Dynamic Consequences of Pricing Strategies for Research & Development and the Diffusion of Innovations

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ABSTRACT

The development and diffusion of innovations is a highly dynamic phenomenon. It is influenced by various factors like price, product quality, and market entry time. The paper discusses the impact of pricing strategies on R&D performance and the diffusion of innovations. It is based on a comprehensive decision support model in the field of innovation management. The model consists of two components: (1) an evolution algorithm modeling the processes of corporate R&D, and (2) a DYNAMO-based modul mapping corporate policy making and the structural fundamentals of market dynamics. The integrated model is used to analyze the dynamic consequences of different pricing strategies on research and development, the readiness for market entry and the resulting competitive advantages.

PROBLEM AND MODEL STRUCTURE

Since several years, the management of technology and innovation is an ongoing research project at the Industrieseminar. Several papers were presented at System Dynamics Conferences reporting on findings about appropriate policies and methodological developments. One of the first applications was devoted to pricing strategies in a dynamic environment (Milling 1986a, Milling 1986b).

PRICING STRATEGIES AND THE DIFFUSION OF INNOVATIONS

Pricing new products is an essential but largely unresolved problem of innovation management. Peculiar difficulties result from the dynamics in demand interrelations, cost development, and the risk of substitution through more advanced products. In an early version of the innovation model, several price setting mechanisms were included for direct investigation:

(1) Myopic profit maximization where there is perfect information on the current state of cost and demand. The optimal price is derived from elasticity of demand ε_t and per unit cost c_t^{std} which depend on long run experience effects and on short term capacity utilization:

$$p_t^{opt} = c_t^{std} \cdot \left(\frac{\varepsilon_t}{1+\varepsilon_t} \right) \tag{1}$$

(2) Skimming price strategy with the objective of serving first customers with high reservation prices and subsequent price reductions. The model applies a simple decision rule modifying p_t^{opt} through a function of market saturation ms:

$$p_t^{skim} = p_t^{opt} \cdot \left(1 + f(ms)\right) \tag{2}$$

(3) Penetration pricing aims at rapidly reaching high production volumes to benefit from the experience curve and to increase the number of adopters. It sets prices according to:

$$p_t^{pene} = p_t^{opt} \cdot \left(1 - f(ms)\right) \tag{3}$$

In the dynamic environment under investigation the classical pricing rule for profit optimization turned out to be superior to the skimming strategy. The appropriate strategy - as suggested by these results - constitutes the attempt to rapidly penetrate the market. This objective is achieved by setting relatively low prices, especially in the early stages of the life cycle, and by providing sufficient production capacity for immediate delivery. Temporary excess capacity hurts the financial performance less than longer delivery delays. The combined price and diffusion effect stimulates the environmental demand dynamics and reduces the risk of loosing potential customers to upcoming substitution products.

COARSE STRUCTURE OF THE COMPREHENSIVE INNOVATION MODEL

Frequently only the market stage, during which the product is sold, is associated with the notion of an innovation. However, before the availability of a marketable product the costly, lengthy and risky period of research and development has to be passed successfully. While the market cycle tends to become shorter and to reduce the time for the corporations to earn their money, the research and development phase requires increasingly more time, personnel and financial resources. These diverging trends make it difficult to achieve a satisfactory profit performance. A comprehensive investigation into innovation dynamics must cover both, the development and the market cycle (Milling 1991a).

The comprehensive innovation model consists of two modules: one reflecting the processes of R&D, the other representing the market cycles. Figure 1 shows the structure of the overall model and its components. Both modules are linked through flows of information to monitor the resource allocation, the intensity of the R&D-processes, the required minimum quality level before a new product is considered ready for market introduction, etc.

