Industrial innovation and firm performance: A re-conceptualization and exploratory structural equation analysis *

Praveen K. Soni

College of Business Administration, California State University, Long Beach, CA 90840, USA

Gary L. Lilien and David T. Wilson

Institute for Study of Business Markets, The Pennsylvania State University, University Park, PA 16802, USA

Final version received October 1992

Successful new products are essential to the financial viability of many firms, with more than half of most firms' sales resulting from products introduced in the past decade. But despite much research attempting to relate industrial innovation and firm performance, a cohesive theory has yet to emerge. We use structural equation models to assess the simultaneous impact of market structure, firm size and diversification on industrial innovation and firm performance. We measure innovative output by both the number and the nature of resulting new products. In a sample of forty firms in the industrial chemicals industry, we found that (a) innovativeness results in better firm performance; (b) intermediate levels of market concentration result in more innovativeness and better performance than more extreme levels; (c) smaller firms are more innovative and perform better than larger firms, and (d) less diversified firms perform better than highly diversified firms.

Correspondence to: Professor P.K. Soni, Department of Marketing, College of Business Administration, California State University, 1250 Bellflower Boulevard, Long Beach, CA 90840-1006, USA. Telephone (310) 985-4763.

* The authors would like to acknowledge Dr. Alok Chakrabarti for his helpful suggestions and for contributing the Innovations database; Trinet Corporation for providing the EIS database; and to Pennsylvania State's Institute for the Study of Business Markets for providing project support.

Intern. J. of Research in Marketing 10 (1993) 365–380
North-Holland

Introduction

The ability to develop successful new products is essential to a firm's long term survival. For example, in a Conference Board survey, 35% of the respondents reported that their companies get at least half of their revenues from products that were not in production ten years ago (Duerr, 1986). A Booz, Allen and Hamilton (1982) survey of 700 companies found that management expected the contribution of new products over the next five years to represent about one-third of corporate profits, with this percentage likely to increase in the future. Kotler (1989) states that most large companies see 50% or more of their current sales from products introduced in the past ten years.

The pressure to produce new products places great emphasis on innovation: 3M for example tries to stay ahead of competition by introducing 200 new products a year (Fortune, 1988). In this paper we address two key questions: (1) what structural factors differentiate more innovative firms from less innovative ones, (2) what is the impact of innovation on firm performance?

Researchers have studied the impact of firm size, technological environment, competition, and the extent of vertical integration on innovation. Such research has produced mixed results for a number of reasons, including the lack of simultaneous analysis of innovation and performance, and the use of patents to measure innovative output. In an extensive literature survey, Baldwin and Scott (1987) note that the challenge for work in

0167-8116/93/$06.00

this area is in modeling the relevant hypotheses where the key variables are endogenous.

In this study, we address their challenge by building an *exploratory* model in a *single* industry of the effect of market structure, firm size, and diversification on innovativeness and performance of industrial firms. We address some of the shortcomings of past research in an endogenous structural equation model that considers the simultaneous, interacting effects of variables in a longitudinal framework, and that uses both the number and nature of new products as measures of innovative output. The availability of specialized databases (described in the methodology section) has made preliminary testing of this more complete model structure possible.

In the next section we discuss theoretical and empirical evidence relating market structure, firm size, and diversification to innovation and performance. We also advance several hypotheses. Next, we develop a structural equation model and use it to analyze the relationship between innovation and performance.

Determinants and consequences of innovation

Innovation and performance

Our focus is on the relationship between innovative activity and firm performance. Firms with sustained R&D programs have been found to experience a greater level of growth and profitability (Mansfield, 1968a, b; Baily and Chakrabarti, 1985).

In a study of Booz, Allen and Hamilton (1982) it was found that the most successful companies make a consistent commitment of resources to new product development. Buzzell et al. (1975), in a study of the PIMS data, found innovativeness to be positively related to performance.

Therefore,

Hypothesis 1 (H1) More innovative firms perform better in terms of sales growth and profitability than less innovative firms.

Classifying innovations

All innovations are not the same and their likely effects on performance will differ depending upon whether they are radical breakthroughs (xerography) or simply a modification of an existing product (this year's faster and/or cheaper copier).

A number of researchers have proposed classification schemes for innovations. Robertson (1971) classified innovations based on the amount of disruption occurring in established behavior patterns. Abernathy et al. (1983) defined innovations based upon the innovation's ability to influence production systems and market linkages. The Booz, Allen and Hamilton study (1982) and Lilien and Kotler (1983) classify innovations on the basis of newness to the company and the customer.

We will use Baily and Chakrabarti's (1985) four-point technological novelty scale to classify innovations, since their scheme suits industrial markets well. Their innovation types are

1. *Radical innovation*—where a product uses a radically different technology to serve the same function.
2. *Major breakthrough*—where a new application of an existing technology results in greatly improved performance.
3. *Improvement of existing technology*—where usage of existing technology marginally improves product quality.
4. *Imitation of existing technology*—where a product is introduced that is only superficially different from those currently available.

Radical innovations versus imitations

Porter (1985) suggests that a pioneer may establish a reputation and gain recognition that will have a positive effect on potential buyers. Lieberman and Montgomery (1988) suggest that first-mover advantages arise from (1) technological leadership through the experience curve affect and R&D success, (2) preemption of scarce assets such as raw materials, employees, and distribution outlets, and (3) buyer switching costs.

Biggadike (1976) found that after new entrants had been on the market for four years, the largest existing competitor's share had decreased-from 47 to 28%, a level that was still significantly higher than that of later entrants. Robinson and Fornell (1985) observed that by the mature phase of the product life cycle, pioneers had a 29% share, early followers a 16% share and later entrants an 11% share.

Lieberman and Montgomery (1988) also reason that late-movers or imitators may benefit from (1) a "free-ride" on pioneer investments due to inter-firm diffusion of technology; (2) resolution of technological and market uncertainty which is especially beneficial to large firms; (3) shifts in technology or customer needs; and (4) incumbent inertia which takes the form of protection of current assets. Schnaars (1986) cites IBM in personal computers, Matsushita in VCRs, and Kimberly Clark in disposable diapers as late movers who have been successful because they were able to exploit existing assets in areas such as marketing, distribution, and customer reputation.

