Using PIMS Data to Estimate Market Share Growth and Sales Response Models [1]

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Zusammenfassung

Um einen höheren Generalisierungsgrad der bei der Schätzung von Marktreaktionsfunktionen erhaltenen Befunde zu erreichen, wird eine der wissenschaftlichen Datenbanken des PIMS Projekts analysiert. Als Marktreaktionsmaße dienen einerseits die Wachstumsrate des Marktanteils, andererseits der Absatz sog. Strategischer Geschäftseinheiten. Kovarianzmodelle für Einzelgleichungen werden durch Kleinstquadratschätzung bestimmt. Ein Mehrgleichungsmodel, das den Absatz als endogene Variable aufweist, bekräftigt die Hypothese von Interdependenzen zwischen aktuellem Absatz und aktuellen Marketing-Ausgaben. Insgesamt gesehen liefert das Mehrgleichungsmodell geringere Absolutwerte für Absatzelastizitäten der Marketing-Instrumente als die Einzelgleichungsmodelle. Die gewonnenen Eregebnisse über Wirkungen verschiedener Elemente des Marketing-Mix werden jenen verwandter Untersuchungen, die ebenfalls auf PIMS Daten basieren, gegenübergestellt.

Abstract

In order to achieve a higher degree of generalization of the results obtained by estimating market response models, one of the scientific databases of the PIMS project is analyzed. The two market response measures used are growth rates of market shares and sales of business units. Single-equation covariance models are determined by OLS. A simultaneous equations model of sales response gives evidence to the hypothesis of two-way causation between current sales and current marketing expenditures. On the whole, the simultaneous equations model provides lower (absolute) values for sales elasticities of marketing instruments than single equation models. Results on the effects of different elements of marketing mix on market response are compared to those of related studies using PIMS data.

Abstract

In order to achieve a higher degree of generalization of the results obtained by estimating market response models, one of the scientific databases of the PIMS project is analyzed. The two market response measures used are growth rates of market shares and sales of business units. Single-equation covariance models are determined by OLS. A simultaneous equations model of sales response gives evidence to the hypothesis of two-way causation between current sales and current marketing expenditures. On the whole, the simultaneous equations model provides lower (absolute) values for sales elasticities of marketing instruments than single equation models. Results on the effects of different elements of marketing mix on market response are compared to those of related studies using PIMS data.

1 Introduction

Most studies estimating market response functions are based on data of single firms or narrowly defined single markets. One way to achieve a higher degree of generalization is to use a single database consisting of data of different firms which operate on diverse markets. This way it might be possible to produce knowledge and normative guidelines for managers if the data necessary to estimate state-of-the-art market share or sales response models are not available.

The study presented in this paper analyzes data from a panel of business units. Business units are divisions within a company that sell a distinct set of products to an identifiable group of customers. A panel is a data set following a given sample of observation units (here: business units) over time. Besides

offering other advantages, this data structure allows to estimate models that control for the effects of missing or unobserved variables.

The market response models considered belong to two types. The first type measures the impact of changes of marketing instruments on changes of market share. In other words, changes instead of levels constitute the main concern. Estimation of coefficients of these models is done by OLS.

The main purpose for studying the second type of response models is the determination of sales elasticities of elements of the marketing mix. This approach provides a direct link to marketing decision models. Some of the sales response models estimated not only regard the effects of marketing instruments on sales, but also causation from sales to selected elements of the marketing mix.

2 Data

The data used are part of the SPIYR database of the PIMS (Profit Impact of Market Strategies) project. SPIYR consists of annual observations of regularly collected data on market and competitive characteristics, strategies and financial performance of strategic business units (SBU's). Approximately 3000 business units participate in the PIMS program (more detailed information on PIMS may be found in [3,5]).

When reporting to PIMS, firms are multiplying the values of variables measured in dollars (like advertising, promotions, sales force, sales, market size) by a firm-specific disguise factor to preserve confidentiality. This factor is kept constant for all reporting years.