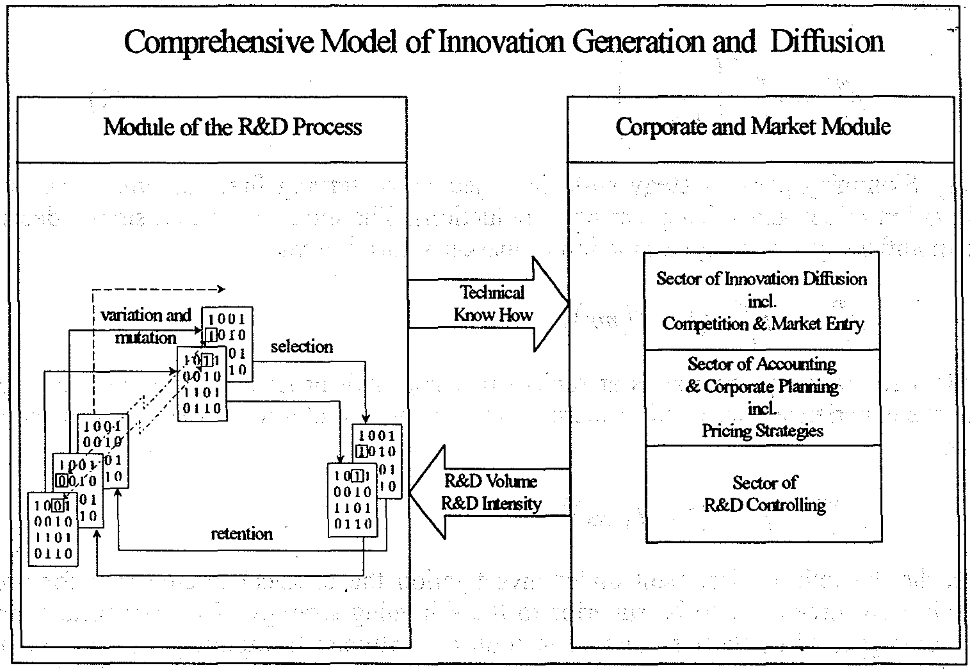

Fig. 1: Coarse structure of the comprehensive innovation model

The module of the research and development phase deals largely with intangible processes. Many attempts were made to define a production function for research and development, using as input the allocated resources like budget, number of people assigned to the task, equipment available, etc. In general, these attempts were not successful in describing how the various factors operate together to achieve the desired results. In this model a different approach is used. An analogy to biological evolution theory defines how new concepts develop by the variation and mutation of existing and known solutions. The respective results are evaluated on the basis of viability. If they seem to be superior to previous combinations, they are selected for further development, i.e. as the basis for future evolution. Otherwise they are discarded. This evolution module is a C-written algorithm that is linked to and interacts with the production and market part of the model (Milling 1991a, Milling 1991b, Maier 1992).

The corporate and market structure is based methodologically upon the System Dynamics paradigms, i. e. the feedback perspective of social systems and the use of computer simulation for gaining a better understanding of its properties. Professional DYNAMO plus was used to represent the module, to link it to the evolution algorithm through the External Function facility, to simulate and analyze the total model.

CONSEQUENCES OF PRICING STRATEGIES IN THE COMPREHENSIVE INNOVATION DIFFUSION MODEL

ELEMENTARY FEEDBACK STRUCTURE OF PRICING, R&D BUDGETING AND SALES

The first step in the analysis of the model behavior is the investigation of the feedback structure of pricing strategies, R&D budgeting, market entry time and the diffusion of innovations (cf. Fig. 2). The central part of the market module is an equation that determines a company's sales volume per period through addition of innovative and imitative purchases and therefore the diffusion of innovations (Bass 1969, Milling 1986). Innovative purchases are calculated as the product of the coefficient of innovation (INC) – this is the fraction of innovators – and the number of potential customers (POTCUST). Innovators buy a new product because they have a general interest in innovations. In contrast, imitators are influenced in their purchasing decision through the number of customers who already bought the product, the so-called adopters. The imitators are computed as the product of the coefficient of imitation (IMC), the potential customers and the adopters. The coefficient of imitation (IMC) defines the probability that the communication between adopters and potential customers – expressed through the term (POTCUST*ADOPTER) – causes the purchase of a product.