Although ambiguous, the weight of the literature suggests that pioneering may be a reason for a firm's better performance. Using the Baily and Chakrabarti (1985) technological novelty scale, we hypothesize,

Hypothesis 2 (H2) Firms producing mainly radical innovations perform better than firms producing mainly imitative innovations.

Researchers have hypothesized a number of structural features that are determinants of innovative activity. We explore some of the main ones below.

Market structure and innovation

Market structure refers to the configuration of firms in a market. Perfect competition and monopoly are two extreme market structures. Schumpeter (1942, 1975) suggests a positive relationship between monopoly power and innovation. Monopoly power and associated profits are an entrepreneur's reward for being first. In a perfectly competitive structure, imitation is immediate, and extraordinary profit does not exist, giving the entrepreneur no incentive to innovate.

Monopoly power may have negative effects as well (Kamien and Schwartz, 1982). The monopolistic firm may try to protect its investment in current technology (Blair, 1972). Baldwin and Childs (1969) argue that a monopoly firm has the resources, the reputation, and can afford to wait and plan to be an early market entrant, introducing a new product after a competing "pioneer" has entered the market. Then the opportunities are more apparent and potential product-problems have been ironed out (Schnaars, 1986). Supporting evidence of this behavior exists both for process innovations (Arrow, 1962) and product innovations (Usher, 1964).

The concentration ratio is the most frequently used measure of market structure. Concentration has seen wide application because of its public availability: it refers to the proportion of sales of an industry accounted for by the top four firms in that industry. The industry is typically defined by a four-digit US Standard Industrial Classification Code.

Mansfield et al. (1977) note that beyond a moderate amount of concentration, further increases are not related to more innovation. Levin et al. (1985) found that innovative activity first increases and then decreases as concentration increases. Both Scherer (1967) and Lunn and Martin (1986) found a positive effect of concentration on R&D effort in low technology industries. Baldwin and Scott (1987) conclude that a positive relationship between concentration and innovative activity exists at low levels of concentration.

One reason for the ambiguous relationship between market structure and innovation may be the inability to incorporate competitive effects in the measurement of market structure (Kamien and Schwartz, 1982). Competition is essential for technological progress (MacLaurin, 1954), and is important in stimulating attempts to innovate (Freeman, 1973). Concentration, however, masks the distribution of market shares. This underlying distribution may indicate the degree of rivalry in a market.

Therefore, in addition to the concentration ratio, we suggest a measure of the market share distribution—Market Share Variance (MSV)—as a second indicator of market structure. We define MSV as:

$$\mathrm{MSV} = \tfrac{1}{3}\left[\frac{\mathrm{MS2}}{\mathrm{MS1}} + \frac{\mathrm{MS3}}{\mathrm{MS2}} + \frac{\mathrm{MS4}}{\mathrm{MS3}}\right],$$

where MSi = market share of the ith largest firm in the market.

By definition, a monopoly structure has only one firm and the least amount of rivalry. The MSV for such a structure is zero. At the other extreme, perfectly competitive structures have the greatest amount of rivalry, and will therefore have greater MSV values. The maximum amount of rivalry is denoted by an MSV of 1, where the top four firms have equal market shares in an industry. This measure is consistent with Buzzell (1981) who found equilibrium market structures to have clear leaders, and less rivalry. Equal-market-share markets exhibit more competition, because the absence of a leader stimulates activity among existing firms to achieve dominance.

Kamien and Schwartz (1982) suggest that intermediate values of market structure may be most conducive to innovative activity since market power is diffuse.

Therefore,

Hypothesis 3 (H3) An intermediate market structure (modest concentration and modest variance) results in more innovative activity than either a monopolistic or perfectly competitive structure.

Size and innovation

According to Schumpeter (1942) and Galbraith (1952) large firms are more innovative than small firms. Competition through innovation results in uncertainty regarding the continued success of current products, and uncertainty about profitability of a firm's own and of competing innovations. These uncertainties are reducible by directing alternate research efforts, the resources for which are available with large firms.

Economies of scale in industrial R&D may require a fixed, minimum investment as well as synergies that increase with size so that innovative returns may increase with the magnitude of effort (Baldwin and Scott, 1987). Kamien and Schwartz (1982) suggest that researchers are more productive when colleagues are available for interaction, and that a large research group permits a productive division of labor. A large firm may have an established reputation and command over channels of distribution making it easier to enter a new market (Nelson, 1959).

There are arguments supporting the superior innovative effectiveness of small firms. First, large firms are bureaucratic, making creative contributions difficult (Cooper, 1964); they neglect the innovator and misdirect research (Blair, 1972); they give inadequate attention to individual incentives and opportunities to generate new ideas (Schmookler, 1972); and they underestimate the demand for a new item, because of a desire to protect investment in current technology (Kamien and Schwartz, 1982).

Baldwin and Scott (1987) conclude that a "critical size" may be necessary for innovation to occur: firms below the critical size may not have the resources to innovate, and firms larger than the critical size do not show a significant increase in innovative activity. Their conclusions are based upon several studies in the US (Mansfield, 1968a, b; Mansfield et al., 1977) and data from other countries (Gannicott, 1984; Uhlman, 1979, Smyth et al., 1972, Adams, 1970).

Mansfield et al. (1977) also suggest that the size-innovative activity relationship depends upon the type of industry and the type of innovation. Small firms focus on areas requiring flexibility, and cater to specialized needs, whereas larger firms focus on areas requiring larger production, marketing or technological resources. Our hypotheses are, then:

Hypothesis 4 (H4) Smaller firms are more innovative in terms of total number of innovations per unit sales than large firms.

Hypothesis 5 (H5) Large firms are more likely to produce radical and breakthrough innovations while smaller firms are more likely to produce improvement and imitative innovations.

Diversification and innovation

A firm's degree of diversification should positively influence its expected profit from its R&D effort, because a more varied firm is in a better position to utilize its research outputs (Nelson, 1959): a firm conducting business in a narrow area may be less capable of producing and marketing a new product unrelated to the firm's main business.