Only business units with data for at least four consecutive years and

Table 1: Number of Units with Different Type of Business

Type of Business		Number of Business Units
Consumer Durables	1	174
Consumer Non-Durables	2	342
Capital Goods	3	248
Raw or Semi-Finished Materials	4	139
Components	5	244
Supplies	6	190
Services	7	47
Retailing and Wholesaling	8	37

no missing values on all relevant variables are included. Table 1 shows the number of units for each type of business. As the number of units in the services and retail/wholesale industries is rather low, business units belonging to these types are ignored.

In the following only analysis-of-covariance models are used in order to account for effects of omitted variables which are specific for individual business units and constant over time. To this end all variables are transformed by subtracting appropriate time-series means for the respective business unit. Due to this transformation all coefficients for unit-specific dummy variables disappear in the resulting models [10]. By reducing the number of coefficients this way, the estimation tasks are simplified considerably.

Table 2: Variables Used in Models of Market Share Growth

Variable	Definition
Market Share	SBU's sales as a percentage of served market total sales
Relative Quality	Difference between the proportion of SBU's sales volume due to goods of superior quality and the proportion of SBU's sales volume due to goods of inferior quality in relation to the SBU's three major competitors plus 100
Relative Price	Average price level of the SBU relative to the unweighted average price of the SBU's three major competitors
Advertising	Media advertising in dollars
Promotions	Promotional expenditures in dollars
Sales Force	Sales force expenditures in dollars

3 Models of Market Share Growth

The coefficients of the models of this section cannot be interpreted as or transformed into elasticities of marketing instruments. The goal is identification of the influence of growth rates of marketing instruments on growth rates of market shares for strategic business units. In this respect these models are related to those in [2] that use percentage change in market share as dependent variable.

All variables contained in table 2 are transformed into growth rates

according to:

$$x_t^* = x_t / x_{t-1} \tag{1}$$

where x_t indicates the value of the variable in year t, and x_t^* its value after transformation into a growth rate.

By transforming disguised variables into growth rates the disguise factor vanishes making values comparable across different firms. Using growth rates emphasizes the impact of changes rather than levels of marketing instruments on market share.

All models have the popular multiplicative form shown in the next equation with market share growth as the dependent variable.

$$msg = a_0 (x_1^*)^{a_1} \quad \cdots \quad (x_n^*)^{a_n} \tag{2}$$

Growth rates of relative quality, relative price, advertising, promotions, sales force and market size as well as the market share of the previous year (which is not transformed into a growth rate) constitute the independent variables.

The multiplicative model is rewritten into the equivalent double log form. After deducing appropriate time-series means of the logged values of the (growth rates) of the dependent as well as the independent variables analysis-of-covariance models are used.

The models of this section differ from those in [2] by:

- implicitly considering effects of omitted variables which are constant over time and specific for individual business units;

- measuring independent variables as growth rates (with the exception of previous market share);
- distinguishing a greater number of types of businesses;
- using time series of observations for each business unit instead of averages;
- being multiplicative instead of linear;
- including relative price among the independent variables;
- excluding market share rank, relative new products and entering or exiting competitors from the set of independent variables.

The hypotheses underlying the models are as follows. Growth rate of market share should increase with growth of relative quality, advertising, promotions and sales force. On the other hand, to increase market share becomes more difficult at higher market shares. Therefore a negativce coefficient for previous market share is postulated. For obvious reasons growth rates of market share are assumed to decrease with increasing relative prices.

Besides multiplicative models two classes of more complex nonlinear response functions were tested as well. For the first class of models coefficients of one instrument depend on the value of another instrument (such models with somewhat involved interactions between instruments were applied successfully to a single-firm data set in [9]). The second class of models was obtained by performing Box-Cox transformations to the variables considered [12,4]. This way more flexible functional forms of response functions follow including the multiplicative model as special case. But for both classes of models goodness-of-fit virtually equaled that for the simpler multiplicative models. Therefore no detailed report of the respective results is given.

3.1 Results

At first analysis-of-covariance models are estimated for each type of business separately using OLS (see table 3).