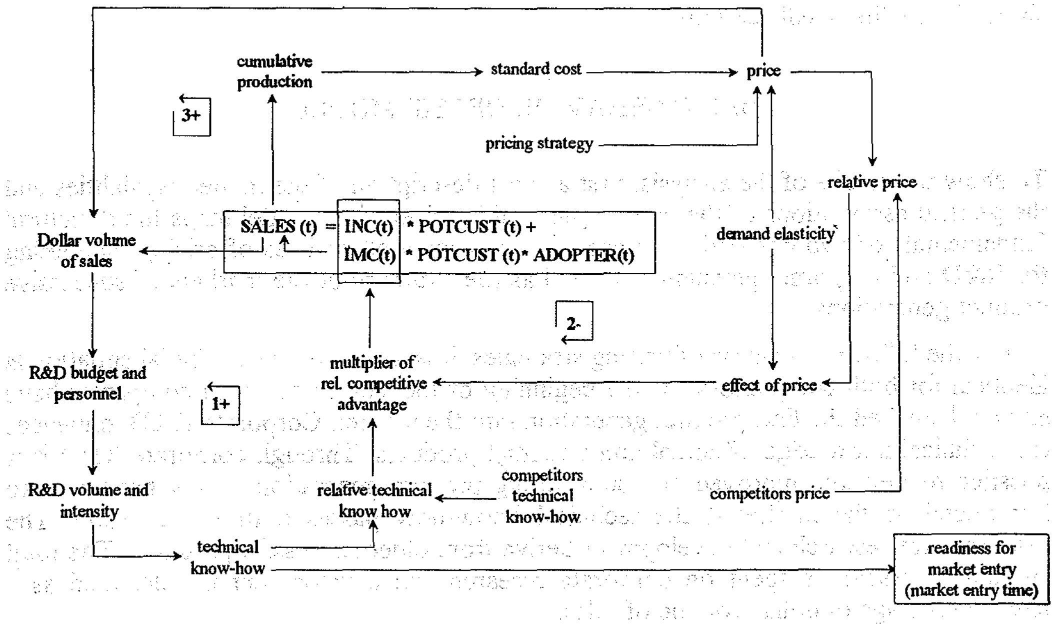

Fig. 2: Feedback structure influencing the diffusion process

The first loop describes the feedback relations between the sales of a product, the R&D process and the effect of relative competitive advantage. With an increasing number of sales volume and a growing dollar volume of sales the R&D budgets and the size of R&D personnel grow larger. By the way of enhanced higher technical knowledge this cause a stronger competitive advantage. The higher the sales volume, the better is the resulting competitive position. That produces increasing coefficients of innovation and imitation and finally leads to higher sales volume again. The sales oriented R&D budgeting strategies implemented and described here cause positive feedback (Maier 1992).

The second feedback loop shows the influence of pricing strategies on sales volume. The actual price of a product is influenced by three factors. The first factor, standard costs, is endogenous. The second and third element influencing the calculation of prices are exogenous elements: the pricing strategy and the demand elasticity. Standard costs are the basis for the calculation of the prices for each pricing strategy. They depend on the cumulative production of a product, influenced by the actual sales volume. Higher cumulative production causes experience effects that reduce the standard costs and therefore the basis for pricing. Lower prices themself affect relative price and improve the effect of price on the coefficients of innovation and imitation. Higher coefficients again produce increased sales.

The price level depends on the pricing strategy. The model includes alternative pricing policies like (1) the strategy of myopic profit maximization, (2) the strategy of skimming pricing or (3) a penetration pricing strategy. Demand elasticity determines the profit margin for the first three strategies and therefore the price. Feedback loop 3 shows the effect of pricing on the dollar volume of sales. Higher prices cause, under the assumption of a constant sales volume, an increasing dollar volume of sales, with all the consequences on the R&D process, the technical know-how and the market entry time as shown in the first feedback loop.

BASIC BEHAVIOR OF THE MODEL

To show the results of the analysis, first a short description of the model capabilities and the general assumptions of the model runs will be given. The model maps the structural fundamentals of two competing companies – including all policies of pricing, budgeting for R&D and corporate planning – as well as the structure of the markets of successive product generations.

For the following analysis of pricing strategies, it is assumed that the initial situation is identical for both competitors. At the beginning of the simulation, both companies have already launched the first product generation into the market. Corporate R&D influences the technical knowledge of actual and potential products. Through corporate R&D it is possible to develop improved and substituting product generations. New products are introduced to the market if the technical know-how passes a threshold value. The resources for research and development derive from older successful products. The total amount of resources spent on corporate research and development is calculated as a fixed percentage of dollar volume of sales.

