A MODEL FOR DUOPOLY COMPETITION IN THE DURABLE HOUSEHOLD GOODS MARKET

by

GÜLAY ARZU INAL

Submitted to the Graduate School of Engineering and Natural Sciences
in partial fulfillment of
the requirements for the degree of
Master of Science

Sabanci University
August 2003

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APPROVED BY:

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DATE OF APPROVAL: 08.22.2003

To Ferda & Mustafa ILHAN

ACKNOWLEDGEMENTS

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ABSTRACT

In this study, a model for duopoly competition in the durable household goods market is presented. The aim is to investigate the various scenarios and policies on a representative dynamic model. System dynamics is used as the methodology, since it is an adaptive tool that allows for feedback mechanisms.

The proposed model consists of six modules: (1) diffusion module, (2) price module, (3) advertising module, (4) word of mouth (WOM) module, (5) cost module, and (6) delivery delay module. Diffusion module consists of innovative demand and imitative demand based on standard Bass model. Advertising effect constitutes the innovative demand whereas WOM constitutes the imitative demand. Price module consists of two sub modules. In the first one, the demand is treated as a function of price, and in the second one price setting process is modeled so a to allow for different pricing strategies. Diminishing returns and accumulated effects build up the advertising module. Conventional WOM effect is modeled in a separate module. The economies of scale and learning curve effects, which may lead to cost decreases during the time horizon, are included in the cost module. Finally, the negative effect of longer delivery times is modeled in the delivery delay module. These modules are replicated for the competitor since a duopoly market structure is investigated.

The market consists of four segments and each segment has an associated product. If the product is not available in a segment, then the customers of that segment purchase the product from the first lower segment with product available. The customers of each segment have price levels for the products and a linear demand curve is used for the demand - price relationship.

The model allows for different market entry times and new product launchings. The necessary module replications are also performed for the entry of the second products (for both of the firms).

In the scenario analysis, various pricing strategies and different product launching times and new product launching decisions both in monopoly and duopoly are tested. The developed model produced valid and consistent results in all scenarios.

ÖZET

Bu çalismada, dayanikli tüketim mali üreten iki firmanin duopol rekabeti modellenmistir. Amaç çesitli senaryo ve politikalari temsili bir dinamik modelde test etmektir. Metodoloji olarak, adaptif yapisindan dolayi geri besleme mekanizmalarini içeren sistem dinamigi kullanilmistir.

Gelistirilen model alti modülden olusmaktadir: (1) difüzyon modülü, (2) fiyat modülü, (3) reklam modülü, (4) tavsiye etkisi (word of mouth) modülü, (5) maliyet modülü, ve (6) teslimatta gecikme modülü. Difüzyon modülü, standart Bass difüzyon modelinde oldugu gibi inovatif ve imitatif taleplerden olusmaktadir. Reklam etkisinden dolayi inovatif talep olusurken tavsiye etkisinden dolayi de imitatif talep olusmaktadir. Fiyat modülü iki alt modülden olusmaktadir. Ilkinde talebi fiyatin bir fonksiyonu olarak inceleyen mekanizma, ikincisinde ise çesitli fiyatlandirma stratejilerine izin veren fiyatlandirma süreci tasarlanmistir. Reklam modülünü azalan getiriler ve birikimli reklam etkileri olusturmaktadir. Tavsiye etkisi ayri bir modülde modellenmistir. Zaman içerisinde maliyette düsmelere yol açabilen ölçek ekonomisi ve ögrenme egrisi etkileri maliyet modülünü olusturmaktadir. Son olarak teslimatin gecikmesinden dolayi olusan olumsuz etkiler teslimatta gecikme modülünde modellenmistir. Duopol bir Pazar yapisi söz konusu oldugundan bahsedilen modüller rakip için de tekrarlanmistir.

Pazar dört katmandan olusmaktadir ve her katmana hitap eden ayri bir ürün vardir. Eger bir katmanda ürün mevcut degilse, o katmanin müsterileri taleplerini ürünü mevcut olan ilk alt katmandan karsilamaktadirlar. Her katmanin müsterileri ilgili ürün için bir fiyat seviyesine sahiptirler ve fiyat talep iliskisi de dogrusal bir islevle modele yansitilmaktadir.

Model firmalarin farkli zamanlarda pazara ürün sürmelerine ve yeni ürün pazara sürmelerine olanak saglamaktadir. Gerekli modül tekrarlamalari her iki firmayi da kapsayacak sekilde, yeni ürünler için de yapilmistir.

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1. INTRODUCTION

Increased competition and variety in customer orders lead to complex environments to be dealt with for industrial firms. In general, the number of entities and the interactions between these entities increase in such complex environments leading to uncertainty in decision-making.

Daft (1998) states that "Uncertainty increases the risk of failure for organizational responses and makes it difficult to compute costs and probabilities associated with decision alternatives." Also Dessler (1998) mentions the difficulty of managing in a dynamic environment. However, there is no escape from these complicated systems, in which decision-making under uncertainty becomes a challenge. To build representative models for selected complex problems is a challenging research area as they investigate such situations and allows for various policies.

The subject of this study arises from this challenge. The investigation of duopoly competition in the durable household goods market is the starting point of this study. The durable household goods market is selected for investigation, since this market is an important one in Turkey. Although the durable household goods market is a mature market in the world, new product developments and related R&D studies still provide opportunities for growth in this market.

In this study, the main functional modules such as marketing, human resources, and finance are not considered. Instead, the decision mechanisms of selected functions are included in order to keep the model simple.

First, the diffusion framework, which builds a base for the selected decision mechanisms, is included along with the selected marketing activities (advertising and pricing). The positive effect of word of mouth, the negative effect of delivery delay, strategic decisions on capacity, possible cost reductions are the other selected decision mechanisms included in the model.

In summary, in this study, a representative model that allows testing various policies (such as different pricing strategies and time to market decisions) in a duopoly competition in durable household goods market is developed with selected decision mechanisms.

The organization of this study is as follows: Chapter 2 states the approach and the methodology behind the model. Chapter 3 explains the model and its modules. Chapter 4 deals with the validity of the model and sensitivity analysis for the selected parameters. Chapter 5 represents the scenarios along with the results and finally Chapter 6 states the conclusions and future research.

2. APPROACH AND METHODOLOGY

In order to build a model as defined in the previous section, the approach to the model structure and methodology must be clarified.

In terms of the approach, the way the model structure defined should be stated. Should we design a totally open-adaptive system or should we set boundaries? Before, answering this question, a brief definition of these terms would be appropriate.

The closed system is a group of interacting elements that do not exchange information, energy, and materials with its environment. In these systems, the predictions can be made relatively easier due to restricted relationships and the system's deterministic structure. However, these predictions do not reflect the rational results and actions for the future of the company, and the possible results for a strategic decision is hard to examine and consider. Therefore, such systems are unable to provide a *totally dynamic structure*.

On the other hand, an open system view may result in more complex models for the organization, which allow any kind of interaction with its environment. Such systems are not deterministic and predictions are harder to make in closed systems. This increases the complexity of the model structure and analysis of the results. However, an increased amount of effort and research for the analysis generally results with rational policies and strategies for the company. In general, organizations and the models are not structured as a totally open system in order to decrease *complexity and the number of parameters*. The designs are tailored to reflect the purpose of the study and the priorities among the members of the environment.

Boone and Kurtz (1992) state some additional characteristics of open systems as follows:

Table 2-1 Characteristics of the open systems (Adopted from Boone and Kurtz, 1992)

Characteristic	**Brief Description**
Cycle of events	Process by which an open system receives inputs from its environment, transforms them, and generates output.
Negative entropy	The ability of a system to repair itself, survive, and grow by importing resources from its environment and transforming them into outputs
Feedback mechanisms	An open systems component that informs the organization of deviations from objectives
Dynamic homeostasis	Process by which open systems maintain equilibrium over a period of time
Differentiation	Structural force in organizations whereby the system develops specialized functions among its various components
Equifinality	Principle that open systems can achieve their objectives through several different courses of action

A system becomes adaptive if there are interactions with the environment that provide feedback to the system and the system itself produces the proper corrections from the mechanism in order to respond to the feedback. Moreover, a balance between the corrections and the feedback has to be reached in order to continue this relationship.

Adaptive organizations are essential mostly in *dynamic environments*, in which reinforcing and balancing relationships arise. According to the changes in the environment, the system produces the most appropriate response to the environment and reaches a balance. Figure 2-2 illustrates an adaptive system that responds to the environmental conditions.

These definitions solve the problem of determining the model structure. Since our aim is to investigate and discuss possible scenarios, possible external effects, we need to build an open-adaptive system. However, as mentioned earlier, a totally adaptive system is really hard to control and test. Therefore, in order to measure the internal effects precisely, we carefully insert external effects. The external effect refers to the effect whose dynamic is not totally designed within the model. In other words, the advertising effect can also be an external one unless the entire dynamics, which generate advertising decisions and effects, are designed within the model. In summary, the model used in the thesis, is an adaptive and controllable open (not totally) system.

System dynamics, as the preferred methodology, enhances the learning in complex systems since it allows simulation. During the simulation, this flexible and adaptive tool –system dynamics– generates the behavior of the system within the defined boundaries and endogenous entities based on the pre-defined relationships and feedback structure. Lyneis (2000) summarizes the main characteristics of system dynamics as follows: "(1) system dynamics models can provide more reliable forecasts of short- to mid-term trends than statistical models and therefore lead to better decisions; (2) system dynamics models provide a means of understanding the causes of industry behavior, and thereby allow early detection of changes in industry structure and the determination of factors to which forecast behavior are significantly sensitive; and (3) system dynamics models allow the determination of reasonable scenarios as inputs to decisions and policies."

However, it should be noted that system dynamics serves the purpose, if and only if, the real conditions and relationships are modeled, and boundaries are drawn attentively. The modeller should reflect the real conditions as much as is possible. Any absent or inaccurate information may lead to a completely different simulation and conclusions.

This methodology not only allows representing material flows within a system but also allows information flows that lead to possible changes in managerial perceptions that influence decisions (Figure 2-1). The absence of such a property, in other words, without the inclusion of the human factor, it is impossible to reflect the real world.

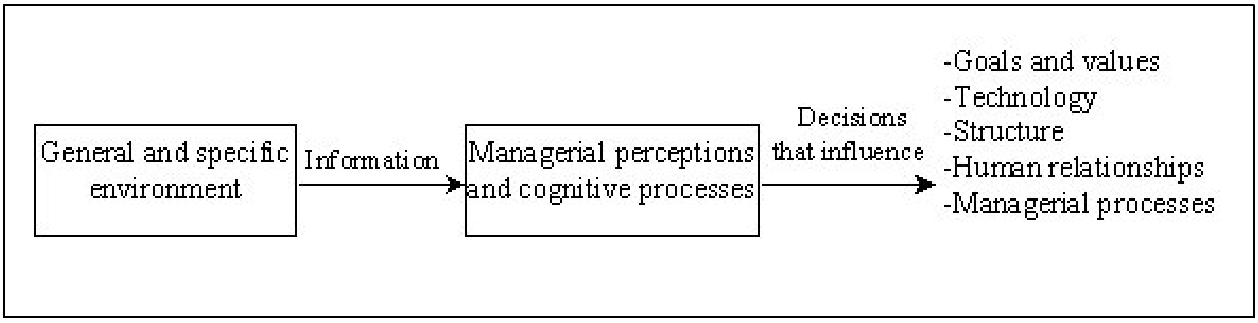

Figure 2-1 Interactions with the environment - information flow (Kast and Rosenzweig, 1985)

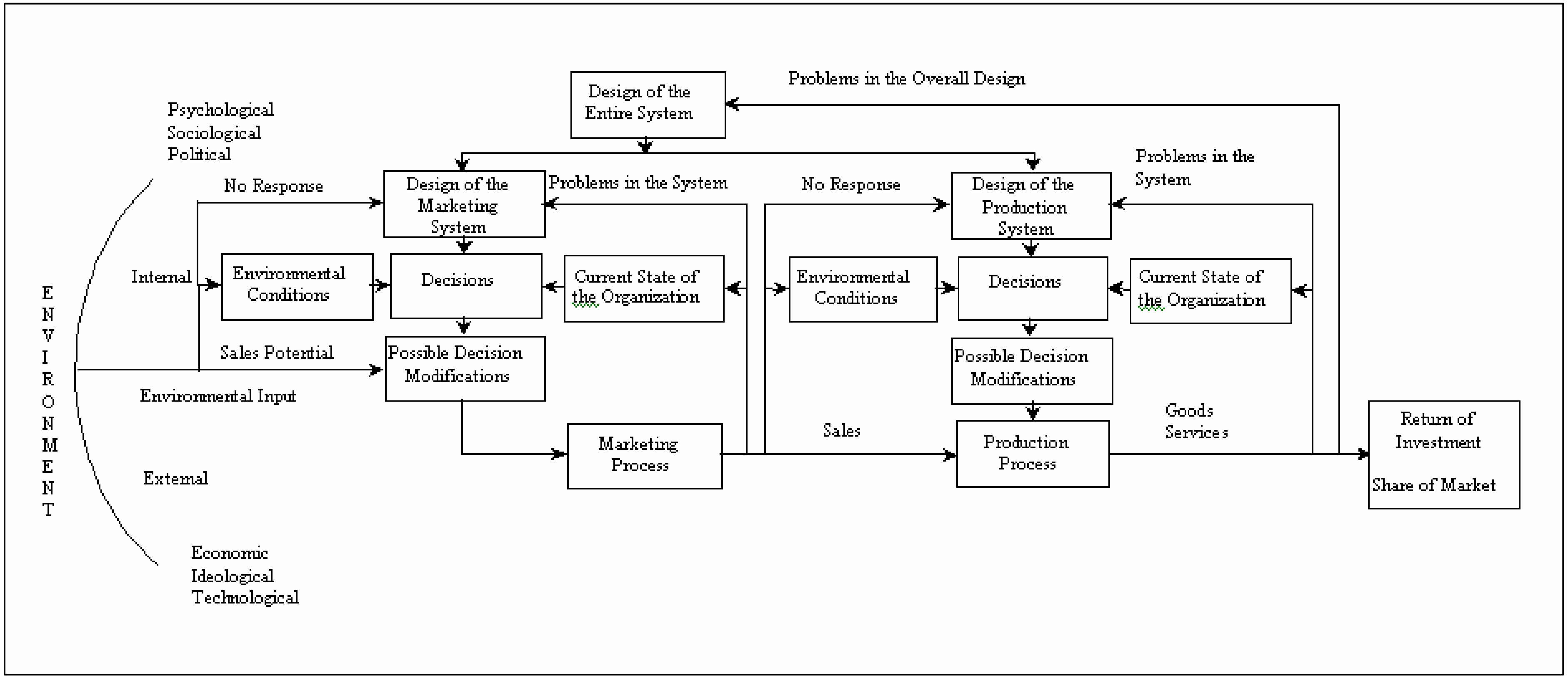

Figure 2-2 Totally adaptive system (Hodgetts, 1986)

3. MODEL

Marketing-production interface and related policies are the basic issues that affect the structure of the market and the company profile. This interface is quite complex and hard to design all at once. Therefore, the model is divided into logical modules and designed sequentially based on various earlier models and research. The modules are as follows:

- Diffusion module
- Price module
- Advertising module
- Word of mouth module
- Cost module
- Delivery delay module

Note that the market structure used in this thesis is explained in Section 3.8. The relationships under a predefined market structure are illustrated in Figure 3-1. It is assumed that all of the l dynamics and relationships are valid for the competitor as well. Price and unique potential customers are the key factors that generate the competition.

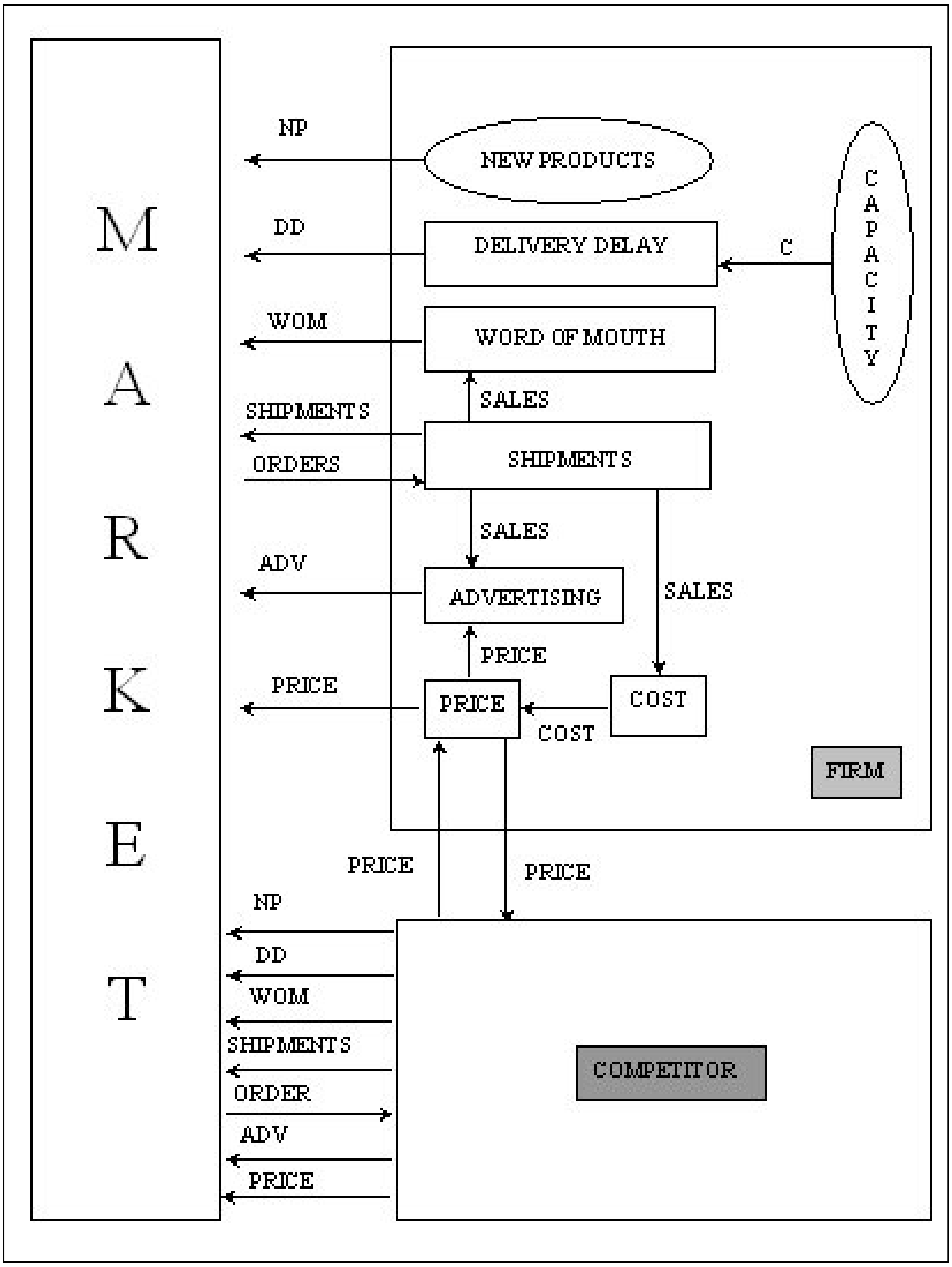

Figure 3-1 Modules and interactions in the model

3.1. Diffusion

The product life cycle is the main concept dependent on the characteristics of companies and the market. This curve represents the behavior of the product during the time horizon. In the business world, the main phases of product cycle are known as introduction, growth, maturity, and decline. In each stage, different marketing and production strategies should be followed based on the product and market characteristics. For example, a company producing high-tech products should introduce successive generations before its competitors do, in order to prevent sharp decreases in the diffusion curve. Sometimes aggressive marketing decisions may lead even to deformations in this curve. An early introduction of a new product that substitutes the firm's current product may unexpectedly decrease sales. Price decisions, advertising, distribution, availability, quality, and product capabilities are some of the factors that affect the structure of the life cycle. Therefore, product life cycle -in other words, the diffusion of products or purchase decisions- is quite a complex and dynamic concept in industry.