The coefficients of determination of these models are high, explaining between 81 and 90 percent of the variance in market share growth. These values are much higher than those for the three business types considered in [2], which lie between 28 and 38 percent. There is a strong relationship between previous market share and market share growth with the expected negative sign for each business type. Sales force expenditures seem to exert a positive influence in all business types. This influence is low in the two industries selling consumer goods, but attains its highest value for capital goods. Only for consumer durables the coefficients for relative price and promotions are significant. In this industry increasing relative prices leads to lower market share growth, increasing promotions on the other hand leads to higher market share growth. For business units in the capital goods, materials and supplies industries higher growth rates of relative quality are accompanied by higher growth of market share. The coefficients for advertising are all insignificant. This finding agrees with the results of most studies showing as a rule very modest relationships between market share and advertising expenditures [13].

The hypothesis of homogeneous coefficients for all business units, irrespective of the type of business they belong to, cannot be rejected. The appropriate F-Test amounts to 0.45 with 4774 and 2049 degrees of freedom. This result justifies estimating a pooled model for all business units by OLS, not distinguishing between different business types. Coefficients of previous market share, relative quality, sales force and promotions are all significant, mentioned here in order of decreasing absolute values. Previous market share

Table 3: Market Share Growth Models

OLS Estimation							
Independent Variable	Type of Business						Pooled
	1	2	3	4	5	6	
Previous Market Share	-0.97	-0.96	-0.95	-0.93	-0.98	-0.97	-0.82
Relative Quality	n.s.	n.s.	0.07	0.06	n.s.	0.08	0.07
Relative Price	-0.13	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Advertising	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Promotions	0.03	n.s.	n.s.	n.s.	n.s.	n.s.	0.02
Sales Force	0.02	0.01	0.09	0.06	0.04	0.05	0.05
R^2	0.90	0.86	0.81	0.82	0.88	0.85	0.83

n.s. not significant at $\alpha = 0.05$

is the most important independent variable. The coefficient of determination of the pooled model amounts to 83 percent of the variance of the dependent variable growth of market share.

4 Sales Response Models

Most marketing decision models serve to either assess normative consequences of given marketing policies or to determine optimal marketing policies, i.e. levels of marketing instruments [16,14,8]. Elasticities of marketing instruments constitute necessary inputs for such models or the decision rules derived from them.

Especially in situations where measurement of market-specific sales response models is either impossible or expensive it would be helpful if managers could resort to general results on elasticities. A number of overview articles on marketing mix elasticities uses meta-analyses [6] to summarize results of individual market response studies each limited to a certain market [1,17]. Meta-analysis compares similar but not necessarily identical estimates of quantities measured in different settings that are seen as treatments of a natural experiment. In most cases ANOVA (or some related method) is used to explain variation of results by interstudy or intermodel differences.

The approach taken in this paper constitutes another another possibility to obtain such results more general than those limited to a certain market. Marketing mix elasticities are determined by analyzing a single database consisting of data business units of different firms which operate on diverse markets.

Let $\tilde{s}$ and $\tilde{x_2}$ be the disguised values (see section 2) for sales and one independent variable obtained by multiplying their original values by a factor k , respectively. x_1 denotes an undisguised independent variable. Now the underlying multiplicative sales response model, that of course consists of original, undisguised variables only may be written as:

$$\tilde{s}/k = a_0 x_1^{a_1} (\tilde{x_2}/k)^{a_2} \tag{3}$$

Taking logs and rearranging gives:

$$\ln \tilde{s} = \ln a_0 + \ln k - a_2 \ln k + a_1 \ln x_1 + a_2 \ln \tilde{x_2} \tag{4}$$

This formulation shows that coefficients can be estimated using the dis-

guised values if a multiplicative sales response model is assumed (see also [7,15]). The disguise factor k influences only the coefficients of the constant and the unit-specific dummies. As has been demonstrated in section 2 estimation of coefficients for unit-specific dummies is not necessary if the respective time-series means are subtracted for all variables. It is well known that the coefficients for independent variables in multiplicative models can be interpreted as sales elasticities of the appropriate instrument.

Table 4 shows the variables used in sales response models. All variables measured in dollars are deflated by dividing into a price index relative to 1973 price levels.