This sales oriented R&D strategy – it is activated in all model runs – produces positive feedback (Loop 1 in Fig. 2). With equivalent initial situation and the same set of strategies both companies behave in an identical way for all product generations, except some minor stochastic differences caused by the evolution algorithm modeling the R&D process. If one company has a competitive advantage, e.g., through earlier market entry, a concentration process will be initiated and continued that causes earlier readiness for market entry and increased sales for all successive product generations. The competitors with the advantage will improve continuously (Maier 1992).

CONSEQUENCES OF PRICING STRATEGIES IN THE COMPREHENSIVE MODEL

The analysis of the following model runs will show the impact of different pricing strategies on the process of R&D and the diffusion of an innovation. In the different model runs the first company uses the strategy of skimming price; alternatively the competitor uses skimming price strategy in the first model run (basic run). In the second and third strategy run he uses myopic profit maximization strategy and the strategy of penetration prices. For all product generations the pricing strategies are the same. The demand elasticity $\varepsilon = \frac{\frac{\delta x}{x}}{\frac{\delta p}{p}}$ has the value -2.

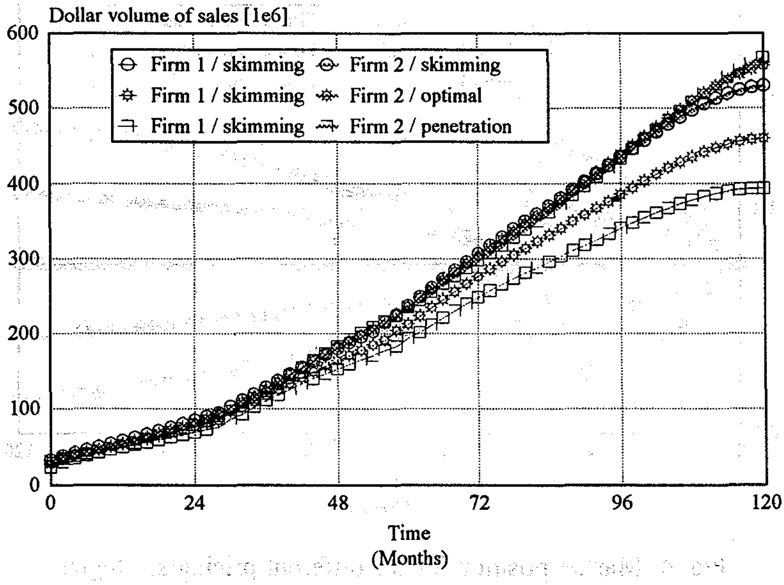

Fig. 3: Dollar volume of sales for the different pricing strategies

Exhibit 3 shows the time path of the dollar volume of sales for both competitors in different model runs. The superior strategy is the penetration strategy of company 2. The dollar volume of sales of firm 2 is nearly 44% higher than the first company's. The second best strategy is the strategy of myopic profit maximization with a sales volume, that is only 2% lower than in the run with penetration pricing. Compared to the first company, in this run the volume is 21% higher. Exhibit 3 also shows that in the case of skimming price strategy for both companies a relatively high volume is reached. The difference between the best strategy and the skimming price strategy is only 7%.

The variable market position gives an aggregation of a company's products market share. Values greater than 1 mean that the market-position is better than that of the competitor. Exhibit 4 the time path of the market-position is shown. Running the model with a parameter set where both competitors use the strategy of skimming prices, there is no effect on the market-position, the value is 1 for both firms during the whole simulation. If the second company is running a strategy of optimal prices or penetration prices it improves its market-position until period 30 respectively 32 – when firm 1 launches as a pioneer the second product generation. Firm 2 loses market-position caused by the first firm's competitive advantage of early market entrance for the second product generation. After period 40 the second company is able to improve its market-position again through the better effect of price and the higher value of the multiplier of competitive advantage. In period 56 respectively 58 both competitors launch the third product generation. Taking the changing market-position as the measure for the quality of a strategy one can state that again the strategy of penetration pricing is the best.