The main factors affecting product diffusion process can be displayed in four groups: (1) the market structure (competition arises in duopoly markets); (2) management decisions (quality, price, advertising, product capabilities, technical know-how through R&D, market entry time, delivery delay, and related capacity decisions); (3) general aspects of innovation diffusion (repeat purchases, substitution, dynamic market potential, and negative word of mouth); (4) the innovation itself (carry-over effects from earlier periods) (Maier, 1998) Since all of these factors affecting the diffusion process purchase of a product are more complicated than the spread of a disease, so specific models should be developed for different combinations of factors.

Studies for modelling the diffusion of products began with Fourt and Woodlock in 1960 and Mansfield in 1961; Bass Diffusion Model believed to be the base of the diffusion models was developed by Bass in 1969. After that, these models are repeatedly tested and developed under various assumptions and conditions. A brief summary of this long journey is presented below.

Fourt and Woodlock (1960) develop a mathematical equation with the following assumptions: (1) there exists a maximum number of potential buyers-defined as the ceiling of the penetration, and (2) in each period the increase in the penetration depends on the remaining potential buyers. The model developed includes parameters of a constant purchasing probability and the ceiling. Equation (3.1) displays the purchase behavior in period *i*, where *x* is the ceiling on maximum number of potential customers, and *r* is the constant probability of purchase.

$$S(T=i)=rx\left(1-r\right)^{i} \quad i = 0,1,2,3\ldots.. \tag{3.1}$$

Mansfield (1961) studied the effect of imitation among the firms and the diffusion of new technology based on this imitation and concludes that the probability of imitation –a firm's introduction of a new technology- is positively correlated with the number of earlier imitators and the profitability of this new technology but negatively correlated with the investment required by the technology involved.

Although Mansfield (1961) investigated such a relationship among the firms in an industry, his research has significantly contributed to the new product diffusion studies in terms of realizing the effects of innovators and early adopters of a new product. In fact, the diffusion of a technology in an industry resembles the diffusion of a new product in a market since they both have similar characteristics.

The most widely used mathematical model is the standard Bass growth model, which basically investigates the timing of initial purchases rather than of repeat purchases. However, the consecutive models developed by Bass and other researchers have captured different conditions under various assumptions, such as the presence of a competitor, repeat purchases, and successive generations.

The basic Bass model includes two fundamental characteristics of diffusion process: innovation and imitation, which are also studied separately by Fourt and Woodlock (1960) and Mansfield (1961). According to Bass (1969), some individuals make purchases independent from other potential adopters in the system. These individuals are named as innovators, and therefore, this purchase is called an innovative purchase. Sterman (2000) defines this approach of Bass as the solution for the start-up problem. The remaining individuals in the system are called imitators since their decision depends on the previous adopters and the characteristics of the product. These two flows are formulated as follows:

$$S_1(t)=p*[m-F(t)] \quad \text{Innovative purchase} \qquad (3.2)$$

$$S_2(t)=[q*(F(t)/m)]*[m-F(t)] \quad \text{Imitative purchase} \qquad (3.3)$$

$$S(t)=[q*(F(t)/m)+p]*[m-F(t)] \qquad (3.4)$$

where:

S(t) : The number of new trials at time t (sales at time t)

m : Market potential (assumed as constant)

F(t) : Cumulative number of trails up to time t

p : Coefficient of innovation

q : Coefficient of imitation.

The model can be reduced to that of Fourt and Woodlock (1960) if the coefficient of imitation is set to zero, and to that of Mansfield (1961) if the coefficient of innovation is set to zero.

After numerous applications, the basic Bass model fit is validated and the principle behind the model has been widely accepted in the marketing field. However, for some cases, the initial Bass model becomes insufficient. For example, it does not include the effect of pricing, successive generations, repeat purchases, and so on. Therefore, many models have been developed for special purposes and cases without violating the principle of imitation and innovation effects within the basic Bass model.

The study performed by Mahajan and Peterson (1978) points out that the total potential adopters can be modelled dynamically. The change in population, marketing activities, and government policy are some of the basic reasons behind the change in the number of total potential adopters. The model developed has produced valid results for the growth of the sales of washing machines in the US.

The case of successive generations is handled by Norton and Bass (1987). The Norton- Bass model assumes that the newer generation may widen the potential market just for this product and discusses two possible results with the entry of a new generation to the market. The purchasers who would have bought the older version may adopt the newer one instead. In other words, the entry of a new generation can decrease the potential customers desiring to buy the older product. The second case is the switch case. The customers already adopting the older version can make a repeat purchase and switch to the new product. The Norton-Bass model is developed based on these assumptions and possibilities. The equations for a two generation case are shown in equations (3.5) and (3.6).

$$S_1(t)=F_1(t)m_1\left[1-F_2(t-t_2)\right] \quad \text{for } t > 0 \text{ where } F_2(t-\tau_2) = 0 \text{ for } t < \tau_2 \tag{3.5}$$

$$S_2(t)=F_2(t-t_2)[m_2+F_1(t)m_1] \quad \text{for } t > \tau_2 \tag{3.6}$$

where:

$S_i(t)$ = Sales of generation i at time t, i = 1,2

$F_i(t)$ = Cumulative adoption function of generation i

m_i = Level of potential adopters reached after the entry of generation i (not willing to adopt the generations < i)

τ_i = Market entry time for generation i.

In equation (3.5), the total sales of generation 2 consist of two groups: (1) people making their initial purchase due to the entry of that generation m_2 and (2) those adopting the earlier versions making a repeat purchase previously named as switch case.

The Norton-Bass model designed for a monopoly market handles repeat purchase in a different manner. A switch case is defined as a repeat purchase and specific to high-tech products. The case of repeat purchase is included in the model developed by Bass and Bass (2001). In the model, repeat purchase and initial purchase are separated. This model has assumptions for high-tech products and a complicated repeat purchase flow.

Successive generations and substitutions among these generations are also investigated by Maier (1998). In this model, a system dynamics based map is constructed and the generic properties of diffusion process as well as substitutions among successive generations are defined. All successive generations compete for a unique aggregate pool unlike the Norton-Bass Model. In Norton-Bass, each generation's potential customers are separated. The model also allows for repeat purchase, which occurs at the end of the average life time of a generation. However, it should be noted that the basic diffusion function is constructed based on Bass model.

Maier (1998) also deals with competition among companies. The model mainly includes the imitative demand and innovative demand introduced by Bass. In contrast to the Norton-Bass model, this model allows for several firms to be active in the market at any given time. The main assumption is that the active competitors have the same market share unless they do not perform different marketing strategies and decisions, which alter purchase probability.

$$innovativedemand_i = (a_i / NC) * m * f_i \tag{3.7}$$

$$imitativedemand_i = (ß_i * f_i / N) * adop_i * m \tag{3.8}$$

where:

α_i = Coefficient of innovation of company i (i = 1,2,…,K)

β_i = Coefficient of imitation of company i (i = 1,2,…,K)

$$\phi_i = \begin{cases} 1, & \text{if company is active in the market (present in the market)} \\ 0, & \text{if company is not active in the market} \end{cases}$$

$NC = \sum_{i=1}^{k} f_i$ Number of total active companies

$adop_i$ = Number of total adopters of company i

N = Initial value of market potential

m = Remaining market potential

K = Total number of companies.

In the equations stated above, the subscript i represents the i^{th} company in the market, and as mentioned earlier, the binary variable F_i controls the presence of the company in the market. The improved version of this model includes the issue of customer loyalty.

3.1.1. The Diffusion Module

The Bass diffusion model constitutes the basic framework of the diffusion module. As mentioned in the earlier sections, which discuss the basic principles and various extensions on base Bass model, the effect of imitators and innovators builds two main functions in the module. The word of mouth effect creates an imitative demand, whereas the advertising effect creates an innovative one.

There are various researches that investigate the relationship between advertising and innovative behavior, such as Robinson and Lakhani (1975), Horsky and Simon (1983), Kalish and Lilien (1986), Simon and Sebastian (1987). Advertising has been agreed upon as the activity that creates innovative demand in the above research and therefore this effect is included in a similar manner to this study.

The inclusion of the word of mouth (WOM) effect was significant due to product type, which is a durable household good. The purchase decision and duration is more complicated than in a frequently purchased non-durable item due to higher price and risk. Therefore, the experience of early adopters has become essential.

Finally the effect of delivery delay is included. This factor becomes an efficiency multiplier on the total effect of innovative and imitative purchase. As waiting time increases, the efficiency decreases based on a graph that is represented in the delivery delay module.

The effect of price is also included in the model. However, this effect is carried to the diffusion model indirectly so related explanations are represented in other modules.

The diffusion module is illustrated in Figure 3-2. As mentioned above, the price effect is carried through advertising and WOM modules. Converters named as *FAE 1*, *WOME 1,* and *FDDE 1* represent these three factors sequentially. The firm's aggregate effect identified as *FAgE 1* sums up these three factors. The numbers at the end of the converters or stocks stand for the product sequence. For example, all 1's in Figure 3-2 represent the diffusion process for the firm's first product. Initial letters stand for the company with "F" representing firm and "C" representing competitor.

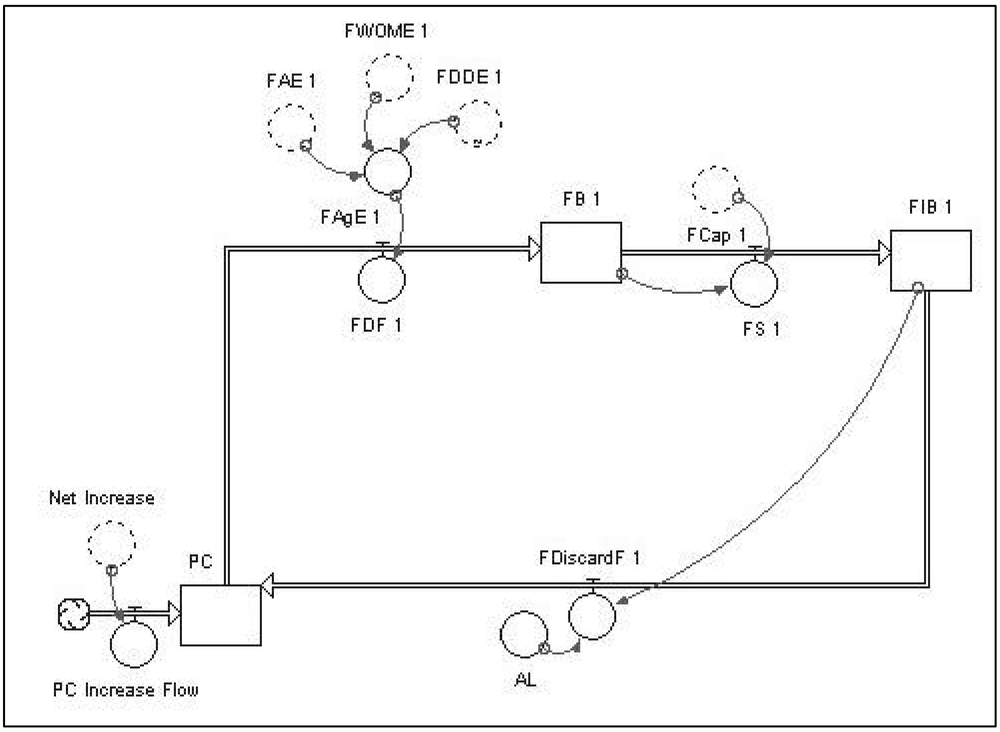

Figure 3-2 Diffusion module

The customers deciding to purchase the product based on the diffusion factors leave the potential customers' pool (*PC*) and come to the backlog stock (*FB 1*). This backlog stock will also be used in the future as a part of delivery delay control mechanism. Powell *et al.* (2001) also mention that backlog is a more robust metric for performance measurement even for unpredictable environments. Note that the customer's flow from *PC* stock to *IB* stock depends on the capacity. This issue is explained at the end of this section.

After backlog stock, these customers' orders are shipped, and this rate becomes sales. Then these customers become a part of the installed base (*FIB 1*) as long as the capacity allows. The accumulated customers in the backlog stock due to restricted capacity become an input to the delivery delay module, and, in the following cycles, this accumulation negatively affects the diffusion. The flows and stock equations are represented through Equations (3.9) and (3.16).

PC.K = PC.J + (PC_Increase_Flow.JK + FdiscardF_1.JK – FDF.JK)*DT (3.9)

PC_Increase_Flow.KL = Net_Increase.K (3.10)

FdiscardF_1.KL = FIB_1.K / AL (3.11)

FDF.JK = FAgE_1.K (3.12)

FAgE_1.K = (FAE_1.K + FWOME_1.K) * FDDE_1.K (3.13)

FB_1.K = FB_1.J + (FDF_1.JK – FS_1.JK)*DT (3.14)

FS_1.KL = MIN(FB_1.K / DT, FCap_1.K) (3.15)

FIB_1.K = FIB_1.J + (FS_1.JK – FdiscardF_1.JK)*DT (3.16)

where:

PC.K : Potential customers (customers[1])

PC_Increase_Flow.KL : Total number of increase in potential customers per year (customers/year)

Net_Increase.KL : Net increase in potential customers per year (customers/year)

FdiscardF_1.KL : Total number of discards per year (customers/year)

FDF.KL : Firm's demand flow per year (customers/year)

FAgE_1.K: Firm's aggregate effect for the first product per year (customers/year)

FAE_1.K: Firm's advertising effect per year (customers/year)

FWOME_1.K: Word of mouth effect for firm per year (customers/year)

FDDE_1.K: Firm's delivery delay effect (dimensionless)

FB_1.K: Firm's backlog (customers)

FS_1.KL: Firm's sales per year (customers/year)

FCap_1.K: Firm's capacity per year (customers/year)

FIB_1.K: Firm's installed base (customers)
DT: Delta time

The unit conversion Backlog/DT in equation (3.15) is essential since the units of capacity and backlog stock are not identical. The unit of flows always should be flow/period.

The installed base is a critical stock since it is both essential in the determination of the market share and the WOM effect. The effected customers reinforce the new purchases.

The repeat purchase is another issue handled in the model. After the completion of the average lifetime, the customers again purchase the product. It is assumed that on the average, the product serves the purpose during its lifetime. The inclusion of the repeat purchase in the model satisfies the continuity of the cycle. Because of the limited life of the product, the customers return to the potential customers' pool and the cycle goes on with repeat purchases (Equation (3.11)).

The total number of potential customers is modeled dynamically. In the study, each potential customer stands for a family therefore, the total number of customers represents the total number of households. Static modeled potential customers would not reflect real world conditions and, therefore, would be a non-realistic assumption as stated in Mahajan and Peterson (1978).

The customers' stock increases based on the net increase rate, gathered from statistics. Since the stock continually changes, the total number of customers is controlled by a separate stock, and the related increase rate is then carried through Figure 3-2 by converter *Net Increase*. As illustrated in Figure 3-3, the total potential customers are held separately, and the net increase is calculated by this separate pool.

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[1] Customers also represent the orders since each customer buys one unit of product.

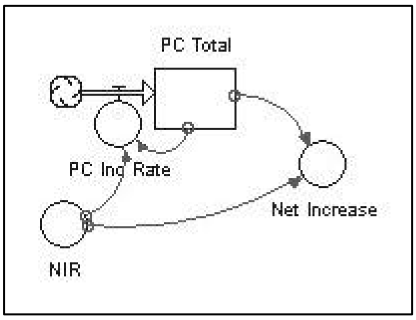

Figure 3-3 Increase in potential customers

$$PC\_Total.K = PC\_Total.J + (PC\_Inc\_Rate.JK)*DT \quad (3.17)$$

$$Net\_Increase.K = PC\_Total.JK*NIR \quad (3.18)$$

$$PC\_Inc\_Rate.KL = PC\_Total.K*NIR \quad (3.19)$$

where:

PC_Total.K: Total potential customers (customers)

PC_Inc_Rate.JK: Total number of increase in potential customers per year (customers/year)

Net_Increase: Net increase in potential customers per year (customers/year)

Figure 3-5 is valid for the situation in which two firms' products are identical. Note that, the inclusion of a competitor with an identical product would change the dynamic structure. Therefore, the firms cannot be modeled independently because each firm will compete for the same potential customers. However, in the competition in which two products are not identical, independently replicated modules would work since their potential customers would not be alike. The diffusion process is the same as the former case (with different products). However, the outflow from potential customers will differ. The allocation is based on the comparison of the two firms' aggregate effects. Also, the terms "firm industry demand" and "competitor industry demand" are introduced. These demands are explained in the price module in more detail. However, it can be said briefly that they represent the small set of potential customers who are willing to adopt the product at a given price level. If these industry demands overlap, i.e., if there are customers who can purchase either from the firm or the competitor, then their relative effects should be compared. If they do not overlap, then as in as the previous case, the aggregate effects are valid. Equation (3.20) displays this allocation.

FDF_1.K = IF ((FAgE_1.K/FID_1.K) + (CagE_1.K/CID_1.K)) > 1 THEN

IF CID_1.K<FID_1.K THEN ((FAgE_1.K/(CagE_1.K + FAgE_1.K))*CID_1.K + (FAgE_1.K/FID_1.K)*(FID_1.K – CID_1.K))

ELSE ((FAgE_1.K/(CagE_1.K + FAgE_1.K))*FID_1.K)

ELSE FAgE_1.K (3.20)

In summary, if two firms launch different products, the module represented in Figure 3-2 can be replicated independently. However, since identical products would cause interactions, this replication will not work, and a structure as represented in Figure 3-5 would be appropriate. In Figure 3-5, both firms compete for a unique potential customers stock and the firms' customers are determined based on the comparison of the two firms' aggregate effects.

As mentioned earlier, the customers' flow from *PC* Stock to *IB* stock totally depends on the capacity and capacity decisions. If there is one product, then an allocation problem will not occur. However, if there are two products, then allocation will become an important decision to consider.