Scherer (1984) found a higher propensity to patent with greater diversification. Lunn and Martin (1986) found none. Kelly (1970) found that the advantages of diversification occur for technically related products in the same two-digit SIC industry group, and Varadarajan (1986) found firms diversified in related areas to be more profitable than firms diversified in unrelated areas. Baldwin and Scott (1987) note that while larger corporations are typically diversified, empirical studies have not dealt adequately with the hypothesis that diversification promotes R&D, and, therefore, innovation. Moreover, studies should account for the different types of diversity that exist. Therefore we propose,

Hypothesis 6 (H6) Diversification is positively related to innovativeness and performance.

Hypothesis 7 (H7) Technologically focused firms are more innovative and perform better than technologically diverse firms.

Model development

Limitations of past studies

We have presented the findings of some theoretical and empirical studies examining the relationship between market structure, firm size and diversification on innovativeness and performance of industrial firms. Some problems with much of the research we have cited are as follows:

1. *Separate analysis of variables*—Innovativeness and performance have been separately and not simultaneously considered, and have been investigated using additive models without interactions. Levin et al. (1985), suggest that structural modelling may be the best way to test such effects.

2. *Innovativeness not viewed as a mediating variable affecting performance*—Some researchers have studied the effect of structural features on innovativeness (Mansfield,

1968a, b; Scherer, 1984; Lunn and Martin, 1986), while others have studied the effect of the same features on performance (Bass et al., 1978; Christensen and Montgomery 1981; Varadarajan, 1986). The mediating effect of innovative activity on performance has not been reported.

3. *Imprecise measurement of constructs*—Past studies often employ questionable empirical measures. For example, innovative activity (the ability to market new products) has been measured by patents awarded, R&D expenses, sales of new products, and labor productivity (Scherer, 1965a, b; Schmookler, 1966; Comanor, 1965; Mansfield 1968a, b). Whereas patents are the result of inventive activity, R&D expenses are an input to the innovative process (Baily and Chakrabarti, 1985). Sales and labor productivity occur due to the adoption of innovations, and are appropriate measures of performance. Similarly, market structure has been measured by aggregate measures such as the concentration ratio which masks the distribution of market shares. The degree of rivalry, which is expected to influence innovative activity (Kamien and Schwartz, 1982) is not captured by this measure.

The model

We attempt to address some of these limitations in our examination of the relationship between innovative activity and firm performance. Innovations are a result of a firm's ability to translate R&D expenditures into new products. Since R&D expenditures are not available for many of the firms we wish

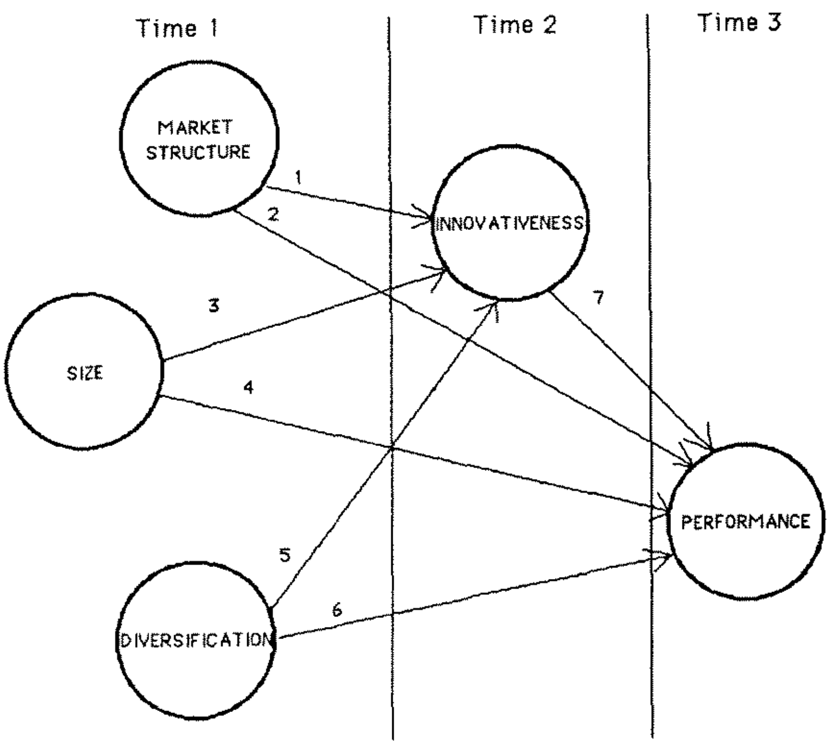

Fig. 1. *Model I*—Structurally saturated model. A structurally saturated model showing that market structure, firm size and diversification have a *direct* effect *both* on innovativeness and on performance. *Model II*—Direct effect only on innovativeness (obtained by droppinq paths 2, 4, 6, and 7). *Model III*—Direct effect only on performance (obtained by dropping paths 1, 3, 5, and 7).

to study, we assume that firms in a industry are equally capable of translating R&D into innovations. Our model, then, considers innovativeness (the output) while dropping the (implied) R&D expenditure input.

Figure 1 shows a saturated model (i.e., a model with all causal links present) of the determinants of innovativeness and performance, which are measured in later time periods than the structural determinants. We call this Model I.

Dropping paths 2, 4, 6, and 7 results in Model II. This model posits a direct relationship between the structural determinants and innovative activity without regard to the effect on performance. Researchers in the area of industrial economics tend to focus attention on this type of model. Dropping paths 1, 3, 5, and 7 results in Model III. This model suggests that innovativeness has no mediating effect on performance. Researchers in marketing and other related areas have studied versions of this model (Bass et al., 1978; Christensen and Montgomery, 1981; Varadarajan, 1986).

Models I, II and III constitute several model extremes. Model II does not include performance, whereas Model III ignores the impact of innovativeness. Model I is quite general, and our empirically estimated model will be a bit more parsimonious, deleting two of the causal links, following a rationale described below.

Methodology

We now discuss the variables, data and methodology used to test our hypotheses.

Variable measurement

Market structure indicates the industry environment within which firms operate, and we measure it using the four-firm concentration ratio. As discussed earlier, we also use Market Share Variance (MSV).