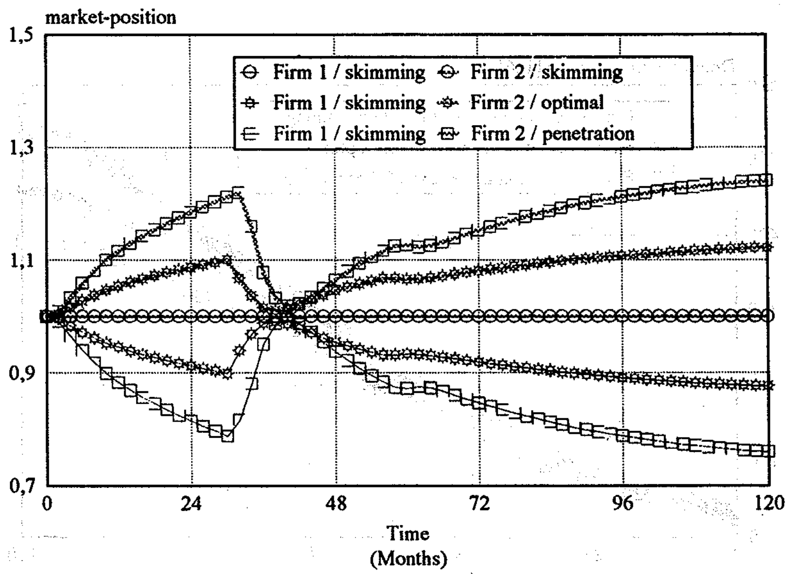

Fig. 4: Market position for the different pricing strategies

Looking at cumulative profits the result is different. In the basic run of the model, where both companies are using a skimming price strategy, cumulative profits reach the highest level. The second best solution in terms of cumulative profits is the strategy of optimal prices. After period 110 the second firm passes the first company and finally reaches a value that is only 9% lower than its cumulative profits in the basic run. Running the model with company 2 using the strategy of penetration pricing the first company is leading nearly almost period 120. At the end of the simulation, company 2 makes up the first firms small advantage. The final level of cumulative profits is 24% lower than in the run with skimming prices.

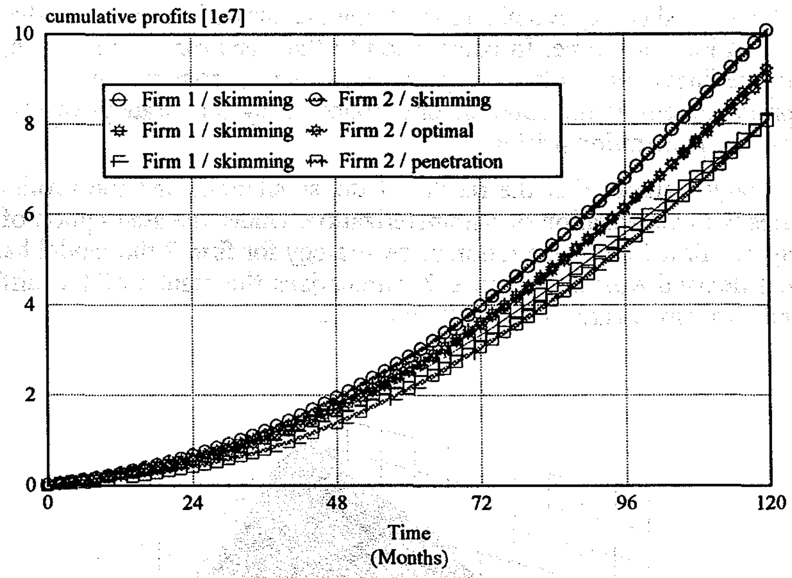

Fig. 5: Time path of the cumulative profits

The last variable to investigate is the readiness for market entry. The companies launch new products if the technical know-how incorporated in a product exceeds a critical value. In the basic run of the model both firms introduce their second product generation to the market at period 29; the third product generation follows in period 55. The model runs clearly show that pricing strategies have an impact on market entry time (Fig. 6). In the case of the profit maximization strategy the second firm's dollar volume of sales is lower than the first firm's. That causes – compared to firm 1 – lower R&D budgets and personnel, consequently reduced R&D volume and intensity and less technical know-how. This finally produces the delay in market entry time for the second product generation shown below.