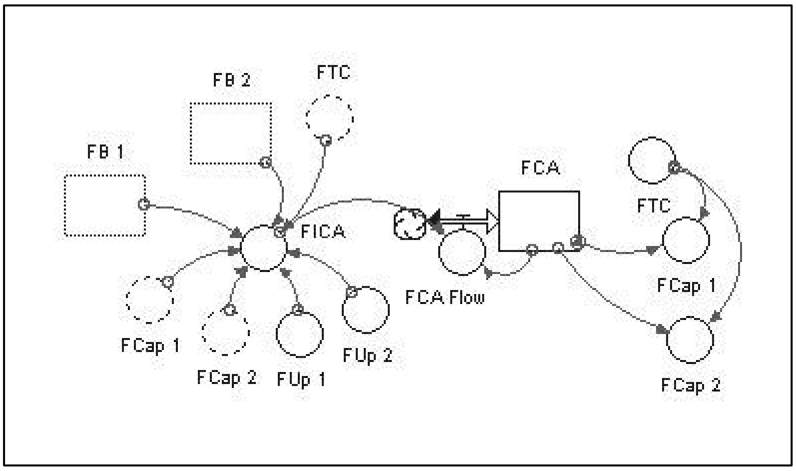

Figure 3-4 Capacity allocation

For the allocation, the presence of the second product is checked initially, and then the total required products are checked whether the sum exceeds the total capacity or not. If both products are in the market and total demand does not exceed the total capacity, then the necessary units are allocated, and the idle remaining capacity is shared between the two products. However, if the total demand exceeds the total capacity, then the profitability of products are compared with the difference between their backlog and assigned capacity. Equations (3.21)-(3.25) display the stated allocation strategy. The related figure is represented in Figure 3-4.

FICA.K = IF FB_1.K > 0 AND FB_2.K > 0 THEN IF (FB_1.K/DT + FB_2.K/DT) > FTC THEN (MAX(0,(FB_1.K-DT*FCap_1.K))*FUp_1.K) /(MAX(0,(FB_1.K-DT*FCap_1.K))*FUp_1.K+ (MAX(0,FB_2.K-DT*FCap_2.K))*FUp_2.K) ELSE ((FB_1.K/DT)/FTC + (1-(FB_1.K/DT)/FTC-(FB_2.K/DT)/FTC)/2) ELSE 1 (3.21)

FCA_Flow.KL = FICA.K – FCA.K (3.22)

FCA.K = FCA.J + (FCA_Flow.JK)*DT (3.23)

FCAP_1.K = FCA.K*FTC (3.24)

FCAP_2.K = (1 – FCA.K)*FTC (3.25)

where:

FICA.K: Firm's indicated capacity allocation (dimensionless)

FTC: Firm's total capacity (products)

FUp_1.K: Firm's unit profit for the first product (dollars)

FUp_2.K: Firm's unit profit for the second product (dollars)

FCap_1.K: Firm's first product's capacity (products)

FCap_2.K: Firm's second product's capacity (products)

FCA_Flow.KL: Firm's capacity allocation ratio flow (1/years)

FCA.K: Firm's capacity allocation ratio (dimensionless)

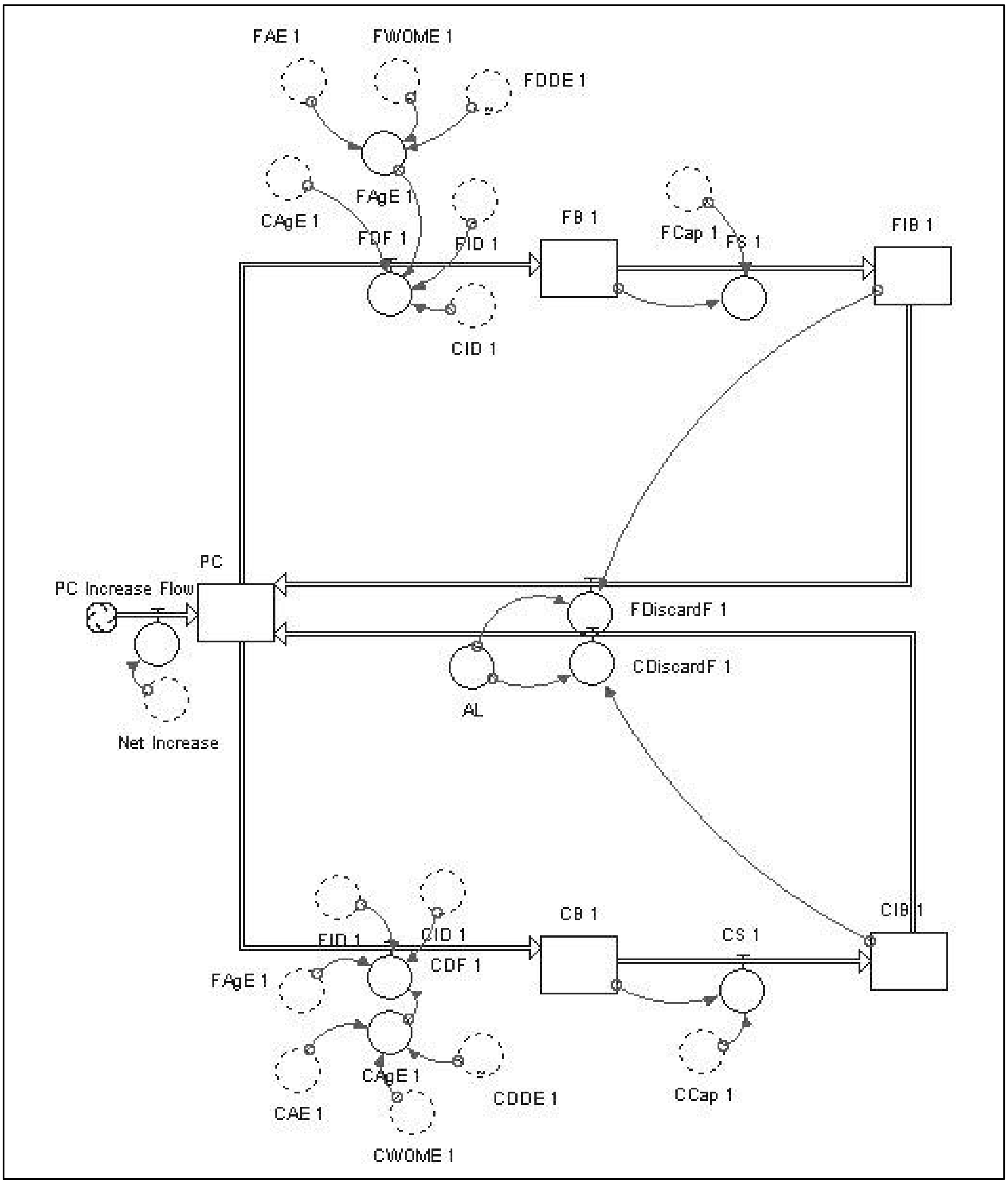

Figure 3-5 Diffusion module for identical products

3.2. Pricing

Price strategy and related dynamics have a vital importance in a competitive environment, since it drives the potential customers and firm's income. Price can affect the whole system from two different aspects: market as a function of price and price setting.

3.2.1. Market as a Function of Price

In the literature, many researchers treat the market as a function of price. Since many social and economic changes affect potential customers and sales, price can also affect the number of potential customers. In the study performed by Mahajan and Peterson (1978), the relationship between the population of the social system and the growth of total potential customers (for the washing machine market) are explored and a strong correlation is found. Therefore, total potential customers are represented as a function of social system population.

After that study, Kalish and Lilien (1986) designed the potential market as a function of price. According to their model, declining prices allow more customers to enter the market. In the model, the constant *m* (potential customers) of Bass' model is redesigned as follows:

$$m=[N(t)*h(p)] \tag{3.26}$$

where:
m: Potential adopters in base Bass Model
N(t): Market potential as a function of time when price is 0
p = p(t): Price as a function of time
h(p): Fraction of market potential, N(t), that finds price, p, acceptable.

Sterman (2000) also deals with the dynamics of price. The main points supported are as follows: (1) industry demand changes with price, (2) demand does not fall below zero when price is too high, and (3) demand never becomes infinite when price is too low but remains less than a specified constant.

In his study, a dynamic demand model is designed based on price. In the model, reference price, reference industry demand elasticity, price, maximum consumption, and demand adjustment delay are exogenous. Entities that build industry demand by various equations.

$$DCS = -R\ ID * RIDE / RP \tag{3.27}$$

$$\text{IID} = \text{MIN}\,[\text{MaxCon}, \text{RID}*\text{MAX}(0, 1\ \ \text{DCS}*(\text{P} - \text{RP})/\text{RID}] \qquad (3.28)$$

Then IID reduces to;

$$\text{IID} = \text{MIN}\,[\text{MaxCon}, \text{RID}*\text{MAX}(0, 1 - \text{RIDE}*(\text{P} - \text{RP})/\text{RP}] \qquad (3.29)$$

$$\text{ID} = \text{SMOOTH}\,(\text{IID}, \text{DAD}) \qquad (3.30)$$

where:

DCS: Demand curve slope

RID: Reference industry demand

RIDE: Reference industry demand elasticity

RP: Reference price

P: Price

IID: Indicated industry demand

ID: Industry demand

DAD: Demand adjustment delay

MaxCon: Upper bound for the demand when price is too low.

According to these equations, the demand decreases when the price is higher than the reference price. In the worst case, the demand can take the value of zero. On the other hand, when price is lower than the reference price, the demand can be equal to the maximum consumption level, at most.

The existence of demand elasticity, reference price, and reference demand strengthen this model, since these variables are the main entities in economic models. Briefly, demand elasticity is the fractional change in demand for a given fractional change in price. Generally, in economic models there is a nonlinear relationship between price and demand. However, in contrast to economic models, Sterman (2000) relates demand and elasticity linearly (Equations (3.27) - (3.30)). Since, this model is still valid for extreme conditions (when price is zero or infinite), the simplicity of linearity seems acceptable. In his text, Sterman (2000) also explains this issue in detail.

3.2.2. Price-Setting

Pricing process is still a challenge in the industry. The main point that makes price such a challenge is its properties that differentiate it from other marketing mix variables. Rao (1984) summarizes these properties of pricing as: (1) the only marketing mix variable which generate revenues; (2) having a direct and immediate effect, ie., to change price is easier than to change product specifications; and (3) making communication easier, prospective customers react price immediately.

Many issues have to be dealt during this process, such as the structure of price (dynamic or not), cost effects, company strategy, competitors' strategy, customer expectation, and other possible events that may lead to strategy differentiation during the time horizon. Rao (1984) adopts a framework, which consists of factors affecting price and makes this process a part of overall marketing strategy. The framework is depicted in Figure 3-6.

The main issue to be identified is the structure of the price (static or dynamic). Robinson and Lakhani (1975) criticize the conventional price theory, which assumes static price under strict conditions (static market and production environments) on the short term. After that, they discuss the effects of learning curve effect and economies of scale, which force price to be dynamic.

Milling (1996) also supports dynamic price. In his study, four main pricing strategies are investigated and simulated for a specific model. Briefly, these strategies are: (1) myopic profit maximization: an optimal price is derived from elasticity and standard costs; (2) skimming price strategy: an optimal price is reduced by a simple reduction strategy through the time horizon; (3) full cost coverage: price is based on standard cost per unit and a profit margin and (4) penetration pricing: similar to skimming strategy, but here prices are more rapidly decreased in order to capture the advantage of the learning curve effect in the earlier stages. In his simulation, penetration pricing is found as the best strategy among the four.

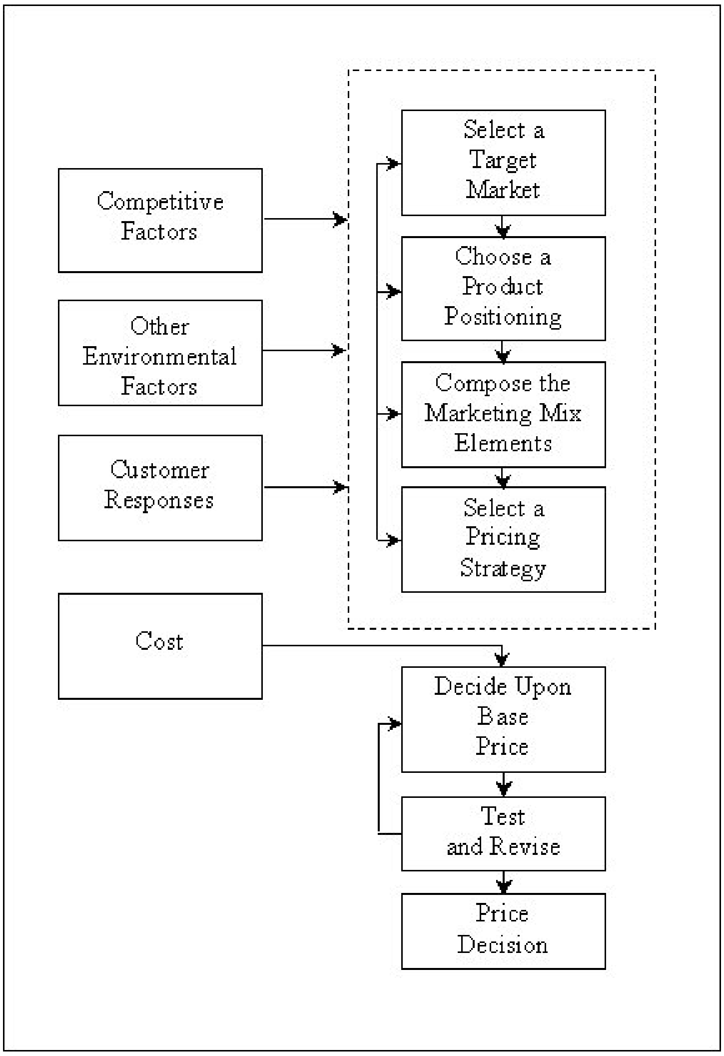

Figure 3-6 Price decision process for a new product (Adopted by Rao (1984) from Cravens (1982))

The study performed by Noble and Gruca (1999) provides a framework for industrial goods pricing. They group pricing strategies under some environmental conditions (e.g. a new product, a substitute). Pricing situations are determined as new product, competitive, product line, and cost-based. The strategies related to the situations are as follows:

- New product pricing situation: price skimming, penetration pricing and experience curve pricing.
- Competitive pricing situation: Leader pricing, parity pricing and low-price supplier.

- Product line pricing situation: Complementary product pricing, price bundling, customer value pricing

- Cost-based pricing situation: Cost-plus pricing

Different researchers also handle most of the above strategies but under different names. For example, Clarke and Dolan (1984) name parity pricing as a match strategy. Again, experience curve, the penetration, and skimming are handled for new products, but in Clarke and Dolan the experience (learning) curve is already included as a part of skimming or penetration strategy. Also Rao (1984) mentions the penetration and skimming strategy as the major strategies for new products.

The simulation performed by Clarke and Dolan (1984) investigates price paths under different strategies. In their study, there is an innovating firm that is first in a monopoly and then in a duopoly environment (by the entry of the second firm). In the paper, they basically investigate myopic, skimming, and penetration strategies for price. They try to determine the price paths for different leader and follower strategies.

Sterman (2000) deals with the factors influence price and defines some parameters that can be used for various strategies. In the study, the effect of costs and the inventory coverage are handled by some sensitivity parameters. It is possible to reflect learning curve effect to the price as mentioned in Milling (1996), Clarke and Dolan (1984), Rao (1984), as well as Noble and Gruce (1999). Since Sterman (2000) handles this relationship with the system dynamics approach, this map seems appropriate for building a framework. This framework can also be enhanced for other possible scenarios. The effect of costs on prices is defined as follows in Sterman (2000):

$$\mathrm{ECP} = 1 + \mathrm{SPC} * \left[\mathrm{EC/EP} - 1 \right] \tag{3.31}$$

where:

ECP: Effect of costs on price

SPC: Sensitivity of price to costs (0 < SPC < 1)

MP: Minimum price

EP: Expected price

3.2.3. The Price Module

Price is dynamic in the model as presented here. The price mechanism consists of two parts: the first forms the demand; and the second determines the price policy.

In the first part, industry demand is formulated as a function of dynamic price. Sterman's (2000) model is used as a framework with some differentiations. The main differentiation is the definition of reference demand. Since potential customers in the model are defined dynamically, a static reference demand may lead to logical problems in the simulation of the model. The model forces the indicated industry demand to be under a maximum consumption, which is here, defined as potential customers. Here, as potential customers decrease by time (since the simulation reaches a balance after initial purchases), the reference demand should adjust itself according to the remaining customers in order to reflect the effect of increasing and decreasing prices. Consequently, reference demand is defined as a percentage of potential customers in order to prevent the previously stated logical problems. (Equation (3.32))

The original model also includes a demand adjustment time which smoothes demand. This adjustment is necessary because there is an information flow. However, this delay may lead to orders more than the potential customers. To prevent such a risk, a MIN function is defined additional to the smooth function (Equation (3.33)). Another addition to the price module is the inclusion of FET converter. This converter holds the entry time of the firm. The firm's industry demand should be zero unless the firm enters the market. This condition is satisfied with Equation (3.34).

$$\text{RID.K} = \text{RID\_Perc.K} * \text{PC.K} \tag{3.32}$$

$$\text{FID\_1.K} = \text{MIN (PC.K, SMOOTH (FIID\_1.K, 0.2))} \tag{3.33}$$

$$\text{FIID\_1.K} = \text{IF TIME} \geq \text{FET\_1.K THEN MIN (PC.K, RID.K * MAX(0, 1 + DCS.K*((FP\_1.K-RP.K)/RID.K))) ELSE 0} \tag{3.34}$$

where:

RID_Perc.K: Reference industry demand percentage (dimensionless)

FET_1.K: The time at which firm's initial product is launched (year)

FP_1.K: Firm's price at any time (dollars/product)

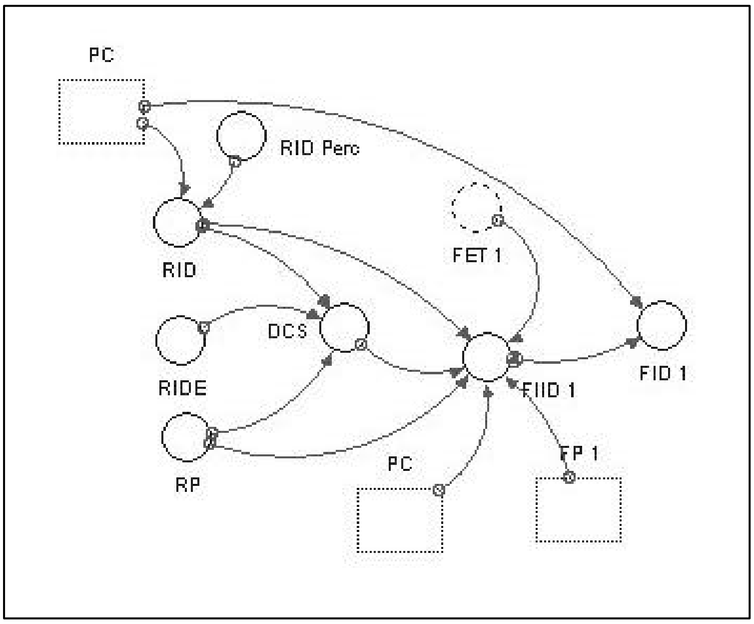

Figure 3-7 Industry demand as a function of price

Since we focus on a case of two firms (duopoly) in the market, the same mechanism is also modeled for the competitor. The unique converters for both of the firms (related to market properties) are defined once and ghost converters are used for the competitor (Figure 3-7). As in the diffusion module, more attention should be paid in the replication in the case of identical products. Ghost and unique converters should be determined carefully. For unique products, ghost nodes should be used for *PC,* but in the case of different products, solely related potential customers' stock should be used. Since the market segment of each different product will also differ, a ghost node would be inappropriate.