Firm size reflects the number of (creative) people in a firm. This is alternately measured by the number of engineers, technical personnel, R&D employees, or, simply by the number of employees. We will use the number of employees because of the difficulty in assessing the number of personnel actually involved in the innovation process.

Diversification captures the likelihood of synergy due to a firm's operations in various markets using varied technologies. We will use Varadarajan's (1986) SIC-based measures of diversification. These are broad spectrum diversity (BSD)—the number of two-digit SIC industries in which a firm operates; and mean narrow spectrum diversity (MNSD)—the number of four-digit SIC industries in which a firm operates. These measures assume equal "dissimilarity" between distinct SIC classes, but Montgomery (1982) has shown a high degree of correspondence between SIC-based objective measures and Rumelt's (1982) categorical subjective measures that have had a wide application.

Innovativeness of a firm is its ability to develop new products. We will use Baily and Chakrabarti's (1985) scheme to measure innovative activity. The number of innovations in each of the four novelty categories comprises our measure of innovative activity.

Both profitability and sales have had wide acceptance as indicators of *performance*. But product level profitability is not appropriate in this study because of accounting differences across firms as well as difficulties in assigning of profits to products. Since sales and sales growth are more easily attributed to individual products, we use these as indicators of performance. We normalize sales revenue and number of innovations by the number of employees to control for the effect of firm size.

Data

To avoid inter-industry differences in innovative activity (Cohen et al., 1987) and to control for the impact of technological environment, we selected a *single (SIC-code-based) industry* with a *high specialization ratio* (most of the output of firms with that classification being that product category) and a *high coverage ratio* (few firms with different classifications producing that product category). We also needed an industry where we had data on innovations and a classification of those innovations into the categories noted above. Industrial chemicals (SIC 282), with a specialization ratio of 0.85 and a coverage ratio of 0.80 (US Census of Manufacturers, 1987), satisfied these criteria.

We combined two different databases to calibrate our model. One, the Trinet Establishment Database, is available on the Dialog Information Retrieval Service and provides information on US establishments with twenty or more employees. The database covers the primary four-digit SIC code, employment, and sales. This database provided measures of market structure, firm size, diversification and performance for the time period from 1976 through 1985.

The Innovations database was developed by Chakrabarti at Drexel University, under grants from the Brookings Institution and the National Science Foundation, and includes commercial innovations in the chemical (excluding pharmaceutical) and instrument industries. An exhaustive search of trade magazines identified "first mentions" of innovations, and industry experts classified those innovations into the four categories developed by Baily and Chakrabarti (1985). Material and fiber innovations which stem primarily from activity in SIC 282 were used here. The time period of observation was from 1976 through 1983.

The intersection of useable data from these two databases over the multiple year time horizon resulted in an analysis sample of forty firms. The measures of the latent constructs were taken in three time periods, as suggested in Fig. 1. Due to our concentration on one industry, and a lack of data on differential innovations in that industry, H2, H5, and H7 could not be tested.

Time lag between variables

Our model includes a lag period to account for the time necessary for innovation development (between the structural determinants and innovativeness), and the time for customer adoption (between new product introduction and performance). We did not consider a contemporaneous model since even imitation innovations take time to be developed and to reach a significant level of sales. Radical innovations should take an even longer time to be developed and to be adopted.

Scherer (1965a, b) used a lag period of four years between number of R&D personnel and patents issued. Comanor and Scherer (1969) suggest a lag of up to two years between new product introduction and performance. Kamien and Schwartz (1982) suggest a one to two year lag period. We took their advice and used a lag period of one to two years for both the innovation process and the adoption process, because most new products in our study are based on existing technology, and require a short time to be developed and to be adopted by customers. We also tested for different lag periods of two, three and four years, and our results were not significantly affected.

Model selection and calibration

Our objective is not to determine *the* model of firm innovativeness and performance but rather to conduct an *exploratory* analysis that allows a test of the hypotheses cited earlier. This can be done by finding the

Table 1
Multiple regression analysis results obtained by using innovation and performance as dependent variables, and the antecedents as independent variables

Dependent variable	Independent variable		β	t	Significant t
Improvement innovations	Employment		−0.60	−3.2	0.003
		$R^2 = 28\%$	$F = 2.52$	$p = 0.049$	
Imitation innovations	Employment		−0.74	−4.86	0.00
		$R^2 = 52\%$	$F = 6.90$	$p = 0.000$	
Sales revenues [a]	Employment		0.73	3.07	0.005
	Concentration		−0.746	−3.64	0.001
	Imitation innovations		0.407	2.154	0.039
		$R^2 = 49\%$	$F = 4.14$	$p = 0.003$	

Only significant independent variables at the 95% confidence level are shown.
[a] Regression analysis using sales growth as the dependent variable did not result in any significant independent variables.

best fitting model using structural equation models (LISREL). The LISREL procedure (Joreskog and Sorbom, 1982) is appropriate since it considers three situations encountered here in which regression parameters fail to give the relevant information (Goldberger, 1973). These are:

1. when the observed measurements (concentration and market share variance) contain measurement errors and when the interesting relationship is among combinations of those variables (market structure),
2. when there is interdependence or simultaneous causation among observed response variables (innovativeness and performance), and
3. when important explanatory variables have not been observed (omitted variables such as internal determinants of innovative activity).

The empirical validity of our models can be judged using test statistics such as error variances [1], squared multiple correlations and coefficients of determination [2], and goodness of fit [3].

LISREL is a generally sound methodology for calibrating models of this sort (incorporating simultaneous, endogenous relationships and measurement error). However, our sample size ($n = 40$) is low for using LISREL. Hence, we use multiple regression analysis first, a more robust (if less sensitive) procedure, and confirm those findings with our more general LISREL analysis.

Multiple regression analysis

We developed four regression model equations from Fig. 1: two equations with innovation measures as the dependent variables and two with performance measures as the dependent variables. We used market

[1] The extent of random error present in the measurement of the theoretical variable by an observed variable. Low values are good.

[2] The squared multiple correlation shows how well the observed variable serves as a measurement of its theoretical definition. The coefficient of determination measures the joint strength of several relationships. Positive values close to 1 represent good models.