	product generation 2			product generation 3		
pricing strategy firm 2	firm 1	firm 2	delay compared to firm 1	firm 1	firm 2	delay compared to skim.-strategy
skimming price	29	29	0	55	55	0
profit maximization	29	30	1	56	56	1
penetration price	29	32	2	58	58	3

Fig. 6: Consequences of pricing strategies on market entry time

Although the first firm has a competitive advantage resulting from its earlier market entry, firm 2 realizes – due to the higher effect of price on the coefficients of innovation and imitation – an increasing sales volume (see Fig. 3). Considering the third product generation, the second company's higher sales volume allows it to make up the first firm's advantage in market entry time. In comparison to the basic run of the model, there is a delay in the readiness for market entry for both firms. From this point of view, the skimming price strategy is the superior one, followed by the strategy of myopic profit maximization and penetration pricing.

The last analysis shows that the results of the simulations and the profitability of a strategy varies with initialization or parameterization. Under the assumption of skimming price strategy for firm 1 and penetration price strategy for firm 2 the model has been run with changed demand elasticity. Figure 7 summarizes the results of the different runs were demand elasticity ε varies from -3.2 up to -1.2.

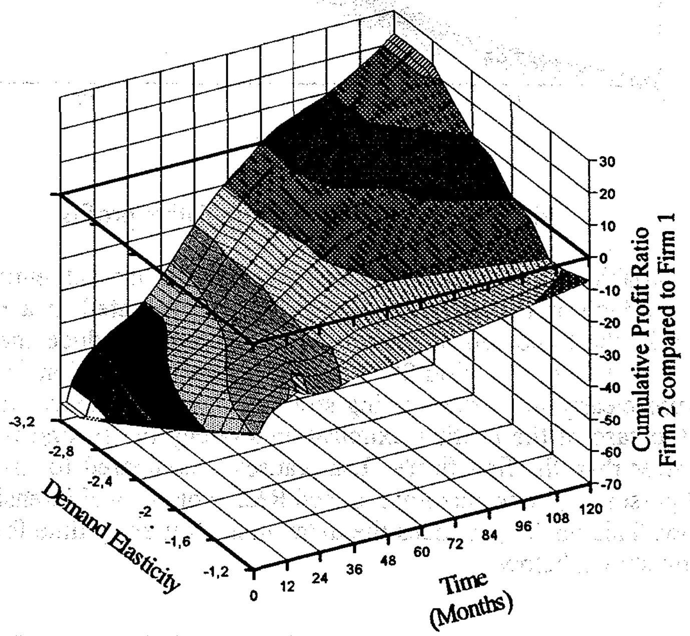

Fig. 7: The impact of different demand elasticities on relative cumulative profit ratio

Due to the different profit margins – resulting from myopic profit maximization that is the basis for price calculation – the use of the absolute value of the cumulative profits is not appropriate. For the evaluation of the runs, the relative cumulative profit ratio is computed as $\left(\frac{\text{cum. profits firm 1 - cum. profits firm 2}}{\text{cum. profits firm 1}} \cdot 100\right)$. The exhibit shows, that with increasing demand elasticity the initial disadvantage of the second company but also its chance of gaining an advantage rises. In the case of lower demand elasticities ($\varepsilon > -2$) firm 2 has a diminishing but still existing disadvantage during the whole simulation.

CONCLUSIONS FOR PRICING

The model runs have shown that the judgment of strategies depends on the objectives of a company. If a firm wants to enhance its dollar volume of sales or the market-position, the strategy of penetration pricing is the superior one; but in terms of sales volume there is only a marginal difference between profit maximization and penetration pricing strategy. Viewing cumulative profits and the readiness for market entry the strategy of skimming prices is the best. The evaluation of an optimal strategy is not possible. The outcome of a strategy and therefore the choice of a strategy depends on to many factors that influence the diffusion process.

The results show clearly the relativity of the judgment of strategies. Neither optimal solutions nor generally valid solutions can be found. Optimization algorithms must fail. The model must always fit the unique characteristics of the problem under investigation.

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