The second part of the price module deals with the price setting process. The interaction between cost and price is based on Sterman's (2000) model. Price is defined as a stock, which allows biflow which is illustrated in Figure 3-8. The final and probably the most critical differentiation includes the competitor's price effect.

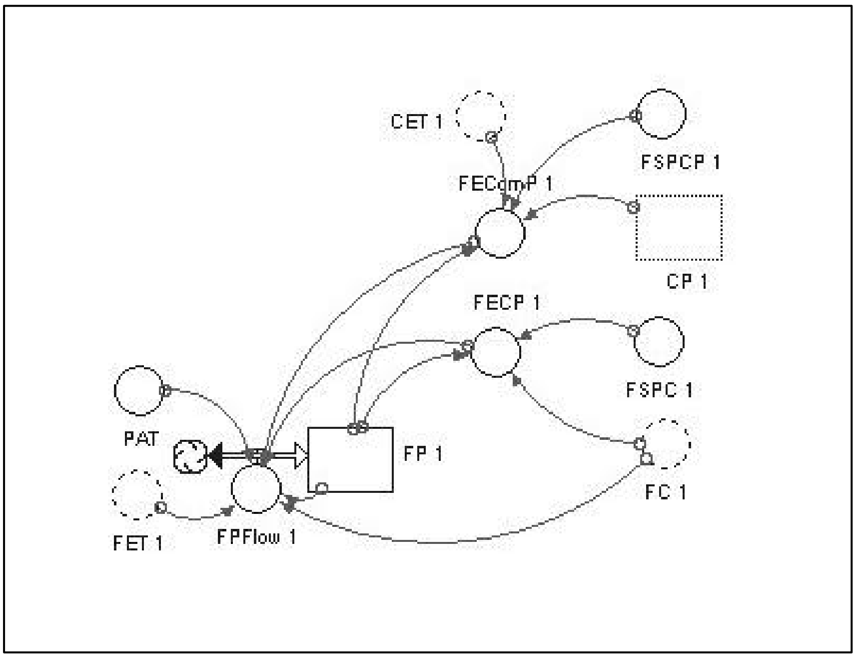

Figure 3-8 Firm's price setting process

The effect of competitor's price is reflected on the map similar to the effect of costs. Such a competition between prices is also formulated in Kim (1988) in addition to Sterman's (2000) formulation. In our formulation, the competitor's entry time is also considered (Equation (3.35)). In our price module, a decrease in the cost may lead to a reduction in the price (based on the determination of the sensitivity coefficient), and similarly a reduction in the competitor's price may force the firm to decrease price until a lower bound, which is set to 1.05% of the cost. The related formulation is represented in Equations (3.36) and (3.38).

$$\text{EcomP\_1.K} = \text{IF TIME} \geq \text{CET\_1.K THEN } 1+\text{FSPCP\_1}*(\text{CP\_1.K}/\text{FP\_1.K-1}) \text{ ELSE } 1 \quad (3.35)$$

$$\text{FECP\_1.K} = 1 + \text{FSPC\_1}*(\text{FC\_1.K}/\text{FP\_1.K-1}) \quad (3.36)$$

$$\text{FP\_1.K} = \text{FP\_1.J} + (\text{FPFlow\_1.JK}) * \text{DT} \quad (3.37)$$

FPFlow_1.JK = IF TIME < FET_1.K THEN 0
ELSE IF (FP_1.K * FEComP_1.K *FECP_1.K) > (1.05)*FC_1.K
THEN (FP_1.K * FEComP_1.K * FECP_1.K-FP_1.K) /(PAT)

ELSE ((1.05*FC_1.K)-FP_1.K)/(PAT) (3.38)

where:

EcomP_1.K: Effect of competitor's price on price (dimensionless)

FECP_1.K: Effect of cost on price (dimensionless)

FSPCP_1: Sensitivity of price to competitor's price (0 < SPCP < 1) (dimensionless)

FSPC: Firm's sensitivity of price to cost (0 < SPC < 1) (dimensionless)

FC_1.K: Firm's cost (dollars/product)

CET_1.K: The time at which competitor's initial product is launched (Year)

CP_1.K: Competitor's price (dollars/product)

PAT: Price adjustment time (years).

In the model price function becomes;

P=f(CompP,FC)

Since the price is modeled as a stock, the change in the price is controlled by biflow which both allows decrease and increase. This flow not only controls the lower bound of price with IF_THEN formulation but also guarantees the presence of the firm with its entrance time (*FET*). Note that presence of the competitor is also controlled with the converter *CET* in Equation (3.38).

This model is also replicated for the competitor's activities. If two firms' products are not identical, a competition based on prices will not occur. Therefore, the module presented above reduces to Figure 3-2.

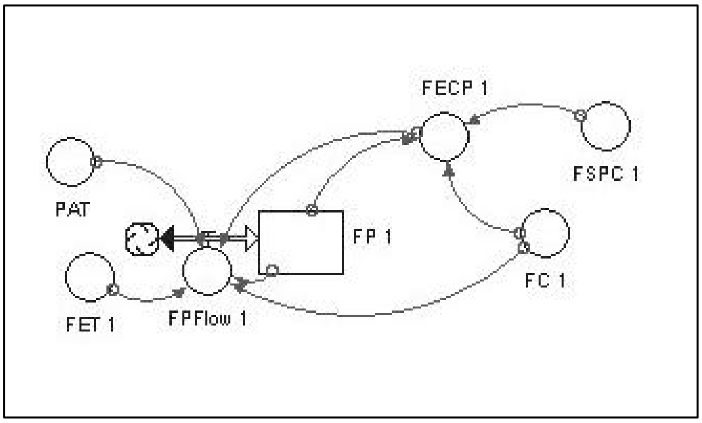

Figure 3-9 Firm's price setting process without competitor

The pricing module is also quite flexible in terms of applying different strategies. The module not only allows us to include other formulas that are dependent on the entry time of the follower but also allows us to define strategies based on parameters. For example, an aggressive strategy can be applied by setting sensitivity parameters equal to 0. It is possible to combine price skimming, learning curve effect, leader pricing, customer value pricing and cost-based pricing from the strategies grouped by Noble and Gruca (1999).

3.3. Advertising

Advertising is one of the most important marketing activity that affects the sales growth of products. Advertising is included in the modeling of the decision process by various researchers. Generally, the innovative demand for a product is defined by the effect of advertising on demand as stated in the diffusion module. In line with the literature, in our model, the factor that forms innovative demand is advertising.

Horsky & Simon (1983) introduce the effect of advertising to the purchase probability by a function of advertising expenditures and an effectiveness coefficient. As can be seen from Equation (3.39), advertising and resources such as reports in the media (represented by α) are the factors, which influence innovative purchase.

$$P(t) = \alpha + \beta * \text{Ln } A(t) + \gamma * Q(t) \qquad (3.39)$$

where:

P(t) = Probability of purchase at time t.

A(t) = Level of producer’s advertising expenditure at time t.

Q(t) = Number of people who have already adopted by time t.

α = Information conveyed to innovators through alternative channels (media reports)

β = Effectiveness of imitative contact

As Horsky and Simon (1983) state the above equation includes diminishing returns. Any innovator becomes a part of imitative purchase (this person may persuade other potential customers to buy the product) and during the time horizon, the total number of potential customers decreases also by the effect of these earlier adopters. This is named as the first diminishing effect. Log transformation, which prevents higher spending on advertising, is the second part of diminishing effects. This formula assumes that advertising expenses are only effective immediately after the release. Thus, Horsky and Simon (1983) omit time lag. However, the effect of a period's expenses should be carried to subsequent periods by proper effectiveness weights.

Kalish and Lilien (1986) also introduce the advertising effect for innovative demand. They also emphasize the definition of advertising level. Either advertising expenses or advertising exposures are employed for the definition of the level.

Simon and Sebastian (1987) handle the effect of advertising differently. In their study, the inclusion of advertising not only seems possible for an innovative purchase but also for an imitative purchase or even both. Since our model only accepts the effect for an innovative purchase, the details are not covered. However, there are some important remarks for the use of advertising and reflecting diminishing and lagged effects that guide our model. In their model, advertising effects are represented by a logarithmic function, which guarantees a diminishing effect of advertising on demand. Also due to affected people and decreased potential customers, the second part of diminishing return is provided. Additionally, they suggest various models for representing the lagged effects of advertising. Three models are represented for different purposes. First one is a simple single period advertising model, second one is a more complicated multi period advertising model that assigns different effectiveness coefficients (Equation (3.40)), and the last one is a highly complicated multi-period model, which includes many exogenous parameters for the weights, which are hard to estimate.

$$f_t(A)=\sum_{t=0}^{t} ?_t \ln A_{t-t} \qquad (3.40)$$

where:

$f_t(A)$ = Cumulative advertising efforts that affect sales in period t

$?_t$ = Effectiveness of advertising in pre-period t. (t can take on various values for periods 0,1,…,t)

A_{t-t} = Advertising efforts released in period t-t. (Summation gives the accumulated efforts till period t)

3.3.1. Advertising Module

The advertising module consists of two parts. The first part displays total advertising expenditures whereas the second part builds the whole advertising activity along with lagged effects and proper coefficients. Figure 1.7. represents the first part of the advertising module.

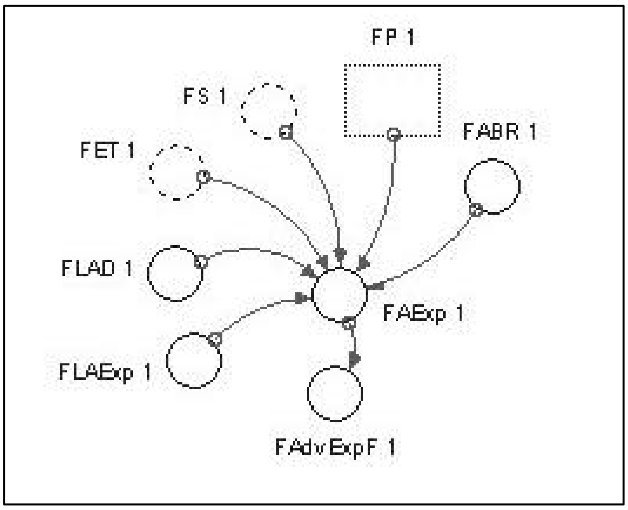

Figure 3-10 Firm's advertising module (Part 1)

Advertising expenses depend on the income from the product and launch expenses (Equation (3.41)). Initial sales efforts are provided by launch advertising expenses and the duration for these expenses. After the determination of the total expenses, the logarithm of the expenses is taken for the diminishing effect of advertising. Converter *FAdvExpF 1* represents this transformation.

FAExp_1.K = IF TIME ≥ FET_1.K AND TIME < FET_1.K + FLAD_1 THEN
(FLAExp_1 + FABR 1*(FP_1.K)*FS 1.JK)
ELSE IF TIME ≥ FET_1.K + FLAD_1 THEN
(FABR_1*(FP_1.K)*FS_1.JK)
ELSE 0 (3.41)

FAdvExpF_1.K = IF FAExp_1.K >0 THEN LN(FAExp_1.K) ELSE 0 (3.42)

where:

FAExp_1.K: Firm's total advertising expenditures per year (dollars/year)

FABR_1: Firm's advertising budget ratio (dimensionless)

FLAD_1: Firm's launch advertising duration (years)

FLAExp_1: Firm's launch advertising expenses per year (dollars/year)

FAdvExpF_1.K: Firm's total advertising expenses' function (dimensionless)

As mentioned earlier, the second part of the advertising module converts these advertising efforts (expenses) to the advertising effect that influences innovative demand. Based on the articles, expenses are used for advertising measure, logarithm transformation is performed, and a multi-period advertising model is employed. Equation (3.43) represents our advertising activity in general.

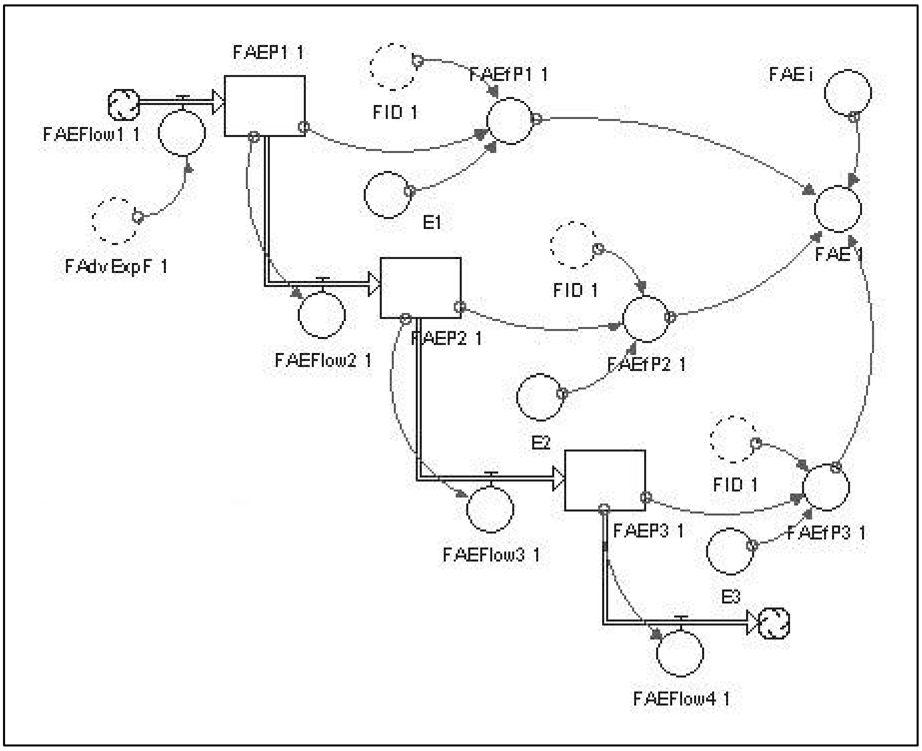

Figure 3-11 Firm's advertising module (Part 2)

In Figure 3-11, each period's advertising expenditure is carried through the subsequent periods by sequentially drawn stocks. While carrying one period's effect to the next, the coefficients *E1*, *E2* and *E3* are used. Also note that the initial effect of an advertising effort is higher than the subsequent periods ($E_1 > E_2 > E_3$).

$$FAE\_1.K = FAE\_i * (FAEfP1\_1.K+FAEfP2\_1.K+FAEfP3\_1.K) \quad (3.43)$$

$$FAEfP1\_1.K = FAEP1\_1.JK * E1 * FID\_1.K \quad (3.44)$$

$$FAEP1\_1.K = FAEP1\_1.J + (FAEFlow1\_1.JK - FAEFlow2\_1.JK)*DT \quad (3.45)$$

$$FAEFlow1\_1.JK = FAdvExpF\_1.K/DT \quad (3.46)$$

$$FAEFlow2\_1.JK = FAEP1\_1.K/DT \quad (3.47)$$

where:

FAE_1.K: Firm's total advertising effect in one year (customers/year)

FAE_i: Firm's advertising effectiveness (dimensionless)

FAEfP(i)_1.K : Firm's advertising effect due to the expenses released in the $(t-i+1)^{th}$ period (customers) i= 1,2,3

FAEP(i)_1.K: Firm's advertising expenditures function related to the $(t-i+1)^{th}$ period. i=1,2,3 (dimensionless)

FAEFlowi_1.JK: Flow of firm's advertising expenses function from the $(t-1+i)^{th}$ period to the $(t+i)^{th}$ period. i=1,2,3 (dimensionless)

Ei : The effectiveness of advertising after i periods. i=1,2,3 (dimensionless)

As in the other modules, the advertising module is replicated for the competitor. However, E_i's (i=1,2,3) are uniquely formulated since this parameter is specific to the market and product. In this module, the product's design quality does not make sense. In any case (identical products or not), each firm's any product should have separate advertising activity module.

3.4. Word of Mouth

The word of mouth creates an imitative demand for a product. A simple and unique formulation is used for this demand. The imitation coefficient and accumulated adopters until that time are sufficient to calculate the effect. This imitation coefficient also includes the probability of meeting an adopter and a non-adopter.

3.4.1. The Word of Mouth Module

The word of mouth module has a quite simple formulation and clear connections. Although this relationship is common in the literature, Sterman's (2000) system dynamics representation is taken as a reference with the necessary adjustments. The related equation and figure are as follows:

$$\text{FWOME\_1.K} = \text{IF TIME} \geq \text{FET\_1.K THEN}$$
$$\text{C*WOMi*FID\_1.K *FIB\_1.K /PC\_Total.K ELSE 0} \qquad (3.48)$$

where:

c: Contact rate (an adopter can meet c non-adopters) (1/year)

WOMi: WOM fraction (an adopter can persuade a non-adopter with probability i) (dimensionless)

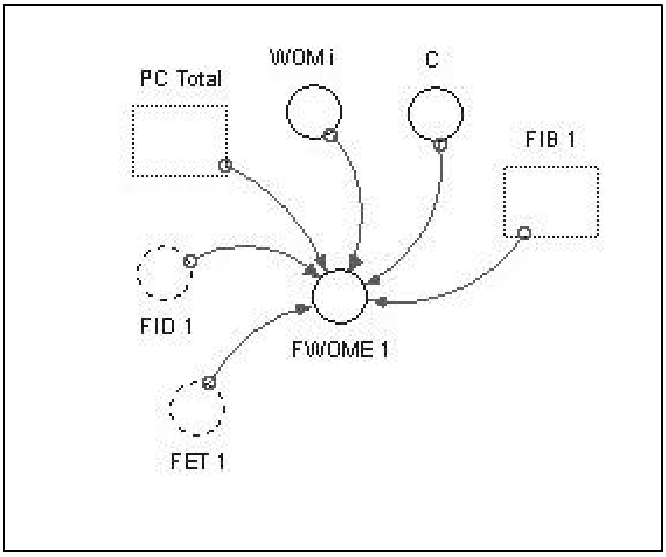

Figure 3-12 Firm's word of mouth module

This module is also replicated for the competitor. It should be noted that neither the firm nor the competitor has a negative word of mouth effect. In the model, all word of mouth effects are assumed to be positive.

3.5. Learning Curve and Economies of Scale Effect

The price of new products decreases over time due to the experience (learning) effect and scale economies. Costs are assumed to fall as accumulated sales and sales within a period increase.

There is a common sense in the formulation of the learning curve effect, which depends on the initial experience, the initial cost and the strength of the learning curve. In general, the total unit cost declines by 20% - 30%, whenever the accumulated volume doubles (Sterman, 2000 and Robinson and Lakhani 1975). A parameter, which represents the strength of the learning curve, is determined based on this reduction percentage. If costs fall by 20% whenever the accumulated volume doubles, then this parameter becomes approximately 0.3. Furthermore, if costs fall by 30%, then this parameter becomes 0.5. Sterman (2000) derives this simple formulation. (Equation (3.49))

$$a=-\ln(1-r)/\ln 2 \qquad (3.49)$$

where:

a = Strength of the learning curve (0.3 = a = 0.5)

r = Cost reduction fraction (0.2 = r = 0.3 – A common sense)

For the effect of learning curve, the following equation is used by Sterman (2000), Robinson and Lakhani (1975) and Sterman *et al*. (1995).

$$C=C_0*\left(Q_0/Q\right)^a \qquad (3.50)$$

where:

C = Cost

C_0 = Initial cost

Q = Experience (Accumulated production volume)

Q_0 = Initial experience

In some research, cost is divided into two parts. The first part of the cost does not depend on the learning curve, whereas the second part does. Consequently, a 20% decrease only affects the second part (Sterman *et al.*, 1995).