[3] This is assessed by the chi-square and the goodness of fit index. The chi-square relative to the degrees of freedom measures the extent of disturbance in the model and should be low. The goodness of fit index is a measure of the amount of variance–covariance accounted for by the model. Its value should be positive and close to 1.

structure, diversification and size as independent variables (along with measures of innovation in the performance equations). Table 1 summarizes our results, discussed below in conjunction with the LISREL results.

LISREL analysis

We now proceed to the LISREL analysis, following the procedure recommended by Joreskog and sorbom (1982).

Step 1. Run the measurement model and determine loadings of the constructs on the observed variables. In this manner, one deals with the limitations of the measurement model prior to fitting a structural model. Figure 2 displays the best-fitting *measurement* model. The error variances were positive, and the squared multiple correlations (SMC's) were high values not exceeding 1 (not shown). The goodness of fit index is 0.695. Of particular interest is that market structure is determined both by concentration and market share variance, and the latter moderates the effect of concentration.

Step 2. Use the loadings obtained in Step 1 as starting values to determine a structural model. This restricts the model fitting procedure to a smaller number of possible models. Aaker and Bagozzi (1979) and Joreskog and Sorbom (1982) recommend a nested approach in which relationships are added to simple models, or removed from complex models to determine a best fitting structural model.

Using Model II (innovativeness mediating performance—see Fig. 1) as a starting point, and by adding and deleting relationships, we were able to obtain a best-fitting structural model (Fig. 3). The chi-square for Model II

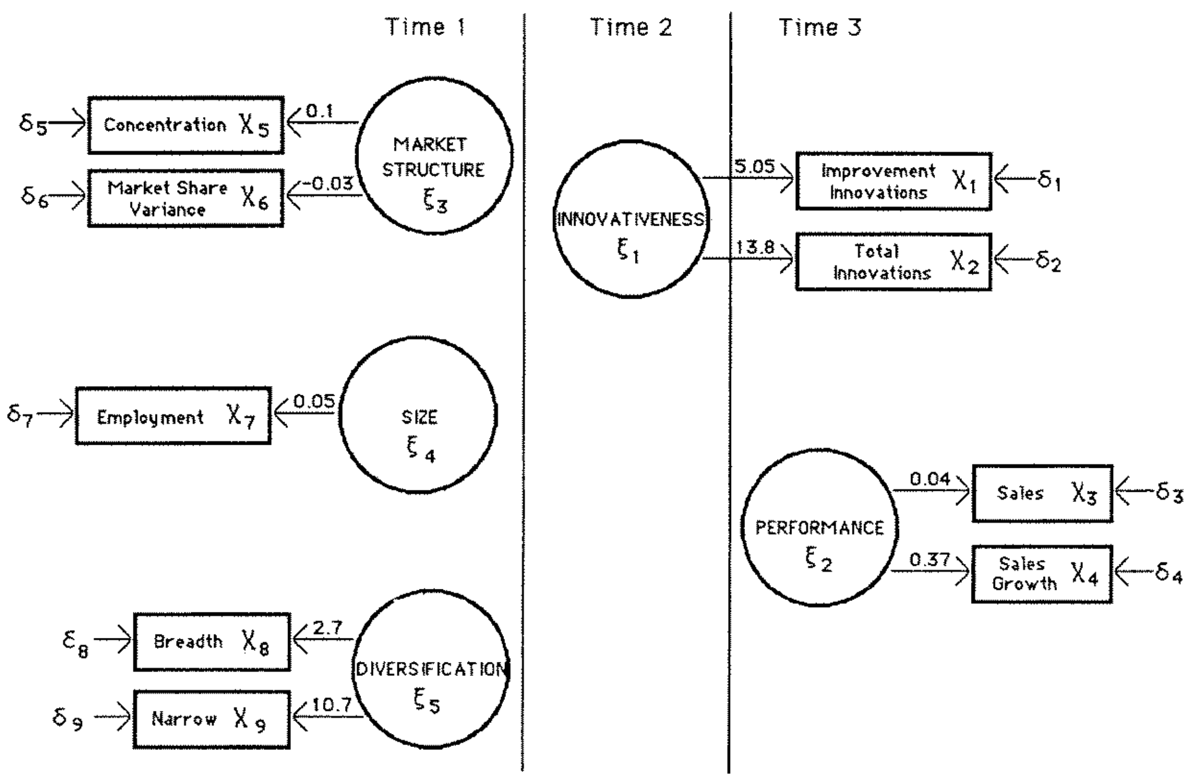

Fig. 2. Measurement model, chi square = 106, d.f. = 31. The relationship between the theoretical variables (constructs in circles) and the observed variables (in rectangles) is shown.

