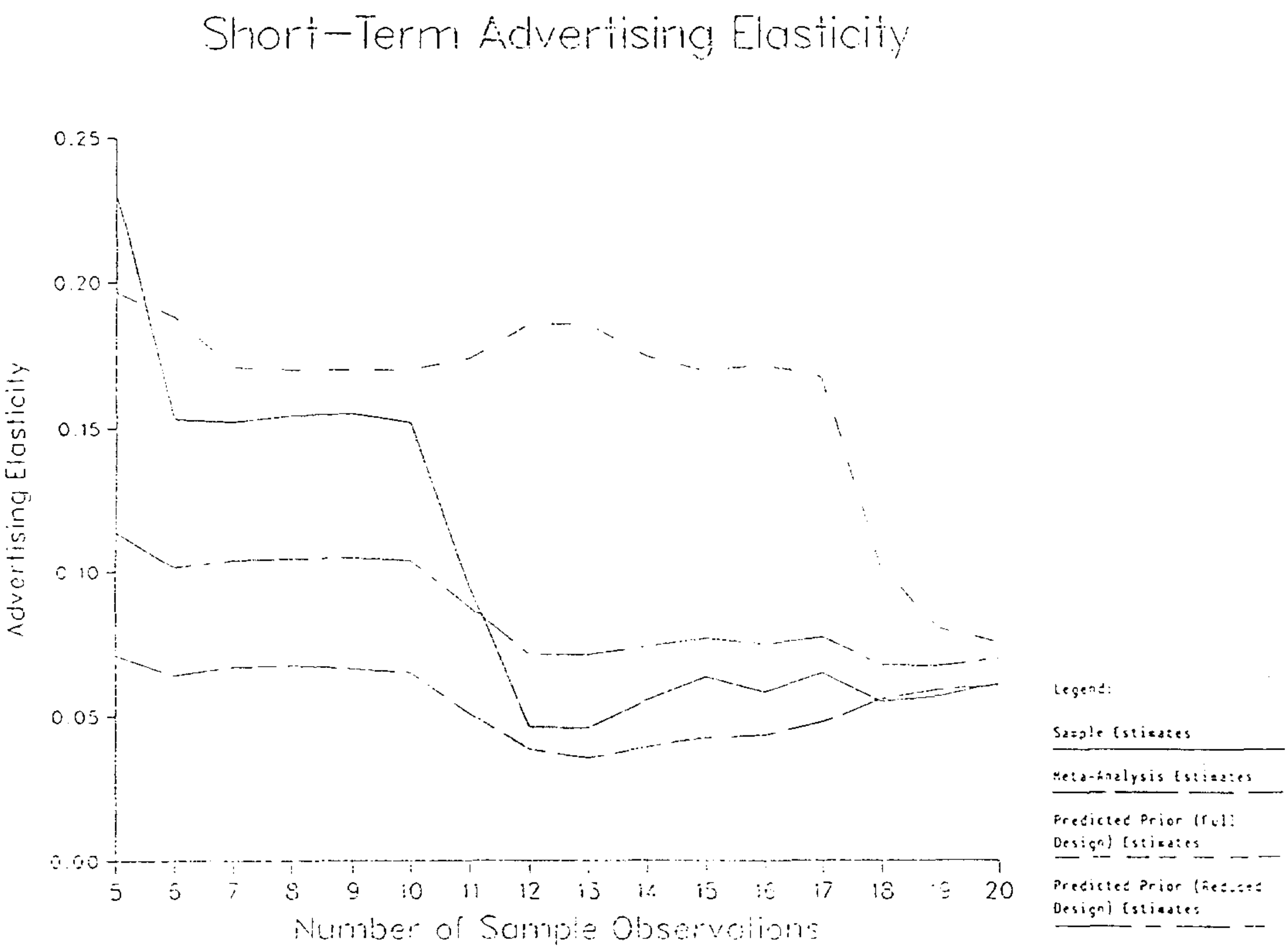
[b] OLS estimates.

information on that parameter. In other words, price is an insignificant predictor and, hence, in Bayesian updating the prior is carried forward. Although technically correct, intuitively this result is of some concern particularly since the recursive price elasticity estimates are found to be statistically significant. This merely highlights a basic problem of Bayesian estimation given incorrect priors, in which instance the expected squared error loss can be substantial (Leamer 1978).