3.5.1. The Cost Module

In the model, the learning curve and economies of scale are included as factors that may lead to cost reductions. The learning curve effect is formulated based on accumulated production volume. As mentioned in the previous section, there is a common sense for representing the learning curve effect.

The Economies of scale effect is represented in the model by a reduction coefficient effect determined over total sales within a term. This reduction coefficient effect is illustrated in Figure 3-13.

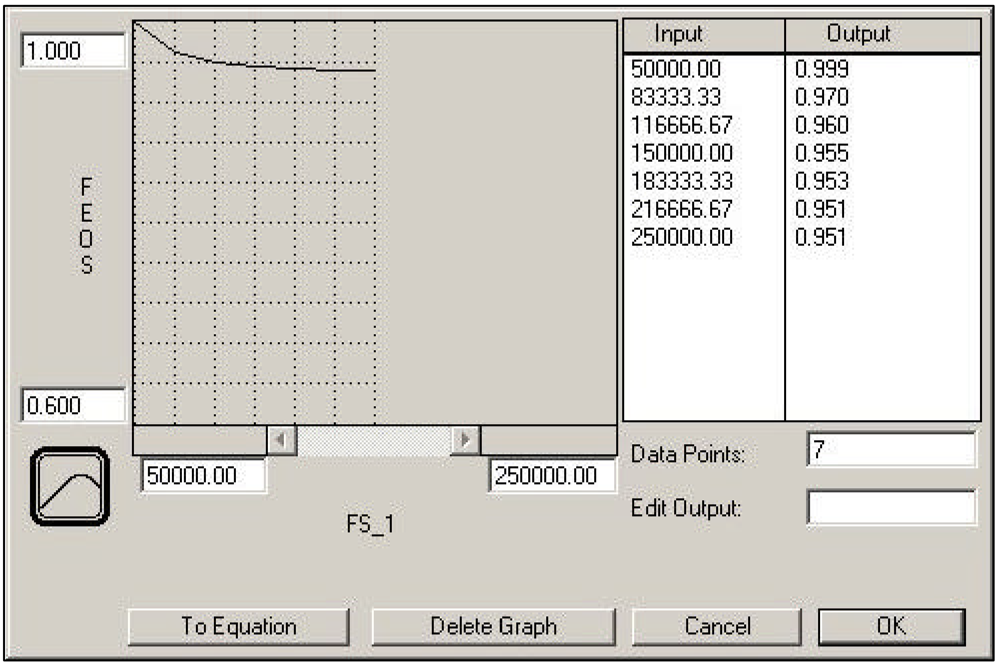

Figure 3-13 Economies of scale effect

Lastly, in the module, these two effects are combined and a final cost is determined. Also as illustrated earlier, only a part of the cost is subjected to the learning curve effect. This ratio is set as 35%. Equation (3.51) illustrates the enhanced cost formula.

FC_1.K= IF TIME ≥ FET_1 THEN ((0.65*FC0_1.K)+(0.35*FC0_1.K)* ((Fexp0_1.K/(Fexp0_1.K+FTS_1.K))$^{\alpha}$))*FEOS ELSE FC0_1.K (3.51)

where:

FC0_.K: Firm's initial cost (dollars)
FExp0: Firm's initial experience (products[1])

FTS_1.K: Firm's total sales (Accumulated production volume) (customers)

FEOS: Firm's economies of scale effect (dimensionless) (Figure 3-13)

This module illustrated in Figure 3-14 is also replicated for the competitor and for the second products for both firms.

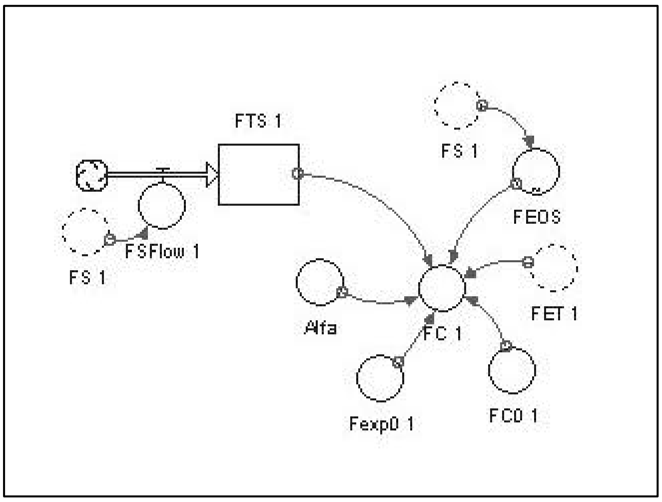

Figure 3-14 Firm's cost module

For the second products introduced by the firms, the initial experience is not a constant. This variable depends on the initial experience and the total production of the first product until the introduction of the second one. The related figure is depicted in Figure 3-15.

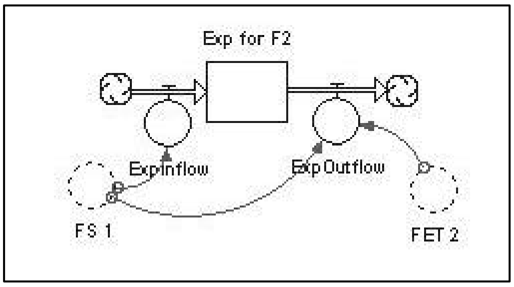

Figure 3-15 Initial experience for the second product

$$ExpInflow.JK = FS\_1.KL \quad (3.52)$$

$$ExpOutflow.JK = IF\ TIME >= FET\_2\ THEN\ FS\_1.KL\ ELSE\ 0$$

$$Exp\_for\_F2.K = Exp\_for\_F2.J + (ExpInflow.JK - ExpOutflow.JK)*DT$$

where:

Exp_for_F2.K: Experience for the firm's second product (products)

ExpInflow.JK: Experience inflow (products/year)

ExpOutflow.JK: Experience outflow (products/year).

3.6. Delivery Delay Effect

Waiting time for the products leads to negative effects on total demand. This delivery delay effect is incorporated into the system dynamics models by Little's Law as stated in Sterman (2000). The ratio between the backlog and the sales of the product is a metric used for measuring the delivery delay.

Forrester (1968) introduces the concepts of market and customer realizations to the delivery delay effect. In his study, the company recognizes delivery delay with a time lag and also the market recognizes this effect with a higher degree delay and time lag. Finally, this factor becomes an efficiency coefficient for the total demand and consequently for the total marketing activities. Forrester (1968) suggests a graph to demonstrate (Figure 3-16) the sales effectiveness based on delivery delay multiplier.

3.6.1. The Delivery Delay Module

The delivery delay module combines both Sterman's (2000) and Forrester's (1968) model. The sales effectiveness graph is taken from Forrester (1968) (Figure 3-16). However, since the time unit is years, the x-scale is also represented in terms of years (1 year). (The flows and relationships mentioned in the previous section can be seen in Figure 3-17.)

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[1] Customers

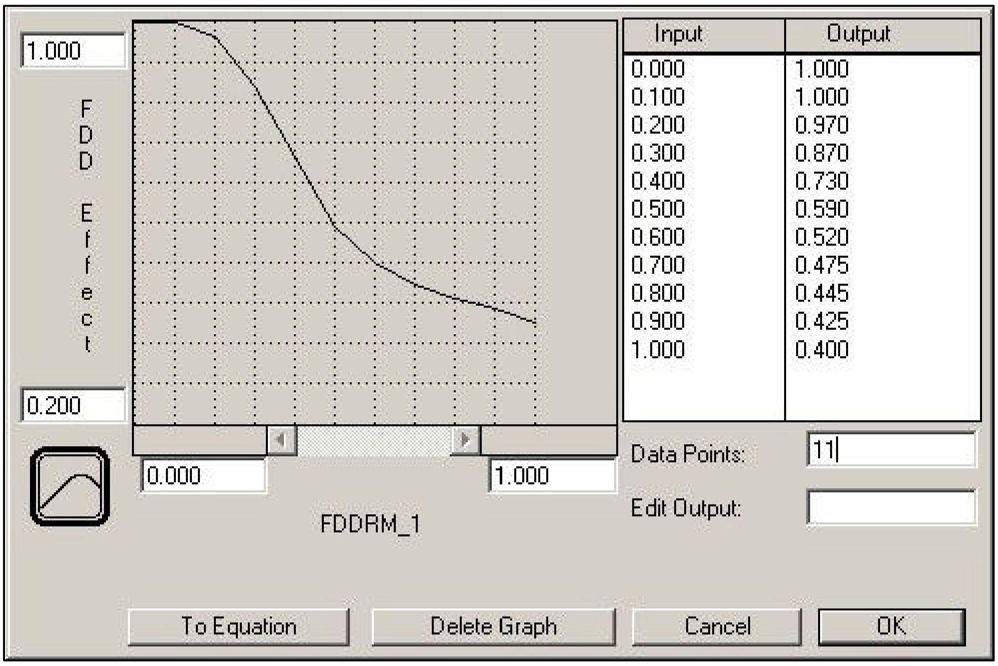

Figure 3-16 Graph for sales effectiveness (Adopted from Forrester (1968))

FDD_1.K = IF FS_1.KL > 0 THEN MAX(0,((B11.K/DT)/FS_1.KL)) – 1)
ELSE 0 (3.53)

FDDRF_1.K = FDDRF_1.J + (FDDFlow1_1.JK) * DT (3.54)

FDDRM_1.K = FDDRM_1.J + (FDDFlow2_1.JK) * DT (3.55)

FDDFlow1_1.KL = (FDD_1.K-FDDRF_1.K)/TRF (3.56)

FDDFlow2_1.KL = (FDDRF_1.K -F DDRM_1.K)/TRM (3.57)

where:

FDD_1.K: Firm’s delivery delay (years)

FDDRF_1.K: Firm’s delivery delay effect recognized by the firm (years)

FDDRM_1.K: Firm’s delivery delay effect recognized by the market (years)

FDDFlow1_1.KL: Increase/decrease in the delivery delay (dimensionless)

FDDFlow2_1.KL: Increase/decrease in the delivery delay (dimensionless)

Since there is an information flow for both the firm and the market, both will realize the real effect with a time lag, and this delay should be reflected with a SMOOTH function. Note that the structure illustrated in Figure 3-17 is another representation of the SMOOTH function.

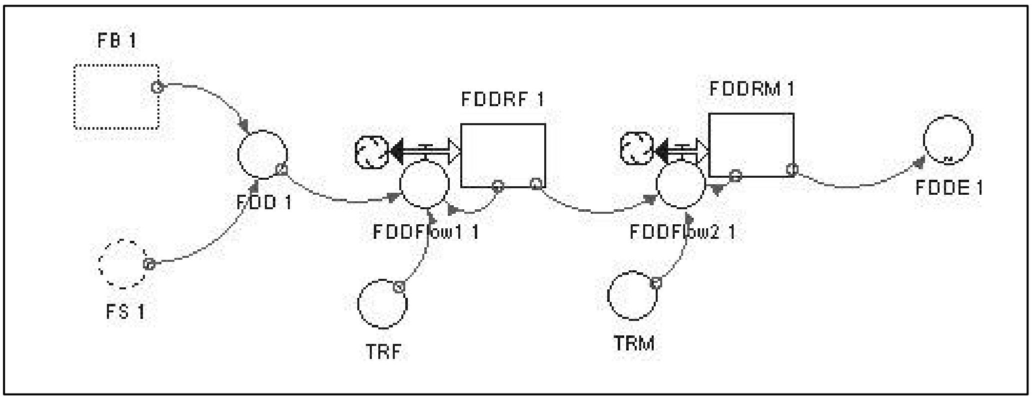

Figure 3-17 Delivery delay module

3.7. Initial Values of Stocks and Parameters

In this section, the initial values of external parameters and stocks are considered. However, the initial values of some converters and stocks are a part of various policies. For example, initial value of firm's price is a consequence of firm's pricing strategy. In this section, the initial values for the base case that are used for model validity and the sensitivity analysis are provided.

3.7.1. Initial Values of Stocks and Parameters in the Diffusion Module

INIT PC = PC_Total (Base Case Value – B CV)

This value differs according to the scenario and related market segment. For example, if Product 2 is launched, then a percentage depends on the presence of the products in the market will be allocated for *PC_Total*. For example if Product 3 is already in the market but if Product 1 is not in the market then this percentage becomes 80%. However, for the base case 100% of the total potential customers are assigned in order to prevent confusion.

INIT PC_Total = 2 750 000

It is possible to take the total number of households in Turkey and the penetration ratio of such products from State Institute of Statistics Prime Ministry Rebuplica of Turkey (SIS). However, in such a situation, the Installed Base stock should not be empty at the beginning of the simulation. This is not the case to be investigated in this study; here, the aim is to investigate various policies based on the initial growth of durable household goods. Therefore, assigning a total number of potential customers would not violate the real situation. The underlying assumption is "*even some of these people were in the installed base at time 0, till the time they purchase the product (this may take years) they would already again come to the potential customers*". However, there is another important issue that should be considered. There are 4 main household goods producer in Turkey (SIS, 2001). But in this study there will be at most two producers. Also note that SIS does not include importations. In order to be consistent, the total number of households is divided by four and then assigned as the initial value. Keeping the total number of potential customers at a lower level provides the opportunity of observing the effects of different scenarios more precisely. The total number of households in 1990 was recorded as 11 188 636 (SIS, 2001), consequently, the initial value is decided as 2 750 000. Note that according to the customer segments, the initial value related to the segments differs as explained in Section 3.8.4.

NIR = 0.028

Net increase rate for the total number of households is estimated based on the total number of households in years 1985 (9 730 018 households) and 1990 (11 188 636 households). An approximate increase rate is derived from the following equation:

$$(1+p)^{5} * 9730018 = 11188636 \Rightarrow p \approx 0.028 \qquad (3.58)$$

AL = 10

The average lifetime of a product is assigned as 10 years.

INIT FB_1 = 0

INIT FIB_1 = 0

At the beginning of the simulation, these stocks are empty. After sales, customers will begin to accumulate.

FTC = 250 000

The firm's total capacity is determined based on SIS data and the sales amount of one of the biggest household goods producer in Turkey. First, the amount provided by

SIS is compared with the sales provided by the factory. Since these numbers are approximately at the same levels, the sales amount provided by the factory is used. The total number of production in a year is taken, and the total number of exports is subtracted. Finally 250 000 products/year is assigned as total capacity.

FCA_1 = 1.0 (BCV)

Since in the base case there is only one product, the capacity allocation ratio is set to 1.0.

3.7.2. Initial Values of Stocks and Parameters in the Price Module

RIDE = 1.6

This elasticity is assumed as a constant for all scenarios. The value is determined by the range stated in Lipsey and Courant (1996). In their study, the approximate values of price-demand elasticity for some products are stated. Furniture and automobiles are the two products closer more resembling the types of durable household goods. Therefore, 1.6 is assumed for durable household goods based on this information.

RID_Perc = 0.8

This percentage is the ratio of the potential customers at the reference price. This is a part of the assumption of gathering reference price information from customers. It is assumed that within a product segment, 80% of the customers have a purchase intention. However, as also stated in 3.8.5, this ratio changes if there is not a product in the upper segments. The related calculation can be seen from Equations (3.65) and (3.66).

RP = 525 (BCV)

Reference price takes different values for different segments. It is assumed that this value is gathered from customers after surveys and from historical data analysis. The methodologies for gathering such information and difficulties are stated in 3.8.2. Also note that there is a trade-off between time and cost of getting such a data and preparing such a survey against this assumption. There is no doubt that the cost would be higher, therefore, this assumption seems reasonable. For the base case, one segment (segment 2) is used, therefore, the reference price is set to 525 $.

PAT = 0.2

The price adjustment time is set to 0.2 years. This value seems reasonable in the durable household goods industry for adjustments and information flow. Also note that 0.2 years is used for other information delays.

INIT FP_1 = 700 (BCV)

FSPCP_1 = 0.5 (BCV)

FSPC_1 = 0.5 (BCV)

3.7.3. Initial Values of Stocks and Parameters in the Advertising Module

INIT FAEP1_1 = 0

INIT FAEP2_1 = 0

INIT FAEP3_1 = 0

The initial values of these three stocks are set to zero. They are used for the determination of each period's advertising expense effect, therefore, the stock should be empty for a new flow.

E1 = 1

E2 = 0.70

E3 = 0.20

These parameters are the coefficients for the advertising effects carried through the subsequent periods. The decrease from first period to second period is 30%, whereas that of the second to the third is approximately 71%. In other words, by the time the probability of to remember advertising is decreases.

FABR_1 = 0.06

This budget ratio seems reasonable. Note that, Forrester (1961) uses this value as well.

FAE_i = 0.0015

This coefficient and WOM effectiveness coefficient are the parameters that control diffusion speed. To estimate these parameters are possible as Bass (1969) does. However, since a historical sales data for a durable household good is not available, the parameters estimated by Bass (1969) are used. In his study, this estimation is done for eleven-product category. First of all, three out of these eleven products are selected, because they are the ones from the durable household goods category. Based on the parameter values, a lower and an upper bound are determined. Note that the consistency of these two parameters is also essential.

The values estimated for innovation coefficient are 0.0026, 0.018, 0.027. However, in this study a single coefficient is not used, rather, this effect is carried through periods along with an expenditures effect. Because of this modification, these values are divided by 26 (13*2), 13 standing for the logarithm of an approximate expenditure and 2 stands for the carrying effect through periods. The range is determined as 0.0001 – 0.001. While determining a value for *FAE_i*, which value should be assigned for *WOMi*? For this parameter, the mean of the three values provided by Bass (1961) is assigned initially.

The values for *c*WOMi* is 0.17, 0.22, 0.25. The average is 0.21. Since *c* is set to 10, the value for *WOMi* becomes 0.021. After this value, the model is reduced and *FAE_i* and *WOMi* are determined simultaneously under different values. Also note that in Bass (1969), the ratio of imitation coefficient to innovation coefficient is given for these products. After determining the beginning values, the effects of other factors are reduced as much as possible. For example, an unlimited capacity is assigned to the firm, the sensitivity of the cost effect on price is set to zero and the potential customers percentage is set 1. With these assignments, we totally close the model to external effects. The repeat purchase is also omitted because this effect is not included in Bass (1969). Under these conditions, the model is run for the different values of *FAE_i* and *WOMi* (Table 3-1). After each simulation the coefficients are again considered and the next simulation's coefficients are determined. For example, after the first run, it is seen that the desired growth rate is not reached and *FAE_i* is iterated and run again. After the second run *WOMi* adjusted and this procedure repeated until the desired growth is reached. Recall that since in this study the aim is to investigate the interactions of two firms with the same growth coefficients and time horizon is set as 12 years, such adjustments would not lead to any inaccurate decisions. The ratio for the 8th run is 14 (0.55/(0.0015*26), which does not violate the ratio provided in Bass (1969).