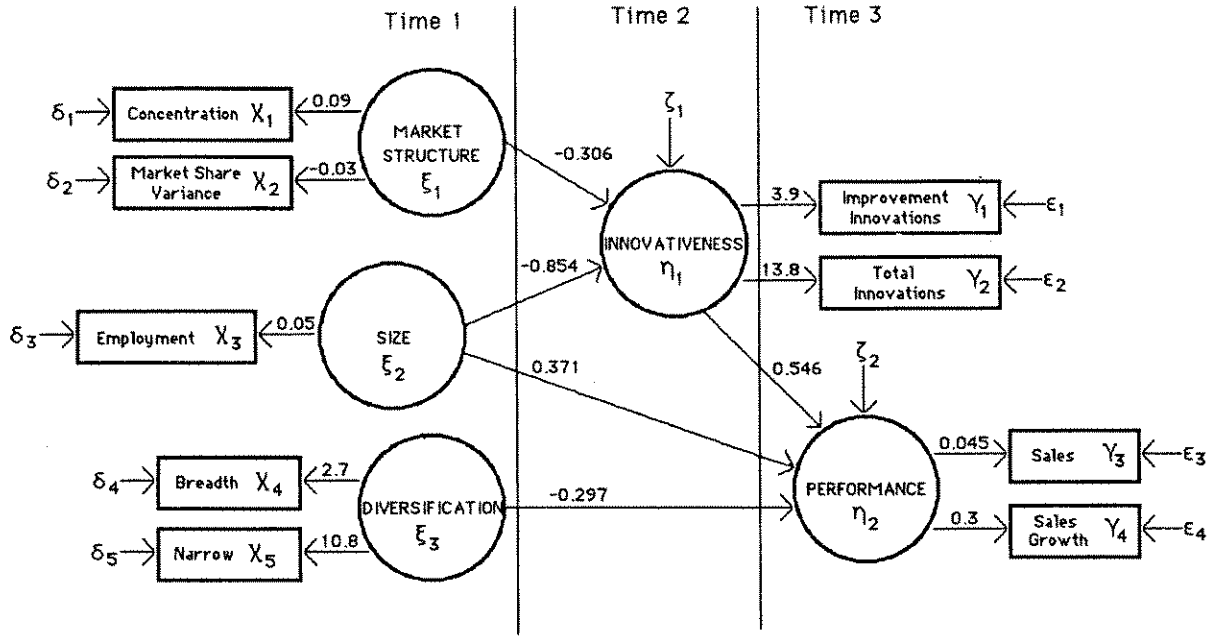

Fig. 3. Best-fitting structural model. A model of innovative activity and performance, chi square = 95, d.f. = 18. It is seen that market structure and size have a direct effect on innovativeness, whereas size and diversification have a direct effect on performance. In addition, innovativeness has a strong positive effect on performance.

is 168.08 with 26 degrees of freedom. For the best fitting model, the chi-square is 94.82 with 18 degrees of freedom. Joreskog and Sorbom (1982) consider chi-square to be a valid test statistic only if all the observed variables have a multivariate normal distribution, and the sample size is fairly large (n = 40 here). They recognize that these conditions are seldom fulfilled in practice, and suggest using chi-square measures in comparative model fitting, such that "a large drop in chi-square, compared with the difference in degrees of freedom, indicates that the changes in the model represent a real improvement" (p. 240).

Following this tack, we find that the drop in chi-square is 73.26 when compared with a loss of only 8 degrees of freedom. This value is significant at the 0.0001 level, and represents major improvement. The goodness of fit index, the error variances and squared multiple correlations also suggest the model is reasonable (Table 2).

Table 2
Relevant statistics of the best-fitting model

Observed variables (X and Y)	Error variances		Squared multiple correlations for	
	δ_y	δ_x	Y	X
Improvement innovations	16.35		0.48	
Total innovations	47.02		0.80	
Sales	0.00		0.45	
Sales growth	0.13		0.17	
Concentration		0.01		0.02
Market share variance		0.00		0.88
Employment		0.00		1.00
Breadth of diversification		1.56		0.82
Narrowness of diversification		36.82		0.76

Squared multiple correlations for structural equations

Innovativeness	0.47
Performance	0.60

Coefficient of determination for Y = 0.91
Coefficient of determination for structural equations = 0.66
Chi-square with 18 degrees of freedom = 94.82
Goodness of fit index = 0.69

Results

Multiple regression

Examination of Table 1 reveals that size as measured by employment has a negative impact on both improvement and imitation innovations, and a positive impact on performance as measured by sales revenues (H4). Also the impact of innovations on sales revenues is positive as hypothesized (H1). These regression results are similar to our LISREL model results (Fig. 3). One difference between the results is that our regression analyses show no impact of concentration on innovation effectiveness and a negative impact on performance, while the LISREL results show a negative impact of market structure (composed of concentration and market share variance) on innovation effectiveness and no direct effect on performance. This minor difference may be due to the collinearity between concentration and market share variance, which precluded our incorporation of the latter in the regression results.

Some of the measures that we used in our model, such as breadth and depth of diversification, and market share variance did not turn out to be significant variables in the multiple regression analysis pointing to the need for larger sample sizes and better measures in more definitive, future research.

On net, however, the regression results are largely supportive of our LISREL results, suggesting at least a reasonable degree of robustness. We now discuss the relationship between our model results and our hypotheses. A summary of our hypotheses and our findings appears in Table 3.

LISREL model

Role of innovativeness

According to Fig. 3,

$$\text{Performance}_{t+2} = +0.546 \times \text{Innovativeness}_{t+1} + \ldots,$$

i.e., innovativeness is positively related to performance (H1, $\beta = 0.546$). Both "improvement" and "imitation" innovations

Table 3
Summary of hypotheses and findings of the best-fitting structural model

Hypotheses	Findings
Innovativeness	
Innovativeness results in high performance (H1)	Supported
Radical innovations result in high performance (H2)	Not tested (due to insufficient data)
Market structure	
Intermediate market structure results in high innovativeness and high performance (H3)	Low market structure results in high innovativeness; No effect on performance
Size	
Small size results in high innovativeness and high performance (H4)	Supported
Small size results in imitation innovations and large size results in radical innovations (H5)	Not tested (due to insufficient data)
Diversification	
High diversification results in low innovativeness and low performance (H6)	No effect on innovation; performance effect supported
Technological focus results in high innovativeness (H7)	Not tested (due to insufficient data)

provide measures of innovative activity. Together they affect performance. The greater the number of innovations, the better the firm's performance. Highly innovative firms successfully bring customer need-satisfying products to the market. Innovative activity has a greater impact on sales growth than on sales revenue. Perhaps, to affect sales revenue materially, an increase in sales with a less than proportionate increase in employment must occur.

Role of market structure

Using either concentration or market share variance alone as a measure of market structure resulted in poor fitting models. Together they formed a single measure of market structure that increases as concentration increases and market share variance decreases, as predicted earlier.

Our analysis indicates that,

$$\text{Innovativeness}_{t+1} = -0.306 \times \text{Market Structure}_t + \ldots,$$

and

$$\text{Performance}_{t+2} = -0.167 \times \text{Market Structure}_t + \ldots.$$

An increase in market structure, as measured by concentration and market share variance, has a direct negative effect on innovativeness ($\gamma = -0.306$) but no direct effect on performance. It does, however, have a small negative indirect effect on performance ($-0.167 = -0.306 \times 0.546$), due to an inverse relationship between concentration and sales growth (H3). This result is contrary to Schumpeter's (1942, 1975) hypothesis. Perhaps high concentration, low variance industries are mature ones where stability of sales and profits makes further investment unprofitable. Such firms may be less compelled to innovate, and shakeouts result in greater concentration (Bain, 1968; Scherer, 1980) and less competition in such industries. Firms operating in low concentration markets with a high degree of rivalry may feel a greater need to be in tune with customer needs, and to build customer advantage through innovation. Retaliation can be met with equal force due to the lack of a clear market leader.