The multiplicative models are rewritten into the equivalent double log form. After deducing appropriate time-series means of the logged values of the dependent as well as the independent variables analysis-of-covariance models are used.

4.1 Single Equation Models

Each model reported in this section corresponds to a single equation with sales as dependent variable. Throughout OLS is used for estimation. The independent variables are relative quality, relative price, advertising, promotions, sales force and market size.

Hypotheses on the signs of marketing mix elasticities, all in accordance with most empirical studies on sales response models, are introduced next. Positive coefficients are expected for the marketing expenditure variables (advertising, promotions and sales force), because sales tend to increase with higher levels of these variables. A positive relationship is also assumed for the variable relative quality. As a price level higher than that of the main compe-

Table 4: Variables Used in Sales Response Models

Variable	Definition
Relative Quality	Difference between the proportion of SBU's sales volume due to goods of superior quality and the proportion of SBU's sales volume due to goods of inferior quality in relation to the SBU's three major competitors plus 100
Relative Price	Average price level of the SBU relative to the unweighted average price of the SBU's three major competitors
Advertising	Media advertising in dollars
Promotions	Promotional expenditures in dollars
Sales Force	Sales force expenditures in dollars
Market Size	Size of served market in dollars
Sales	SBU's sales in units as sales revenue/(relative price $\times$ price index)

titors usually leads to lower sales, the coefficient for relative price should be negative. Higher size of the market served by a business unit should facilitate achieving higher sales. Therefore a positive coefficient is expected.

At first models are estimated for each type of business separately (see table 5). The coefficients of determination are rather high, explaining between 54 and 77 percent of the variance in sales. Advertising elasticity is significant only for business units selling consumer durables. In this case the advertising elasticity has the expected positive sign. The high positive influence of

market size on sales for all business types is not surprising. Of the marketing expenditure variables considered, sales force expenditures have the highest elasticity values lying between 0.35 and 0.55. Elasticity of relative price is significant for all business types amounting between -0.44 and -1.10. Compared to the other elements of marketing mix, relative price seems to exert a rather strong influence on sales. With the exeption of units selling raw or semi-finished materials, promotions elasticities are significant lying between 0.08 and 0.15. The results further confirm a positive significant influence of relative quality in four of the six business types considered.

The hypothesis of homogeneous coefficients for all business units, irrespective of the type of business they belong to, cannot be rejected. The appropriate F-Test amounts to 0.39 with 5775 and 2478 degrees of freedom. This result justifies estimating a pooled model for all business units (see table 5). The coefficient of determination for the pooled model amounts to 72 percent of the variance in sales. The elasticity for relative price has the highest absolute value, followed by market size, sales force, relative quality and promotions. The elasticity for advertising is not significant.

4.2 Simultaneous Equations Models

Marketing expenditures on advertising, promotions, sales force may influence sales. But causality may also go from sales to marketing expenditures if firms set marketing budgets on the basis of current sales [8].

Sales response models are incomplete if they do not include a description of firms' decision rules for setting the marketing mix. Therefore models should also consist of equations for each of the marketing expenditure variables. In this study it is assumed that advertising, promotions and sales force

Table 5: Sales Response

Single Equation Models OLS Estimation							
Independent Variable	Type of Business						Pooled
	1	2	3	4	5	6	
Relative Quality	n.s.	0.20	0.26	0.24	n.s.	0.14	0.15
Relative Price	-0.88	-1.10	-0.82	-0.80	-0.44	-1.10	-0.67
Advertising	n.s.	0.03	n.s.	n.s.	n.s.	n.s.	n.s.
Promotions	0.15	0.13	0.08	n.s.	0.10	0.09	0.09
Sales Force	0.45	0.35	0.55	0.36	0.40	0.44	0.43
Market Size	0.44	0.41	0.44	0.79	0.39	0.56	0.48
R^2	0.76	0.77	0.64	0.73	0.54	0.68	0.72

n.s. not significant at $\alpha = 0.05$

expenditures are multiplicative functions with the independent variables current sales, sales of previous year and their own value in the previous year. In accordance with the single equation models of section 4.1, sales response is formulated as a multiplicative function of relative quality, relative price, advertising, promotions, sales force and market size.