Table 3-1 Simulation design for FAE_i and WOMi (without repeat purchase)

RUN #	FAE_i	WOMi
1	0.00055	0.021
2	0.001	0.021
3	0.001	0.025
4	0.001	0.03
5	0.001	0.04
6	0.0015	0.04
7	0.0015	0.05
8	0.0015	0.055

The graph of 8th run is illustrated in Figure 3-18. However, when repeat purchase is included the peak point shifts to right. A new simulation design is prepared, and these coefficients are again tested under repeat purchase (Table 3-2). The desired growth is reached by the coefficients of Run # 11 (The ratio is 18). The graph is can be seen from Figure 3-19. Also note that the graphs for other simulations are represented in the Appendix A.

Table 3-2 Simulation design for FAE_i and WOMi (with repeat purchase)

RUN #	FAE_I	WOMi
9	0.0015	0.055
10	0.0015	0.06
11	0.0015	0.07

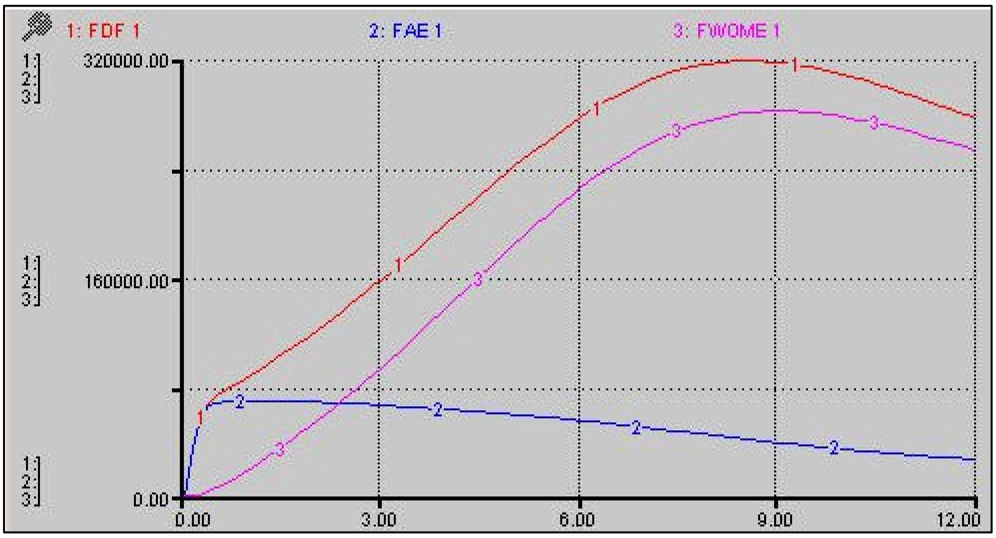

Figure 3-18 Innovative and imitative demand for run # 8 (without repeat purchase)

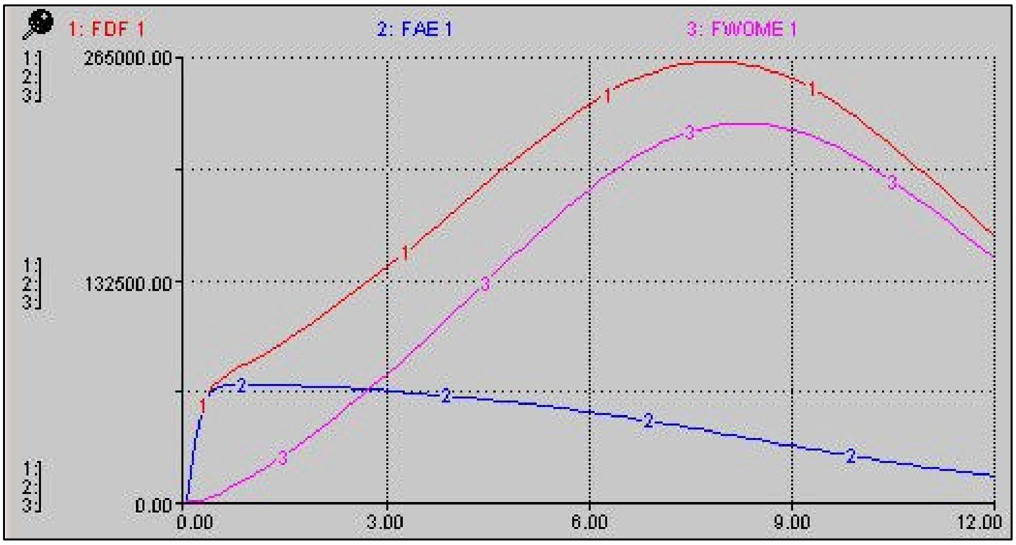

Figure 3-19 Innovative and imitative demand for run # 11 (with repeat purchase)

FLAD_1 = 3 (BCV)

FLAExp_1 = 1 000 000 (BCV)

3.7.4. Initial Values of Stocks and Parameters in the WOM Module

c = 10

c is assigned as 10. This means, one adopter meets 10 non-adopters in a year.

WOM_i = 0.07

As stated in the previous section, Bass' (1969) parameter estimation is used for assigning a value. This parameter is determined together with the *FAE_i*. The related graphs and simulation designs are provided in Section 3.7.3.

3.7.5. Initial Values of Stocks and Parameters in the Cost Module

INIT FTS_1 = 0

FC0_1 = 525 (BCV)

Initial cost takes different values for different segments since reference prices differ. The value is determined based on the minimum price level in Section (3.8.4). For the base case segment 2 is used; therefore, the related initial base cost is set to 525.

Fexp0_1 = 500 000

This parameter stands for the firm's initial experience. The total of two years' capacity is assigned for this parameter (250 000 * 2). Note that the sensitivity analysis of this parameter is also performed.

Alfa (α) ***= 0.3***

This parameter displays the strength of the learning curve. For a decrease by 20% in the cost (related cost part), *Alfa* should be taken 0.3. This is the value used for the base case and all scenarios, but note that this is also tested in the sensitivity analysis section.

EOS Effect

As also stated in 3.5.1, this effect is illustrated by a table function (Figure 3-13)

3.7.6. Initial Values of Stocks and Parameters in the Delivery Delay Module

INIT FDDRF_1 = FDD_1

INIT FDDRM_1 = FDDRF_1

The initial values of these stocks are a part of the information flow in the delivery delay module. Therefore, they are dependent on the previous information stock or converter.

TRF = 0.2

TRM = 0.2

The time for market and company to recognize the delivery delay is set as 0.2 years. Also mentioned in *PAT* (initial value section), this delay is reasonable in durable household goods industry for information flows.

FDDE Coefficient

The details and related table function values are provided in Section 3.6.1 and in Figure 3-16.

3.8. Market Structure and Customer Behavior

Before introducing the market structure and customer behavior, some examples from the literature are summarized. Later, price perception and level, in other words, the main common point with the models is discussed based on marketing literature and related definitions. With this explanation, the properties of market structure and underlying assumptions are introduced in the subsequent section.

3.8.1. Examples From the Literature

The study performed by Moorthy (1988) is composed of two identical firms, which competing on a single product attribute and price. Basically, this attribute is defined as quality because in the model, customers always prefer more of this attribute. Also, customers differ in their willingness to purchase the product. In the study, product's perceptional position and physical position is not distinguished. Also, it is assumed that higher quality products cost more to produce than do lower quality ones.

In the model, there are two firms indexed 1 and 2, which can produce a product within interval $[0,\infty)$. This one-dimensional scale represents the product's attribute upon which the firms are compete.

In the customer part of the model, a consumer of type-t is willing to pay *ts* for a unit of product *s*. These consumer types classify customers and build customer segments.

Customers can observe all available products before their decision to buy. They prefer the ones that provide higher surplus. Note that the surplus is the difference between what they are willing to pay and what they are asked to pay.

Vandenbosch & Weinberg (1995) extend the study performed by Moorthy (1988). They introduce another attribute and perform the study on a two dimensional scale. The absolute difference between the products is measured by multiplication of the absolute differences of both in two dimensions. If absolute difference is zero, then each firm can obtain 50% of the market.

Dobson and Kalish (1988) summarize the most common properties of the theoretically oriented articles: customer willingness to pay (measured in dollar-metrics scale) is defined and decision to buy is based on maximized welfare, which is determined as the difference between reservation price and actual price. The typical simplifying assumption is the only attribute "quality". This attribute brings ease of selection because always more of it is preferable. Also fixed costs are omitted.

In the model, each customer provides a reservation price and selects the product based on the difference between this reservation price and the product's actual price. Data about the market is collected via a survey (Conjoint analysis). Both variable and fixed costs are included. However, in the model, competition and repeat purchase are omitted.

The market structure build in Rao's (1991) study differentiates from the basic assumptions in theoretically oriented approaches observed by Dobson and Kalish. Rao (1991) divides the market into two segments; each of behaves with different expectations. The first segment's behavior solely depends on price comparison, whereas the second segment compares both prices and brands.

Ruebeck (2002) also defines the market structure in a manner similar to Moorthy (1988), Dobson and Kalish (1988), Vandenbosch and Weinberg (1995). Consumers purchase the product (computer hard disk drive) based on the utility function, which is defined as the difference between the willingness to pay for the specific quality levels and price of the product.

In the study performed by Ofek & Srinivasan (2002), a measure of market value that compares the incremental unit cost of the improvement and the probability of customers' purchase the firm's product. Customers' preferences are gathered by a conjoint analysis and the profitability of the improvements on the products are conducted based on the developed metric. This metric mainly depends on the customers' utility from an additional attribute. Again, similar to other studies, this utility function also constitutes price and customers' welfare.

Kopalle, Rao & Assunçâo (1996) handle the issue of reference price. In their study, a dynamic reference price concept is introduced. They formulate reference prices as a function of previous period's price and reference price. This approach is also supported by (Nagle, 1987) and by many researchers.

The utility function proposed by Armony & Haviv (2003) differs from earlier models. In their study, customer's choice depends on the service price and the expected waiting costs. Therefore, according to the provided service or product specifications, customers' surplus may include various parameters.

3.8.2. Price Perception and Price Levels

Price perception is the most common issue in the examples. Almost in every study, terms such as reservation price, reference price, maximum welfare or surplus that are based on actual and reference levels. These all terms are a consequence of "price sensitivity". Mainly purchase decision is an output of these levels. We also use similar levels in the model. But what are those levels? What is the logic behind these levels? Is it possible to estimate these levels? Many more questions can be derived. Before introducing the details of the model, the answers to these questions are discussed.

First of all, we should discuss whether it is possible to measure the value of a product with its price, because the value of the product is the main point behind the price sensitivity. The concept of product analysis pricing that was developed in the Glacier Metal Company, Ruislip, Middlesex, England, identifies this issue. This concept aims to measure the value and consequently the price associated with the products.

Gabor (1988) summarizes Product Analysis Pricing (PAP) as follows: "The central idea of Product Analysis Pricing (PAP) is that the price which the buyer is prepared to pay is directly determined by those aspects of the product that have significance for him. It claims that these aspects can be quantified and a value schedule attached to each, based on the buyer's judgment rather than on the *cost of the product*. The appropriateness of the quotations derived from these values, and the extent to which the prices approximate the optimum level can be judged by the percentage of the market captured." (Gabor, 1988)

Customers' behavior and purchase intention is independent from the costs. The market structure and related price levels for different market segments are assigned based on the design quality provided by the company.

This cost-independent level can be thought as a reference price, which identifies the customers who are willing to pay at a specific price. However, firms do not always sell the product at this level. They apply various pricing strategies -as stated in pricing section- based on their long range planning, aims and competitors' behavior. But, how low and how high can this price can? Does the company still sell at a very low price? What determines this low price? It is obvious that the next issue is the determination of these limits along with underlying reasons.

In general there is an upper limit for the consumer to pay for a product. This limit is not only dependent on affordability but also on their rational observation based on the product attributes. There is a point when the homogenous customer says 'This product is not worth this price and also I cannot afford it at this level'. This level is commonly used in various researches. Dobson and Kalish's study can be shown as an example. As many researchers they refer this level as a 'reservation price'.

There is a common sense of 'price is an indicator of quality'. To select the expensive product instead of a cheaper one results from two beliefs: (1) to impress others, (2) to avoid the risk associated with the cheaper one. (Gabor, 1988) The risk associated with cheaper one is the belief that cheaper item cannot provide the satisfaction that is promised with the design quality. Therefore, the concept of minimum price, that makes people believe that the design quality can satisfy their expectations, arises. Any price lower than this minimum price level leads to no sales based on the perception. Similar to the level (reference price), this perception of minimum price is *independent from costs*. Because the issue of cost is not the customers' problem, they never care about cost or companies' profit. However, this lower bound for the price has a strong relationship with the substitutes' prices and competitors' pricing policies. In a monopoly, the customers' beliefs for the minimum price will have a strong relationship to the customer's pricing policy. If there are competitors in other segments, this lower bound will be automatically dependent on the other segments. It is obvious that price perception cannot be investigated by itself alone. The dynamics related to the product type, market structure, segments, expectations should all be considered together. Then this perception would be stricter. These dynamics are also valid for the maximum limit. Beside the complexity of this issue, in general for the limits it can be said that, the lower limit stands for quality beliefs and the upper limit stands for affordability and willingness level. Outside these limits price build a barrier that stops purchase.

The determination of these limits is a complex issue as mentioned above. Surveys and past sales data are the techniques used for this purpose. However, surveys are more preferable than purchase data. Nagle (1987) summarizes the reasons behind this preference as follows:

- Survey data cost much less than purchase data to collect
- It can be collected for large durable goods, such as automobiles
- It can be collected even before a product is designed, when the information is most valuable in directing product development

- It can be collected quickly (Nagle, 1987)

However, there is a problem which Nagle (1987), and other researchers state with survey data and the customers' responses in survey data, which do not reflect their real purchase intention. Especially questions directly related to price are under a great risk. However, this is still the preferable method due to above reasons.

Gabor (1988) summarizes the main questions that should be asked for determination of the limits.

- If you wanted to buy a product with X, Y, Z attributes and saw what you were looking for, which is the highest price you would be prepared to pay?
- Which is the lowest price at which you would still buy – I mean the price below which you would not trust the quality? (Gabor, 1988)

If these questions are asked to a homogenous group, the researcher can determine the highest and lowest levels for the price. Of course, the answers would not be identical but close due to the homogeneity of the group's affordability and willingness, or purchase intention.

3.8.3. Market Structure of the Model

The market consists of two identical firms as mentioned in the earlier sections. These firms compete on a single attribute, design quality, as similar to the earlier researches stated in Section 3.8.1. If two products have the same design quality, then the concept of pricing and advertising is introduced for competition.

There are specific design quality levels for the products. Any two products having the same design quality are referred as "identical products". The term identical not only refers to the functional properties but also refers to the physical properties such as material, color, and so on.

The market consists of four customer segments and each design quality satisfies the expectations of customers only in the related segment. If and only if there is not a product in the related segment, then the customer can purchase the product from a lower segment with product available (not from upper segment due to affordability).

Another concept is affordability and willingness for purchase. The market segments consists of homogenous customers in terms of affordability and willingness for buying a product. In other words, these customers' purchase intentions are similar.

The firms are identical in terms of producing products from any design quality level. They both know the market and they can both have the opportunities for reaching the different segments. Also, they both can introduce two products.

Another assumption is about the costs of products. As also assumed in Moorthy (1988), producing higher quality products cost more than producing lower quality products. A linear relationship is also assumed for quality and price. Then the market segment is related to the concept of price sensitivity. The segments and related sensitivities (limits) are stated in the next section.

3.8.4. Market Segments and Price Perception

There are four segments in the market. The highest segment (#4) consists of relatively wealthy customers who have purchase intention for the product with design quality level. The next segment is a more moderate segment but still have a purchase intention for a superior product. The second segment can be named as the base segment, which includes the highest share among the other segments. On the other hand, the lowest segment is related to the product design quality level one. The products in this group are assumed as having the basic function of the product.

The percentages are assumed as:

- 10% for segment 4 – related product is Product – 4
- 20% for segment 3 – related product is Product – 3
- 50% for segment 2 – related product is Product – 2
- 20% for segment 1 – related product is Product – 1

As mentioned previously, the customers of segment 4 can purchase the Product-3, if the Product-4 has not been introduced to the market yet. If Product-3 has not already been introduced as the Product-4, then the customers of first two segments will automatically buy Product-2. This chain goes on in this manner. The rule is "the customer of a higher segment can purchase the product from lower segments unless the related product introduces to the market." Of course, the inverse is not valid. Since a customer from segment 1 cannot afford a product from higher segments, he/she cannot purchase the product. Therefore, he/she will wait till the introduction of Product-1.

The following graph is used in the model for calculating the potential customers' percentage. Although, quality 5 should not be in the graph (there are four products and segments), due to property of discrete graph, it is automatically included and related PC percentage is again automatically set to 10%.

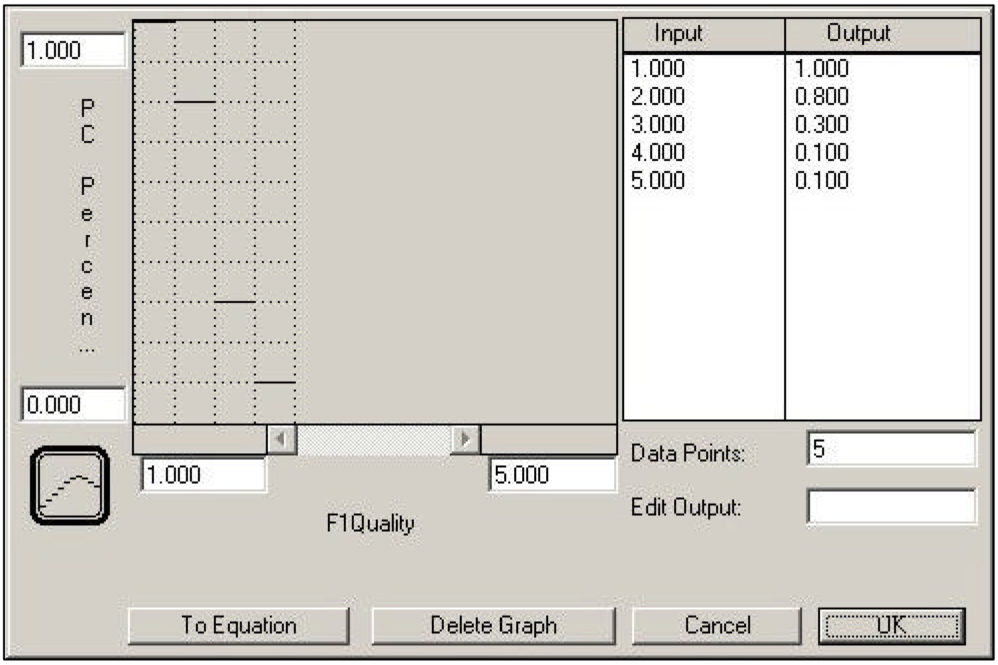

Figure 3-20 Quality versus PC percentage

The price perception of the segments is determined by the reservation prices. These upper limits are assumed to determined by historical data and survey. The demand within a segment is modeled by a linear demand curve as stated in Section 3.2.3 and in Equations (3.32), (3.33) and (3.34). Therefore, after setting a reservation price it is possible to determine the reference price level and minimum level for a segment.

Recall that the segments and the price perceptions is an available information for both of the firms. Also note that the elasticity is set to 1.6 (Section 3.7.2).