Role of firm size

Our model shows that,

$$\text{Innovativeness}_{t+1} = -0.854 \times \text{Size}_t + \ldots,$$

and

$$\text{Performance}_{t+2} = +0.371 \times \text{Size}_t + \ldots.$$

Large firm size results in low innovativeness ($\gamma = -0.854$) and high performance ($\gamma = 0.371$), resulting in a small negative total effect of size on performance (H4). Of the three structural determinants, size has the largest impact on innovativeness. Although large firms do innovate, their proportional ability to do so may be limited by the technology and the market. Also, standardizing the number of innovations and sales by the number of employees may disproportionately penalize large firms. These results are consistent with the results of Mansfield (1968a, b) and Schmookler (1972), in that economies of scale appear to have an impact only up to modest size firms, suggesting that a critical mass of innovative personnel may exist. Also the product life cycle may moderate the impact of size since Pavitt and Wald (1971) found opportunities for small firms to be the greatest in the early stages of the product life cycle, whereas the later stages proved more profitable for larger firms.

Role of diversification

The best fitting model shows that,

$$\text{Performance}_{t+2} = -0.297 \times \text{Diversification}_t + \ldots.$$

Diversification had no effect on innovativeness and a negative effect on performance ($\gamma = -0.297$, H6). This suggests that firms should consider remaining in their area of distinctive competency. It is also possible that the negative effect of diversification is collinear with size, and the joint effect of large size and high diversification is to decrease a firm's innovativeness and performance.

Conclusions and implications

Through a longitudinal analysis of a single industry and the employment of structural equation modelling, we were able to partially test a more complete model structure of industrial innovation than has been previously reported. This methodology is in keeping with a call for research made by Baldwin and Scott (1987, p. 112) who consider that "modeling and testing the relevant hypotheses in a dynamic process with industry structure, firms' R&D effort, and innovation all endogenous pose some of the greatest challenges for future work." We consider the exploratory nature of this study a beginning of the development of a more complete theory of the relationship between structural features, innovativeness and firm performance.

To summarize:

— We performed a simultaneous and longitudinal analysis: Our variables were time lagged, and analyzed simultaneously to determine combined effects.

— We used new products as the innovative output: New products are the result of an entrepreneur's efforts to commercialize a technology, and are more appropriate measures of the success of innovative activities than patents (the focus of most other studies).

— We developed a new measure of degree of rivalry: Kamien and Schwartz (1982) suggest the need to consider the degree of rivalry as a determinant of innovative activity. We developed Market Share Variance, which measures the degree of rivalry in an industry as a second indicator of market structure.

Our work has some key weaknesses: it is exploratory, is based on linear models and limited to one industry for which data were available. We had some measurement problems, including finding no radical innovations among our data. In addition, our work is limited by the lack of cyclical feedback effects (i.e. performance → size → R&D investment → innovation → performance, etc.), and by the lack of consideration of other variables that could have an impact on innovative activity, including measures of the technological environment, conditions of entry, and the degree of product differentiation.

A key conclusion of this study is that market structure and firm size affect innovativeness and that innovativeness in turn (along with firm size and diversification) has a positive effect on performance. The lagged structure of our analysis allows us to make some loose causal inferences from these results. This suggests that firms that continue to develop and market new products (thereby meeting changing customer needs) are likely to perform better than firms that are less tuned to their customers.

Industries characterized by low concentration and a high degree of rivalry are conducive to successful innovation due to the stimulus of competition and the absence of a threat of significant retaliation from a "big" competitor. However, an intermediate level of competition and rivalry may be even more conducive to innovation because such a structure can support sufficient competition to foster innovation while providing more tangible rewards for the (larger) innovator. Such rewards are difficult to obtain in a perfectly competitive structure. Large firms are not innovative in proportion to their size, but are more likely to have the resources to research, develop, and market radical and major breakthrough innovations. Small firms appear to find it easier to imitate.

In sum, this study suggests how some of the inconsistencies and methodological problems in the reported research can be overcome to develop a better understanding of the relationship between market structure, innovation and firm performance. The preliminary results suggest how rewards differ by market structure, underscoring Porter's (1985) notion of the critical nature of appropriate market and competitor selection in determining superior performance.

References

Aaker, D.A. and R.P. Bagozzi, 1979. Unobservable variables in structural equation models with an application in industrial selling. Journal of Marketing Research 16 (May), 147–158.

Abernathy, W.J., K.B. Clark and A.M. Kantrow, 1983. Industrial renaissance: Producing a competitive future for America. New York: Basic Books.

Adams, W.J., 1970. Firm size and research activity. Quarterly Journal of Economics 84, 386–409.

Arrow, K., 1962. Economic welfare and the allocation of resources for inventions. In: R.R. Nelson (ed.), The rate and direction of inventive activity, New Jersey: Princeton University Press.

Baily, M.N. and A.K. Chakrabarti, 1985. Innovation and Productivity in U.S. industry. Brookings Papers on Economic Activity, 2.

Bain, J.S., 1968. Industrial organization. New York: John Wiley and Sons.

Baldwin, W.L. and G.L. Childs, 1969. The fast second and rivalry in research and development. Southern Economic Journal 36(1) (July), 18–24.

Baldwin, W.L. and J.T. Scott, 1987. Market structure and technological change. New York: Harwood.

Bass, F.M., P. Cattin and D. Wittink, 1978. Firm effects and industry effects in the analysis of market structure and profitability. Journal of Marketing Research 15 (Feb.), 3–10.

Biggadike, E.R., 1976. Corporate diversification: Entry strategy and performance. Cambridge: Harvard University Press.

Blair, J.M., 1972. Economic concentration: Structure, behavior and public policy. New York: Harcourt Brace Jovanovich.

Booz, Allen and Hamilton, 1982. New product management for the 1980's, Vol. 4 New York: Booz, Allen and Hamilton, Inc.

Buzzell, R., 1981. Are there "natural" market structures? Journal of Marketing 45 (Winter), 42–51.