The updated advertising elasticity estimates are immediately close to the long-run estimate and remain quite stable given varying sample sizes. With few sample observations, the updated estimates are substantially smaller than the corresponding sample estimates.

The estimation results are summarised in Figure 1. That figure also illustrates the estimates derived from (5) for both the full design and the reduced design. For $b_o = z_o \hat{c}$ with $\hat{c}$ derived from the original full design in Assmus, Farley, and Lehmann (1984), the updated GLS estimates only adjust towards the long run sample estimate once 18 or more sample observations are incorporated. Before that, the estimates are reasonably stable around a substantially large value. That value is close to the initial corresponding sample estimate. This is intuitively reasonable as the sample observations are likely to drive the updated estimates given the counterintuitive negative prior derived above. Biases, some of which have been discussed above, seem to prevent to updated estimate from further adjusting to the sample estimate as more observations are incorporated; only when 18 or more data points are incorporated is a significant adjustment noticable.

For $b_o = z_o \hat{c}$ with $\hat{c}$ derived from the reduced design (see Table 1), the updated GLS estimates are closer to the long-run sample estimate than those based on the full-design prior discussed above. Hence, design reduction seems to be justified even when the Goldberger-Theil estimator in (5) is relied upon. Still, the initial estimates are substantially larger than the long run sample estimate and only converge towards that estimate once 18 or more sample observations are incorporated. The meta-analysis prior estimates are immediately close to the long-run sample estimate and exhibit a remarkable stability relative to the other estimates. This illustration is an excellent example of potential usefulness of the suggested recursive estimator in (3) based on a reduced meta-analysis design. Further calibration of the approach is warranted before its full practical value can be established.



<u>Figure 1</u>

ADVERTISING ELASTICITY ESTIMATES

FOR NEW DATA SET

4. SUMMARY AND CONCLUSION

Meta-analysis results have been suggested as useful priors in Bayesian estimation in the hope to enhance parameter efficiency and stability given limited sample sizes. Within a non-probabilistic representation of Bayesian updating, it is shown in this paper that the prior information is confined to the prior estimates which belong to the same cell of the meta-analysis design as the new study for which stable estimates are sought. This raised the problem of empty and scarcely-populated cells inherent in the natural-experiment design underlying the meta-analysis methodology. In deriving prior estimates, analytic discussion and empirical illustration suggest that reducing the design as to enhance proper sampling in the cells is preferable over regression predictions within a full design.

FOOTNOTES

[1] In general, prior estimates could be obtained for all parameters in the model either from separate meta-analyses on each individual parameter (Vanhonacker 1989b) or a single meta-analysis on all parameters simultaneously. The latter has not been done in marketing applications but seems preferable because parameter estimates have covariance structures which might be incorporated to enhance parameter efficiency and, hence, sharpen statistical inference.

[2] Note that the results reported in Table 2 are based on Tellis (1988)'s original coding scheme which is different from the one on which his reported results are based.

APPENDIX 1 : Expression of Prior b_o^*

From expression (2), we have

$$b_o^* = b_o - z_o D\bar{\beta}_\Delta$$

or, alternatively,

$$b_o^* = b_o - z_o(Z'\Delta^{-1}Z)^{-1}\ Z'\Delta^{-1}\ \bar{\beta}_\Delta$$

By definition

$$\bar{\beta}_\Delta = \bar{\beta} - \bar{\beta}_j e$$

where $\bar{\beta}$ is a column vector containing the means of the cells to which each corresponding past study belongs, $\bar{\beta}_j$ is the mean for the cell to which the new study belongs, and e is a vector containing all ones.