The firms aim to position the product for a single segment. Since the firms have the price perception data (levels for the products), they introduce the product to the related segment with a Target Costing approach. With this approach they aim a cost that will reach the minimum price level in the long term. Also the firms are aiming to get 5% profit in the worst case; this minimum price level should be equal to the 5% profit margin from the scope of the firms. Also note that with the Target Costing approach, the principle of cost-independent price levels are not violated. This principle is discussed in Section 3.8.2.

At this moment, the effect of learning curve and economies of scale become an important issue. With these effects, an approximate lower bound for the cost can be determined. In Equation (3.59), first the effect of learning curve is calculated (20% decrease per doubling the accumulated production volume) and then this part is multiplied by the economies of scale effect. In this calculation, an approximate level for the doubling is determined based on the total capacity of 12 years (simulation horizon). This means a total of 3 million products. When the learning curve effect formulation is applied this number is equivalent to a decrease of 44% (Assuming an initial experience of 500 000 products).

The level of EOS effect is set to the usage of maximum capacity usage (4.9 % decrease in the cost). Then this cost level is set to minimum price level with a profit margin of 5% (Equation (3.60)). The minimum price level is known due to reference price and linear demand curve (Equation (3.64)). Therefore, the initial cost determined is the as same as the RP. Note that more than a twice doubling is assumed as stated earlier and this assumption is the underlying reason of this result ($RP=C_0$). Recall that, in fact, these levels are independent from each other. However, since a target costing approach is used, and a consistency for the simulation is essential, such a calculation is preferred for assigning initial costs. It is also possible to assign independent initial costs; however in that case the minimum price level should be controlled with the lower bound of customer' price perception, not in terms of cost. This is especially essential if the model is run with four segments. Because "active four segments" means "four separate price perceptions and levels".

$$[0.65*C_0 + 0.35*C_0*0.56]*0.951 \approx 0.8045\ C_0 \tag{3.59}$$

$$0.8045*C_0*1.05 \approx 0.85\ C_0 \tag{3.60}$$

$$0.843*RP = P_{min} = 0.85\ C_0 \tag{3.61}$$

$$C_0 \approx RP \tag{3.62}$$

The next issue is the determination of lower and upper bounds for the price levels. The upper bound is the point that no customer desires to purchase the product. In other words, 0% of the customers desire to purchase the product. On the other hand, the lower bound is the point that all the customers desire to purchase the product. Equation (3.63) represents the upper bound whereas Equation (3.64) represents the lower bound. Recall that reference industry demand percentage is set to 80% (Section 3.7.2).

$$(0.8*PC)*(1-RIDE[(FP-RP)/RP] = 0*PC \tag{3.63}$$

$$(0.8*PC)*(1-RIDE[(FP-RP)/RP] = 1.0*PC \tag{3.64}$$

The reservation prices and the price levels, that are determined based on the references prices and equations represented above, are displayed in Table 3-3. Recall that the reference prices are assumed to be collected from homogeneous customers within a segment.

Table 3-3 Price levels for the segments

Segments	**Reference Price ($)**	**Min. Price (Lower Bound) ($)**	**Max. Price (Upper Bound) ($)**	**Initial Cost - C_0 ($)**
1	250	211	406	250
2	525	443	853	525
3	1200	1012	1950	1200
4	2500	2109	4062	2500

In the model, the relationship between the reference price and quality is shown by the following graph.

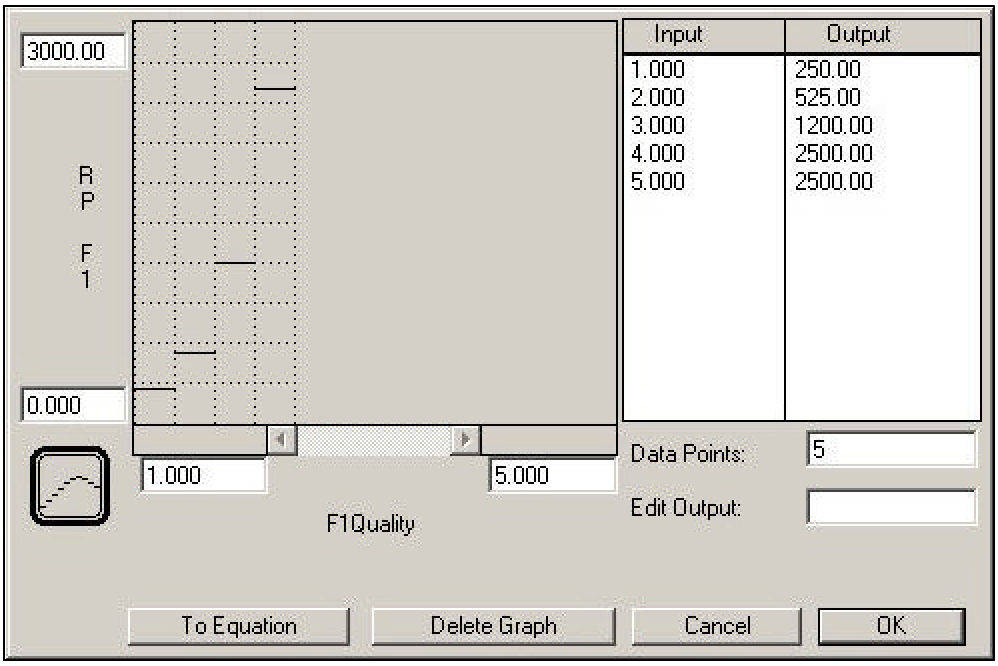

Figure 3-21 Quality versus reference price

3.8.5. Market Segments Under Different Competition Scenarios

Roughly, price level or, in other words, reference price is the value of the product. The existence of a competitor's product in the other segments will affect the number of people who will have a purchase intention not the price level. Therefore, the reference demand percentage related to the reference price is set again when the number of competitors change.

For example, if all the competitors are active in the market in all segments, then the reference demand percentage at the specified reference price is 80%. However, if segments 1 and 2 are empty (no products), then the percentage of segment 3, at the specified level for Product-3 will differ. The number of customers who are willing to adopt Product-3 becomes:

80% of segment 2 + 100% of segment 1 + 100% of segment 2 (3.65)

Therefore the percentage becomes:

$$[0.80\ (0.50) + 1.0\ (0.20) + 1.0\ (0.10)]\ /\ 0.80 = 0.875 \quad (3.66)$$

The 0.80 in the denominator stands for the ratio of segments (1,2 and 3) compared to the total potential customers. The result 0.875 is the PC percentage of reference price of Product-3 when segments 1 and 2 are empty. The result would not change based on the presence of Product-4.

3.8.6. Modeling Different Segments with System Dynamics

All possibilities for the market entry times and product qualities are included in the model, in order to build a market structure as stated in the previous section. According to the scenario (quality levels and entry times), the related paths will become active and the rest redundant.

The basic functions and dynamics also work as the same stated in the earlier sections (i.e. advertising, diffusion and etc.). The main difference is the dynamic number of sub-potential customers related to the presence of products with the related design quality. These dynamic potential customers are controlled via the inflows and outflows based on the entrance sequence and products' design qualities. For example, if the firm launches product 3 and then the competitor launches product 4, then the firm will lose (0.3-0.2)/0.3 % of its market. Recall that the market size of segment 3 and 4 are 20% and 30% respectively, and if product 4 is not launched to the market, its percentage becomes 30%. The reduction ratios, that are calculated based on the entrance time and product quality, are entered to the outflow of each stock in the diffusion framework. On the other hand, the inflow of the segment 4's potential customers is 10%. Therefore, while taking the specified percentage from one stock with an outflow, the same value is assigned to another stock by an inflow simultaneously, and these formulations carry the market structure and specifications to the model.

4. MODEL VALIDITY

Model validity is an important phase of the model-based methodologies. In System Dynamics, this step has a vital importance. Barlas (1996) explains the underlying reason as follows: "Validity of the results in a model-based study are crucially dependent on the validity of the model".

There is not a unique procedure for model validity. The path to be followed depends on the aim of the study and availability of the information. In this study, the framework provided by Barlas (1996) is used. The tests are also included in other studies such as Forrester (1961) and Sterman (2000), however, the sequence and the classification make this reference preferable.

In order to validate the model, direct structure tests and structure oriented behavior tests are performed. Behavior pattern tests are omitted because these tests are strongly related to the aim and content of the study. The underlying reason can be to explore a real system (application base study), to investigate an existing theory, to make an interactive simulation gaming or to learn the systems. These different objectives lead to different model validity procedures. Barlas (1996) states, "the models the models built for learning may not necessitate as much behavior accuracy testing as the traditional applications do." Since the aim of this study is to understand the dynamics in a duopoly and compare the possible behaviors against different scenarios, the last group of tests is not applied.

The following topics explore direct structure tests and structure-oriented behavior tests sequentially.

4.1. Direct Structure Tests

These tests discuss the validity of the model equations directly without dynamic simulations. Structure confirmation tests (both empirical and theoretical), parameter confirmation test (both empirical and theoretical), direct extreme condition test and dimensional consistency test are conducted.

Structure confirmation test means comparing real system information and model structure. The equations mostly depend on the literature and industry dynamics. The structure and the information conveyed through the structure are extensively discussed with the thesis advisor and two experts.

Parameter confirmation test means the evaluation of constant parameters against the real life. This test also consists of two parts: a conceptual part and a numeric part. All parameters that are included in the model have real life meanings that are also used in other kind of models. Also note that an accurate estimation is possible if the extended data is available from the industry. To overcome this problem, for the parameters hard to estimate and determine, the estimations performed in the earlier studies are taken and adapted to the study (for word of mouth effectiveness and advertising effectiveness).

Direct extreme condition does not involve simulation. In this test, each equation is taken by itself and the possible output of the equation is discussed under extreme conditions. This test is done regularly during the model building. After the development of each module and its integration to whole model, extreme cases are argued and, if necessary, corrections are made on the equations.

As a last step, the dimensional consistency test is performed. In this test, right-hand side and left-hand side of the equations are checked. The equations are manually checked. Note that, the equations are also checked by an expert. The model passed the test without including any meaningless parameters. However, during this test only one equation seems problematic. The effect of advertising expenses is reflected to the model with a logarithm function. This structure depends on the literature, known as the diminishing effect, and is used in this way in other models as well.

4.2. Structure Oriented Behavior Tests

These tests check the validity of the model indirectly by applying certain behavior tests on model-generated behavior patterns. (Barlas, 1996). These tests involve simulation.

In indirect extreme condition test, extreme values are assigned to the some selected parameters and model behavior investigated. In this test, extreme values are assigned to parameters; the firm's advertising budget ratio (FABR), firm's price and total capacity and reasonable patterns are obtained from the results.

FABR is increased by a pulse function in the first test. In period 5, the advertising budget ratio is increased to 36% of the total sales. The model had not performed an impressive response against this aggressive pulse function. This behavior is expected due to the diminishing property of advertising also stated by various resources in the marketing literature. The related curves are illustrated in Figure 4-1.

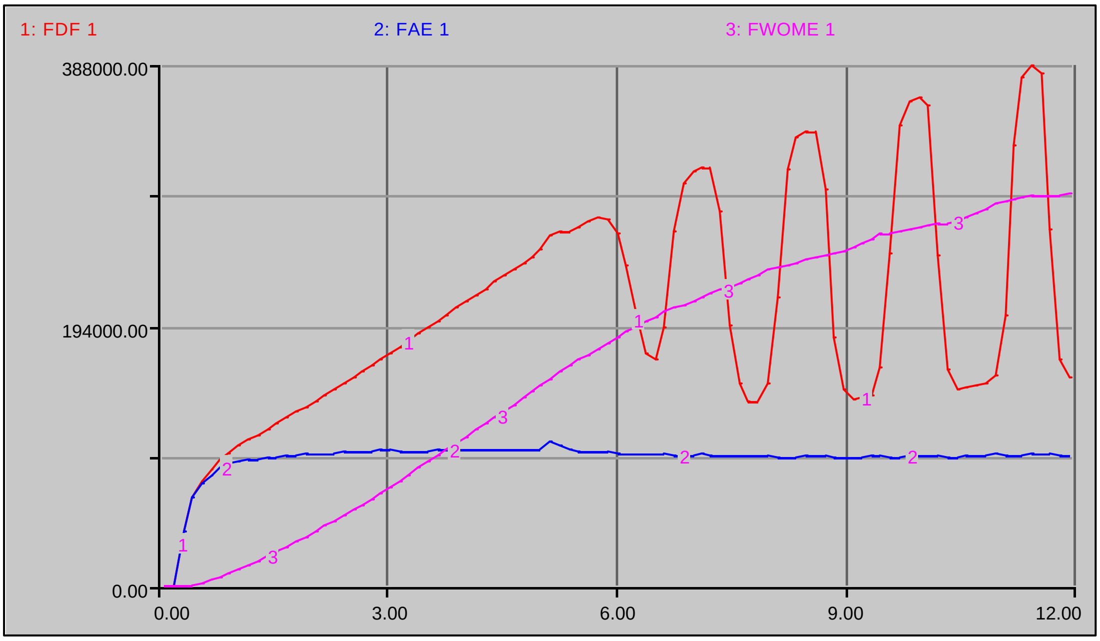

Figure 4-1 Direct extreme condition test for FABR

In the second test, the sharp price increase and decrease are tested. First, the price is increased by $300 and by a pulse function and then in the second test the price is decreased by $300.

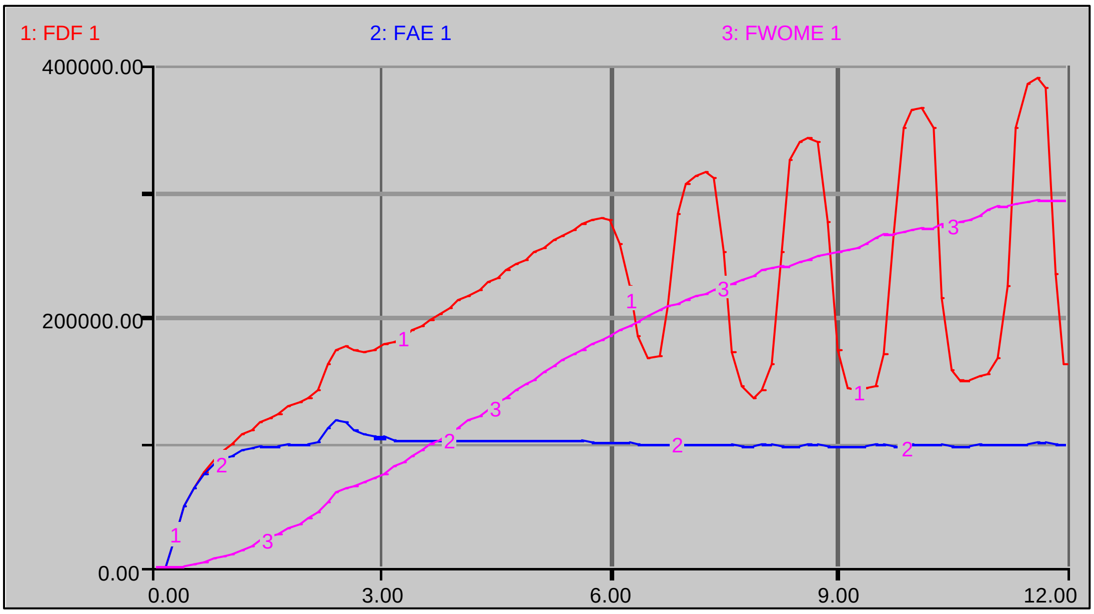

Figure 4-2 Direct extreme condition test for the firm's price (Decrease)

In Figure 4-2, the impact of $300 decrease is apparent. However, the impact of the same amount of decrease ($300) is still apparent but not as much as observed in the first case (Figure 4-3). The underlying reason is the closeness of the minimum and maximum levels of the price. In the first test, the price is increased from $518 to $818 and $818 is approximately equals to the maximum level (Maximum price – $853); however, in the second test the price falls to $217, almost the half of the minimum price level. Since the maximum size of market has already been reached by the lower bound of the price, much of this effect becomes redundant.

The final direct extreme condition test is applied to initial capacity value, is adjusted by a step function and increased by 100 000 in period 6. The resulting graph is illustrated in Figure 4-4. The reason of the sudden peak after capacity expansion is the waiting customers in the backlog approximately since period 5. After this peak, the sales gradually rise and reach the new capacity level.

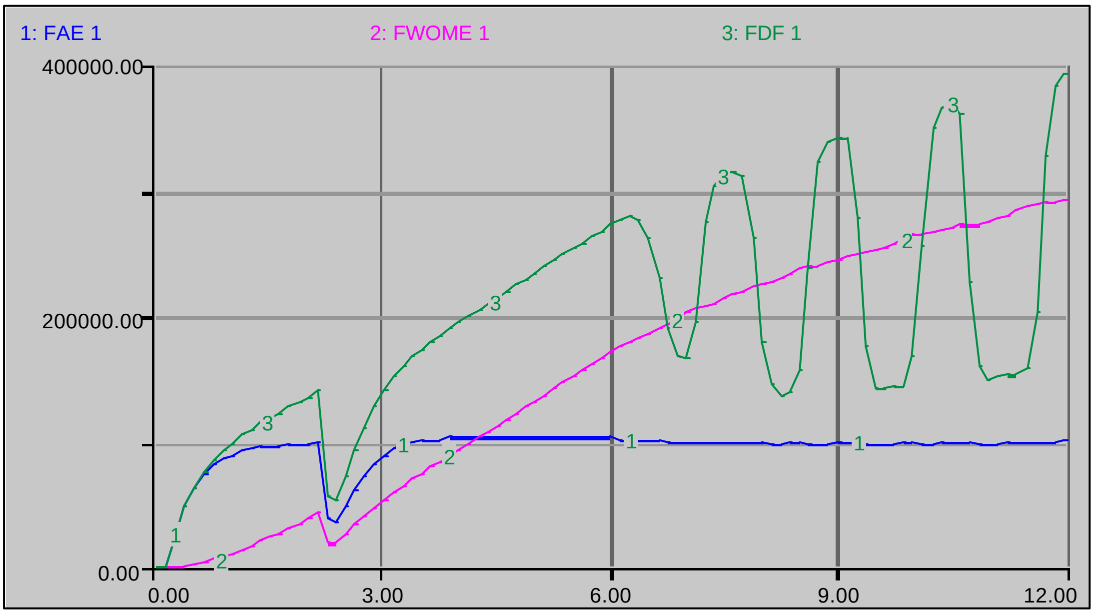

Figure 4-3 Direct extreme condition test for the firm's price (Increase)

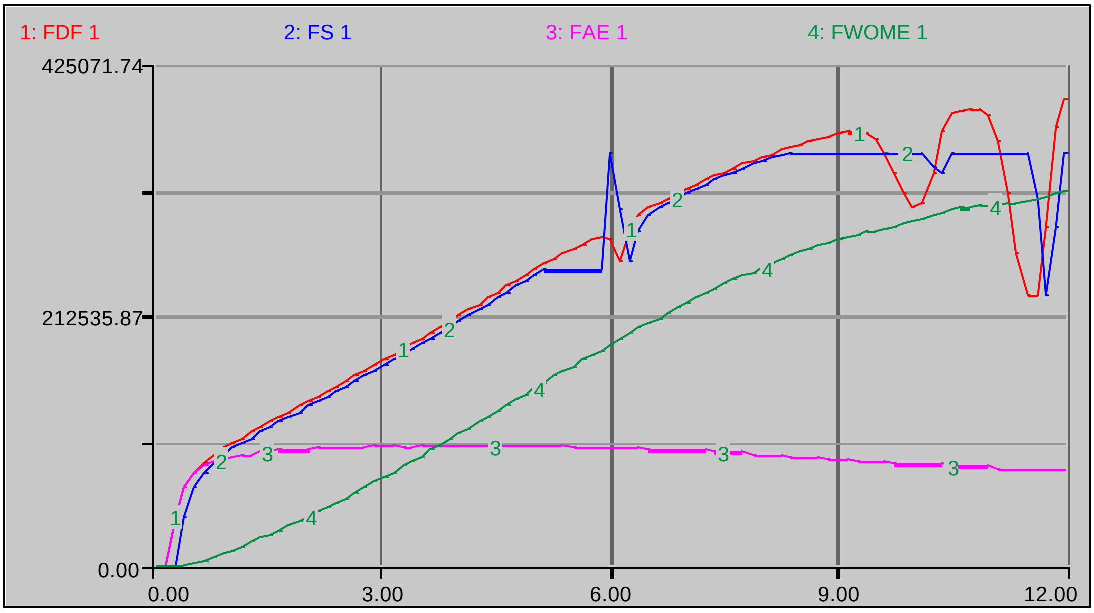

Figure 4-4 Direct extreme condition test for the firm's initial capacity

These tests display that the model behaves as expected under extreme conditions. The next group of tests is behavior sensitivity tests.