The approach taken here is different from that found in Hagerty et al. [7], who assume that past (but not current) sales influence the decision about marketing expenditures. This leads Hagerty et al. to postulate a unidirectional flow from past sales to current marketing expenditures and current sales. They determine OLS estimates which are consistent and unbiased if the additional assumption holds that the residuals of the sales equation are independent of the residuals of the decision rules for the different categories

of marketing expenditures.

If, on the contrary, marketing expenditures are set on the basis of current sales, OLS leads to inconsistent estimates. Therefore two-stage and three-stage least squares are used here to obtain consistent estimates of the coefficients.

Bearing in mind the results for the single equation models discussed in section 4.1 the data are pooled over business units of all types.

4.3 Results

At first coefficients of the simultaneous equations model are estimated by two-stage least squares. Compared to the pooled single equation model of section 4.1 elasticity of promotions becomes insignificant and the sales force elasticity drops from 0.43 to 0.29. The changes of other coefficients are smaller. The decision-rule equations for the endogenous variables advertising, promotions and sales force show a strong positive influence of current sales. One may conclude that firms set respective marketing budgets according to current sales. The coefficients of previous expenditures and previous sales are much smaller than those of current sales, i.e. influences of these variables on marketing expenditures seem to be weaker.

To also use a full-information technique, three-stage least squares is applied as second estimation method for the simultaneous equations model. Compared to the two-stage estimates, only the coefficient for relative price undergoes a somewhat notifiable change. Its absolute value decreases from 0.60 to 0.41. In other respects, results are very similar to those obtained by two-stage estimation.

Hagerty et al.[7] computed mean elasticities based on OLS estimates for 25 groups of SBU's. This way they obtained insignificant elasticity estimates for relative quality, advertising and promotion. The estimation of a simultaneous model shown here on the contrary resulted in a significant positive elasticity for relative quality, which agrees with the results gained by Jacobson and Aaker [11]. The absolute value of the elasticity of relative price is lower (the elasticities are -0.60 or -0.41) than that published by Hagerty et al. (amounting to -0.99). On the other hand, coefficients for sales force and for market size are very similar.

5 Conclusions

The main purpose of the study presented here was the determination of different types of market response models on the basis of the SPIYR database of the PIMS project. This way a higher degree of generalization of results seems possible compared to studies that are based on data of single firms or narrowly defined single markets.

To take account of the effects of omitted variables which are specific for individual business units effects seems to have paid off, especially in the case of the market share growth models. Variance explained is much higher than for the related models in [2] that ignore such effects.

A comparison of results for market share growth models vs. sales response models is made now. It should be born in mind that discrepancies may also be attributed to the different independent variables involved. Both model types agree on the finding that sales force expenditures influence the respective dependent variable. There is really no difference with regard to advertising. In almost all cases its coefficient is not significant. For pro-

Table 6: Sales Response

Simultaneous Equation Model Two-Stage Least Squares Estimation				
	Endogenous Variable			
Independent Variable	Sales	Advertising	Promotions	Sales Force
Relative Quality	0.16			
Relative Price	-0.60			
Advertising	n.s.			
Promotions	n.s.			
Sales Force	0.29			
Market Size	0.56			
Sales		0.51	0.48	0.73
Previous Sales		-0.02	-0.02	-0.07
Previous Advertising		0.06		
Previous Promotions			0.06	
Previous Sales Force				0.09

n.s. not significant at $\alpha = 0.05$

motions the single sales equation draws attention to a significant if small influence. But this difference to the market share growth models disappears if a simultaneous equations model is used. The two model types disagree on the influence of relative price. Contrary to market share growth models sales response models give evidence to a strong effect of relative price.