Since $\bar{\beta} = Zc$ is implied by a meta-analysis design, we can express b_o^* as

$$b_o^* = b_o - z_o c + \bar{\beta}_j\ z_o De$$

or, since $E(b_o) = z_o c$, for $E(\hat{c}) = c$, (i.e., $\hat{c}$ is an unbiased estimator of c), we have

$$E(b_o^*) = \bar{\beta}_j\ z_o De \tag{1-1}$$

When the design matrix Z contains a constant (or intercept) in the first column, it is important to note that e can be written as

$$e = Z \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix} .$$

Accordingly, since

$$z_o\ De = z_o(Z'\Delta^{-1}Z)^{-1}Z'\Delta^{-1}e$$

we have
$$z_o De = z_o(Z'\Delta^{-1}Z)^{-1} Z'\Delta^{-1}Z \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

$$= z_o \begin{bmatrix} 1 \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

which implies that $z_o De = 1$.
Incorporating this into (1-1), it is evident that

$$E(b_o^*) = \bar{\beta}_j .$$

In general
$$b_o^* = \bar{\beta}_j + z_o(\hat{c} - c),$$

or
$$b_o^* = \bar{\beta}_j + z_o \cdot \text{ (Bias in } \hat{c}). \tag{1-2}$$

APPENDIX 2:

A. FREQUENCY DISTRIBUTION AND SUMMARY STATISTICS : Advertising Elasticity [a]

Number of Group Members	Frequency	Group (Cell) Mean		Group (Cell) Mean	
		Mean	Range	Mean	Range
1	8[b]	0.4294	0.0280 - 1.1140	0.0000	
2	6	0.1806	0.0325 - 0.5750	0.0117	0.0000 - 0.048
3	2	0.1328	0.0423 - 0.2233	0.0006	0.0003 - 0.000
4	6	0.1545	0.0283 - 0.3532	0.0402	0.0012 - 0.211
6	1	0.0660		0.0024	
8	1	0.3810		0.0195	
18	2	0.1000	0.0836 - 0.1164	0.0147	0.0067 - 0.022
28	1	0.4045		0.1128	

[a] Reduced design based on Assmus, Farley, and Lehmann (1984).
[b] Read: out of 27 groups, there were 8 with only one member.

B. FREQUENCY DISTRIBUTION AND SUMMARY STATISTICS : Price Elasticity [a]

Number of Group Members	Frequency	Group (Cell) Mean		Group (Cell) Mean	
		Mean	Range	Mean	Range
1	35[b]	-7.6070	- 129.5/5.1200	0.0000	
2	16	-1.6265	-4.8260/0.1005	1.1146	0.0007/11.195
3	13	-1.1562	-33.498/42.748	234.017	0.0021/941.23
4	11	-1.6845	-0.2353/0.1225	0.5685	0.0236/1.7645
5	3	-1.6234	-0.5202/-2.0260	0.6661	0.0294/1.1073
6	1	-1.4578		0.4532	
7	1	-1.4969		1.9202	
8	4	-1.4412	-0.3346/-2.5125	0.7201	0.1704/1.6493
10	2	-2.1156	-0.4831/-3.7480	1.7248	0.6077/2.8418
11	1	-0.4693		0.1127	
12	1	-0.5885		0.1281	
13	1	-2.1045		4.0153	
14	2	-2.4671	-1.6836/-3.2506	2.1164	1.1458/3.0869
15	1	-2.4080		1.5931	
18	1	-1.1497		2.8159	
20	1	-2.6846		11.7310	
22	1	-2.8268		3.6249	
52	1	-1.1165		2.1274	

[a] Reduced design based on Tellis (1988).

[b] Read: out of 96 groups, there were 35 with only one member.

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