Buzzell, R.D., B.T. Gale and R.G.M. Sultan, 1975. Market share—The key to profitability. Harvard Business Review (Jan.-Feb.), 97–106.

Christensen, H.K. and C.A. Montgomery, 1981. Corporate economic performance: Diversification strategy versus market structure. Strategic Management Journal 2 (Oct.-Dec.), 327–343.

Cohen, W.M., R.C. Levin and D.C. Mowery, 1987. Firm size and R&D intensity: A re-examination. The Journal of Industrial Economics 35(4) (June), 543–565.

Comanor, W.S., 1965. Research and technical change in the pharmaceutical industry. Review of Economics and Statistics 47(2) (May), 182–190.

Comanor, W.S. and F.M. Scherer, 1969. Patent statistics as a measure of technical change. Journal of Political Economy 77(3) (May/June), 392–398.

Cooper, A.C., 1964, R&D is more efficient in small companies. Harvard Business Review 42(3) (May/June), 75–83.

Duerr, M.G., 1986. The commercial development of new products, Vol. 3. New York: The Conference Board.

Fortune, 1988. 3M: Keeping the fires lit under the innovators. Fortune (March 28).

Freeman, C., 1973. A study of success and failure in industrial innovation. In: B.R. Williams (ed.), Science and technology in economic growth. New York: Wiley.

Galbraith, J.K., 1952. American capitalism. Boston: Houghton Mifflin.

Gannicott, K., 1984. The determinants of industrial R&D in Australia. Economic Record 60, 231–235.

Goldberger, A.S., 1973. Structural equation models: An overview, In: A.S. Goldberger and O.D. Duncan (eds.), Structural equation models in the social sciences. New York: Seminar Press.

Joreskog, K.G. and D. Sorbom, 1982. Recent developments in structural equation modeling. Journal of Marketing Research 19 (Nov.), 404–416.

Joreskog, K.G. and D. Sorbom, 1984, LISREL: Analysis of linear structural relationships by the method of maximum likelihood (Version VI). Chicago: National Educational Resources.

Kamien, M.I. and N.L. Schwartz, 1982. Market structure and innovation, Cambridge: Cambridge University Press.

Kelly, T.M., 1970. The influences of firm size and market structure on the research efforts of large multiple-product firms. Ph.D. Dissertation, Oklahoma State University.

Kotler, P., 1989. Marketing management: Analysis, planning and control, 5th edition. New Jersey: Prentice-Hall.

Levin, R.C., W.M. Cohen and D.C. Mowery, 1985. R&D appropriability, opportunity and market structure: New evidence on some Schumpeterian hypotheses. American Economic Review 75(2) (May), 20–24.

Lieberman, M.B. and D.B. Montgomery, 1988. First-mover advantages Strategic Management Journal 9 (Summer), Special Issue.

Lilien, G.L. and P. Kotler, 1983, Marketing decision making: A model-building approach. New York: Harper and Row.

Lunn J. and S. Martin, 1986. Market structure, firm structure, and research development. Quarterly Review of Economics and Business 26, 31–44.

MacLaurin, W.R., 1954. Technological progress in some american industries. American Economic Review 44(2) (May), 178–189.

Mansfield, E., 1968a. The economics of technological change. New York: Norton.

Mansfield, E., 1968b. Industrial research and technological innovation: An econometric analysis. New York: Norton.

Mansfield, E., J. Rapoport, A. Romeo, E. Villani, S. Wagner and F. Husic, 1977. The production and application of new technologies. New York: Norton.

Montgomery, C.A., 1982. The measurement of firm diversification: Some new empirical evidence. Academy of Management Journal 25 (June), 299–307.

Nelson, R.R., 1959. The simple economics of basic scientific research. Journal of Political Economy 67(3) (June), 297–306.

Porter, M.E., 1985. Competitive advantage: Creating and sustaining superior performance. New York: The Free Press.

Robertson, T.S., 1971. Innovative behavior and communication. New York: Holt, Rinehart and Winston.

Robinson, W.T. and C. Fornell, 1985. Sources of market pioneer advantages in consumer goods industries. Journal of Marketing Research 22 (Aug.), 305–317.

Rumelt, R.P., 1982. Diversification strategy and profitability Strategic Management Journal 3 (Oct.-Dec.), 359–369.

Scherer, F.M., 1965a. Firm size, market structure, opportunity and the output of patented inventions. American Economic Review 55(5) (Dec.), 1097–1125.

Scherer, F.M., 1965b. Size of firm, oligopoly and research: A comment. Canadian Journal of Economics and Political Science 31(2) (May), 256–266.

Scherer, F.M., 1967. Research and development resource allocation under rivalry. Quarterly Journal of Economics 81, 359–394.

Scherer, F.M., 1980. Industrial market structure and economic performance. Boston: Houghton-Mifflin.

Scherer, F.M., 1984. Innovation and growth: Schumpeterian perspectives. Cambridge: MIT Press.

Schmookler, J., 1966. Invention and economic growth. Cambridge: Harvard University Press.

Schmookler, J., 1972. The size of firm and the growth of knowledge. In: Z. Griliches and L. Hurwicz (eds.), Patents, invention and economic change. Cambridge: Harvard University Press.

Schnaars, S.P., 1986. When entering growth markets are pioneers better than poachers? Business Horizons (March–April).

Schumpeter, J.A., 1942. Capitalism, socialism and democracy. New York: Harper.

Schumpeter, J.A., 1975, Capitalism, socialism and democracy, third edition. New York: Harper and Row.

Smyth, D.J., J.M. Samuels and J. Tzoannos, 1972. Patents, profitability, liquidity and firm size. Applied Economics 4(2) (June), 77–86.

U.S. Census of Manufacturers 1987. Industry series: Plastics materials, synthetic rubber and manmade fibers, US Department of Commerce, Bureau of the Census.

Uhlman, L., 1979. Wie viele kleinere und mittlere unternehmen betreiben forschung und entwicklung? Ifo-Schnelldienst (13/79), 7–13.

Usher, D., 1964. The welfare economics of invention, Economica N.S. 31, 279–287.

Varadarajan, P., 1986. Product diversity and firm performance: An empirical investigation. Journal of Marketing 50 (July), 43–57.