Besides single equations, simultaneous sales response models were estimated. They include a description of firms' decision rules for setting the marketing mix. If the model is estimated by two-stage least squares, pro-

Table 7: Sales Response

Simultaneous Equation Model Three-Stage Least Squares Estimation				
	Endogenous Variable			
Independent Variable	Sales	Advertising	Promotions	Sales Force
Relative Quality	0.17			
Relative Price	-0.41			
Advertising	n.s.			
Promotions	n.s.			
Sales Force	0.28			
Market Size	0.56			
Sales		0.51	0.47	0.73
Previous Sales		-0.01	n.s.	-0.04
Previous Advertising		0.05		
Previous Promotions			0.05	
Previous Sales Force				0.07

n.s. not significant at $\alpha = 0.05$

motion elasticity becomes insignificant and sales force elasticity decreases. Single equation models apparently overestimate the influence of these two instruments. With regard to other independent variables the differences between equivalent coefficients of single equations and the simultaneous equations model are smaller. If three-stage least squares is applied as estimation method, the absolute value of the coefficient for relative price decreases by a certain amount. On the whole, these results seem to emphasize the necessity to use a simultaneous equations model.

The results of this study could be relevant to managerial decision making, especially in situations where determination of tailor-made market response functions and elasticities is not possible. Together with findings of other studies, the study provides information on the importance of selected marketing instruments for the two market response variables considered. The elasticities estimated by means of sales reponse models could moreover be input to well-known decision rules (see e.g. [8]) that allow managers to evaluate the performance of alternative marketing policies.

References

[1] Assmus, G, Farley, J.U., Lehmann, D.R. (1984): How Advertising Affects Sales. Meta-Analysis of Econometric Results. In: Journal of Marketing Research, 65-74.

[2] Buzzel, R.D., Wiersema, F.D. (1981): Modeling Changes in Market Share. A Cross-Sectional Analysis. In: Strategic Management Journal, 27-42.

[3] Buzzel, R.D., Gale, B.T. (1987): The PIMS Principles. The Free Press, New York.

[4] Chapman, R.G. (1982): Generalized Functional Forms of Sales Response Models. In: AMA Proceedings, 447-450.

[5] Day, G.S. (1987): Analysis for Strategic Market Decisions. West Publishing Company, St. Paul.

[6] Farley, J.U., Lehmann, D.R.(1986): Meta-Analysis in Marketing. Generalization of Response Models, Lexington Books, Lexington, MA.

[7] Hagerty, M.R., Carman, J.M., Russel, G.J. (1988): Estimating Elasticities with PIMS Data. Methodological Issues and Substantive Implications. In: Journal of Marketing Research, 1-9.

[8] Hanssens, D.M., Parsons, L.J., and Schultz, R.L. (1990): Market Response Models. Econometric and Time Series Analysis, Kluwer Academic Publishers, Boston, MA.

[9] Hruschka, H. (1991): Marktreaktionsfunktionen mit Interaktionen zwischen Marketing-Instrumenten. In: Zeitschrift für Betriebswirtschaft, 339-356.

[10] Hsiao, C. (1986): Analysis of Panel Data. Cambridge University Press, Cambridge.

[11] Jacobson, R., Aaker, D.A. (1987): The Strategic Role of Product Quality. In: Journal of Marketing, October, 31-44.

[12] Jain, D.C., Vilcassim, N.J. (1989): Testing Functional Forms of Market Share Models Using the Box-Cox Tranformation and the Lagrange Multiplier Approach. In: International Journal of Research in Marketing, 95-107.

[13] Leone, R.P, Schultz, R.L. (1980): A Study of Marketing Generalizations. In: Journal of Marketing, Winter, 10-18.

[14] Lilien, G.L., and Kotler, P.(1983): Marketing Decision Making, Harper and Row, Cambridge, MA.

[15] Moore, M.J, Boulding, W. (1988): Using Disguised PIMS Data to Assess the Optimality of Managerial Strategic Choices. Working Paper, Fuqua School of Business, Duke University.

[16] Parsons, L.J., and Schultz, R.L.(1978), Marketing Models and Econometric Research. 2nd Edition, North Holland, New York.

[17] Tellis, G.J.(1988): The Price-Elasticity of Selective Demand. A Meta-Analysis of Econometric Models of Sales. In: Journal of Marketing Research, 331-341.