Behavior sensitivity tests help to determine the parameters to which the model is highly dependent and sensitive. The sensitivity analysis for the following parameters is performed;

- advertising effectiveness coefficient

- word of mouth effectiveness coefficient
- learning curve strength
- initial experience

For the advertising effectiveness coefficient, the range 0.0001 – 0.0025 is tested under the base case conditions. The simulation design is illustrated in Table 4-1. The comparative graphs are taken for word of mouth effect, advertising effect and total demand flow. In this analysis all the other effects are included in contrast to the way for the determination of *FAE_i* parameter. For the illustration purposes the total demand comparative flow is provided in this section (Figure 4-5), the rest can be found in Appendix B.

Table 4-1 Simulation design for sensitivity analysis of FAE_i

RUN #	**FAE_i**
1	0.0001
2	0.0007
3	0.0013
4	0.0019
5	0.0025

In Figure 4-5, it is seen that the growth is highly dependent on this parameter; this is also a known issue. Thus, the estimation of this parameter is very important. However, as mentioned before, this parameter is determined consistent with *WOMi* and assigned to the competitor as same as the firm. Also note that, the value assigned for the parameter is between values 3 and 4. The curves 3,4 and 5 are close to each other, whereas 1 and 2 are very apart.

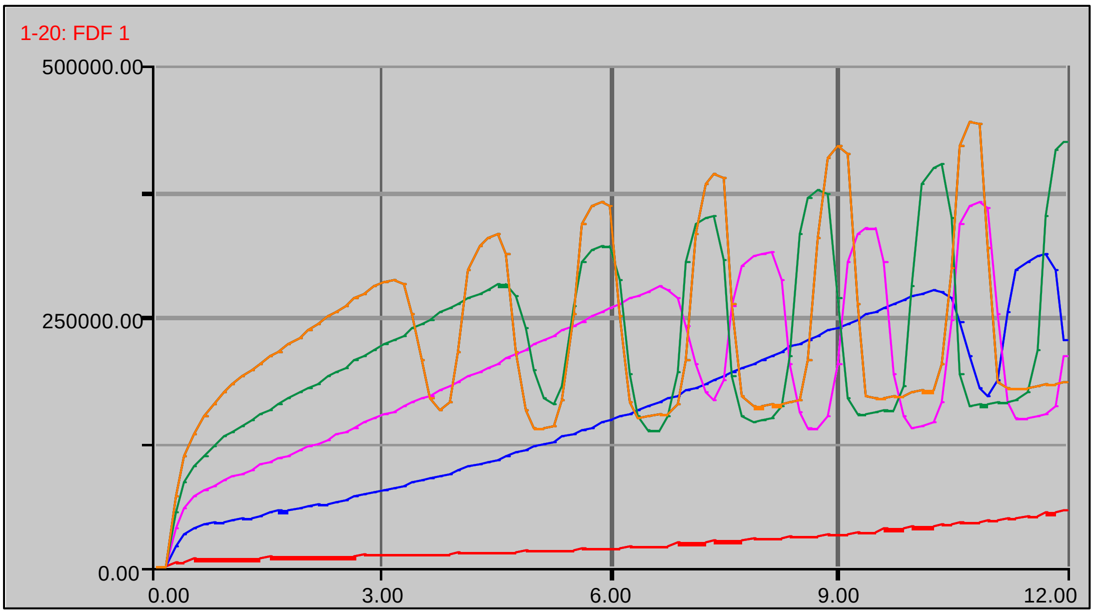

Figure 4-5 Sensitivity analysis for FAE_i (FDF_1)

For the word of mouth coefficient, the range 0.1 – 0.01 is tested under the base case conditions. The simulation design is represented in Table 4-2. Similar to the *FAE_i* analysis, the comparative graphs are taken for the word of mouth effect, advertising effect and total demand flow (Total demand flow can be seen from Figure 4-6, the others are available in the Appendix C.).

Table 4-2 Simulation design for sensitivity analysis of WOMi

RUN #	WOMi
1	0.01
2	0.0325
3	0.055
4	0.0775
5	0.1

The growth rate is also highly dependent on *WOMi*. The difference between the curves is getting smaller after 3rd simulation run and the selected value of the parameter is within this range.

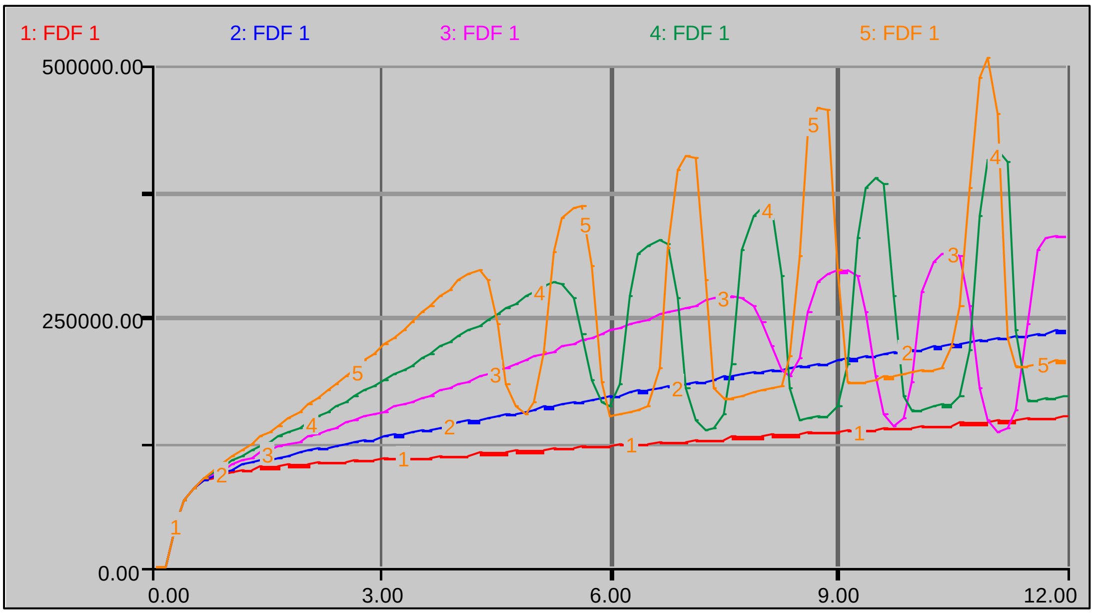

Figure 4-6 Sensitivity analysis for WOMi (FDF_1)

The learning curve strength is another parameter tested in this section. The suggested values for this parameter is 0.3 – 0.5 in the literature. Therefore 5 times model is run between the suggested ranges (Table 4-3). The firm's cost, firm's price and firm's demand flow are checked during the 5 simulations. Firm's demand flow is illustrated in Figure 4-7, whereas the others are illustrated in the Appendix D. It is obvious that the model does not strongly depend on this parameter within the suggested range. Therefore, the initially assigned value is appropriate.

Table 4-3 Simulation design for sensitivity analysis of learning curve strength (α)

RUN #	a
1	0.3
2	0.35
3	0.4
4	0.45
5	0.5

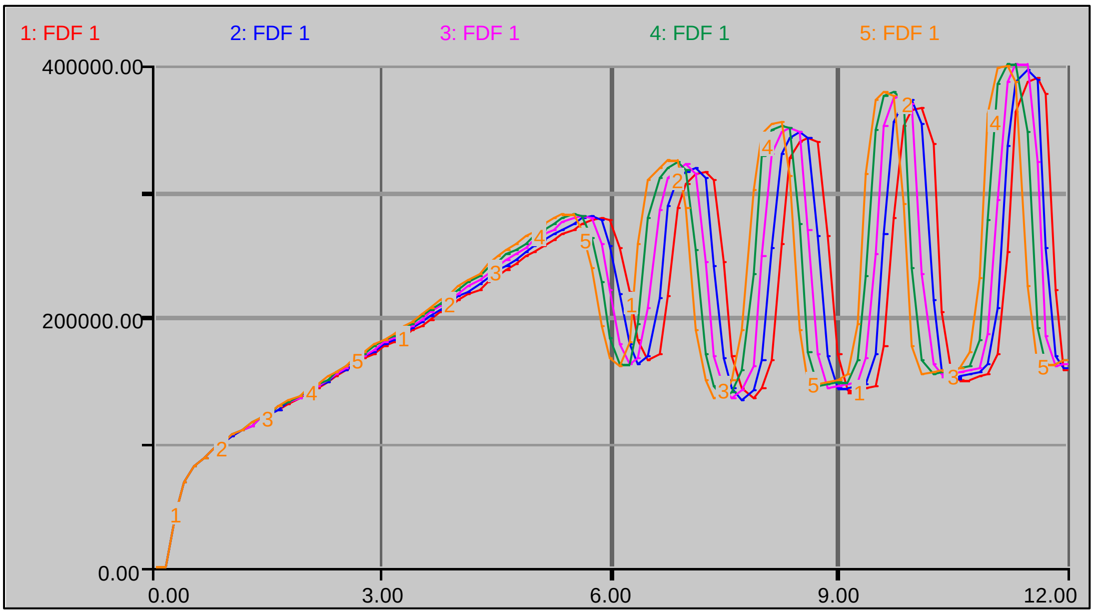

Figure 4-7 Sensitivity analysis for learning curve strength (FDF_1)

The initial experience is also simulated 5 times within the range of 300 000 – 800 000. Table 4-4 represents the simulation design and Figure 4-8 represents the effect of this parameter of firm's demand flow. Note that firm's cost and firm's price are illustrated in the appendix. Similar to the learning curve strength, the model does not strongly depend on this parameter and the assigned initial values (500 000 = two year's total capacity) is proper for the possible scenarios.

Table 4-4 Simulation design for sensitivity analysis of initial production experience ($Fexp_0$_1)

RUN #	$Fexp_0$_1
1	300 000
2	425 000
3	550 000
4	675 000
5	800 000

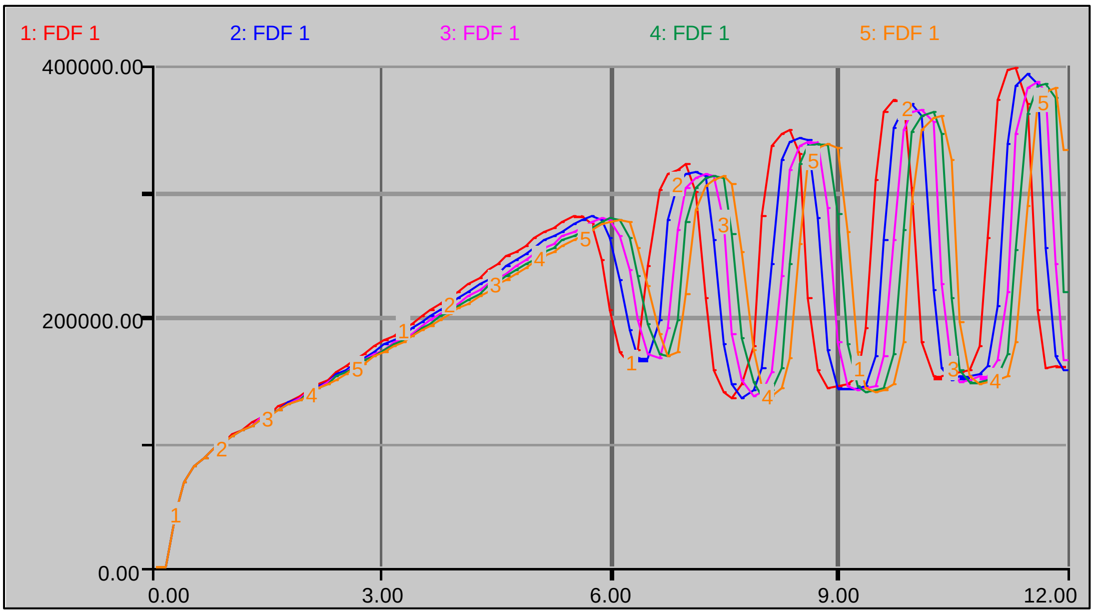

Figure 4-8 Sensitivity analysis for initial production experience (FDF_1)

There are also other tests in structure oriented behavior tests such as modified-behavior prediction test. Since the data is essential for these tests, they are skipped.

5. SCENARIO ANALYSIS

In this section basically two groups of scenarios are presented and results are discussed. The first group deals with various pricing strategies whereas second group deals with the advantages and the disadvantages of the second product launching under different market structures (monopoly and duopoly).

5.1. Pricing Strategies

The first scenario group compares the pricing strategies. In the simulation design the firm is designated as the first mover and competitor is designated as the second mover (late entrant). The firm can apply two different pricing strategies: (1) skimming pricing and (2) penetration pricing. As a response to the skimming pricing, the competitor either matches the price or cuts the price (aggressive response). On the other hand, as a response to the penetration strategy the competitor matches the price since the price levels are already very low. This design is replicated for the different entry times of the competitor; recall that the firm enters to the market in period 0. What if the competitor moves one period later, two periods later or three periods later? This group of scenarios is also replicated for different market segments. First, the scenarios are run in segment 2 and then the same scenarios are run in segment 3. Figure 5-1 illustrates the scenario design.

In order to compare these three scenarios, the profit levels of the firm and competitor, the profit difference (in percentages) and the market share of the companies are considered. Based on these reports the advantages and disadvantages are discussed.

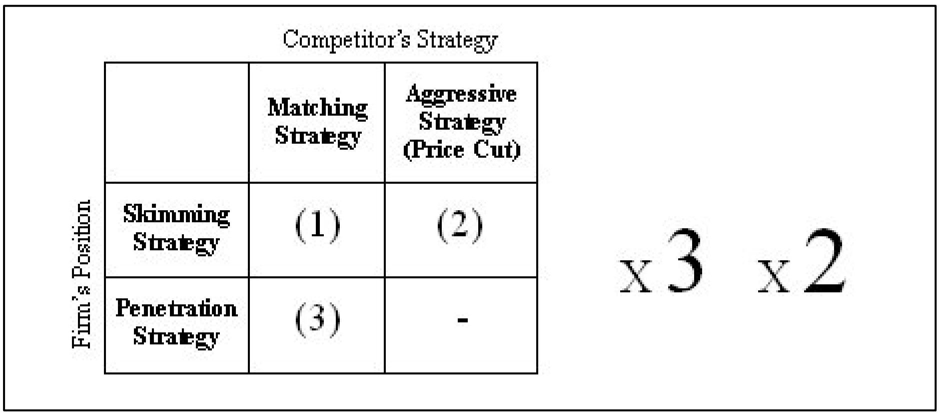

Figure 5-1 Scenario design 1

5.1.1. Pricing Scenarios for Segment 2

In the case of skimming – matching, the firm sets a high price to increase the profit, while decreasing the advantage of high volume sales and lower costs. As a response the competitor sets its price at the same level as the firm.

The initial price of the firm is set as 800. Recall that this value is directly related to the market segment and its associated product design quality (segment 2 – product 2). The competitor's price is assigned based on the price level of the firm. The cost sensitivity parameters (*FSPC* and *CSPC*) are set as 0.02, since this strategy and response are not cost-dependent. The competitor sensitivity parameters (*FSPCP* and *CSPCP*) are set as 0.2, which implies an intermediate dependence on the competitor.

Table 5-1 Results for skimming-matching case (segment 2)

Metrics **CET[1] (Year)**	**Firm's profit (1) (million $)**	**Competitor's profit (2) (million $)**	**Profit ratio ((1-2)/1) (%)**	**Firm's market share (%)**
1	209,433.79	188,846.14	9.83	52.00
2	218,343.57	167,404.83	23.32	55.00
3	228,419.07	142,344.34	37.68	58.00

[1] Competitor's entry time

In the second scenario, the firm also sets a high price. However, in contrast to the previous case, the competitor responds aggressively by decreasing the price level of the competitor.

The initial price of the firm is set as 800 similar to the previous case. However, the competitor cuts the firm's price approximately by 15%. The other parameters are kept the same as in the previous case except the competitor's "competitor's price sensitivity parameter". This parameter is decreased, because the competitor does not act dependent on the leader's price (firm's price) any more instead it aggressively cuts the price. Therefore this parameter is set as 0.02, which represents a low dependence.

Table 5-2 Results for skimming-price cut case (segment 2)

Metrics **CET (year)**	**Firm's profit (1) (million $)**	**Competitor's profit (2) (million $)**	**Profit ratio ((1-2)/1) (%)**	**Firm's market share (%)**
1	185,560.33	195,395.46	- 5.30	49.00
2	192,151.63	166,500.72	13.34	52.00
3	196,066.70	135,110.02	31.08	55.00

In the penetration strategy, the firm sets a low level price in order to increase the sales volume and use the advantage of decreasing costs due to learning curve and high capacity usage ratio. As a response, the competitor also sets lower price as long as its own cost allows. Recall that there is a threshold for the prices for both of the firms; at least a profit margin of 5% is desired.

The initial price of the firm is set at 700. The competitor's price is assigned dependent on the price level of the firm. In this case, the cost parameters have a vital importance. Therefore they are set as 0.5 (which represents a high dependence on the costs). On the other hand, the competitor's price parameters are set as 0.02.

Table 5-3 Results for penetration-matching case (segment 2)

Metrics **CET (year)**	**Firm's profit (1) (million $)**	**Competitor's profit (2) (million $)**	**Profit ratio ((1-2)/1) (%)**	**Firm's market share (%)**
1	49,138.18	39,459.53	19.69	55.00
2	51,799.67	32,875.24	36.53	59.00
3	53,008.09	26,650.36	49.72	63.00

In order to compare the results of these three scenarios summary graphs are drawn. Firm’s profit, competitor’s profit, profit difference (%) and firm’s market share can be seen in Table 5-1 through Table 5-3 and in Figure 5-2 through Figure 5-5.

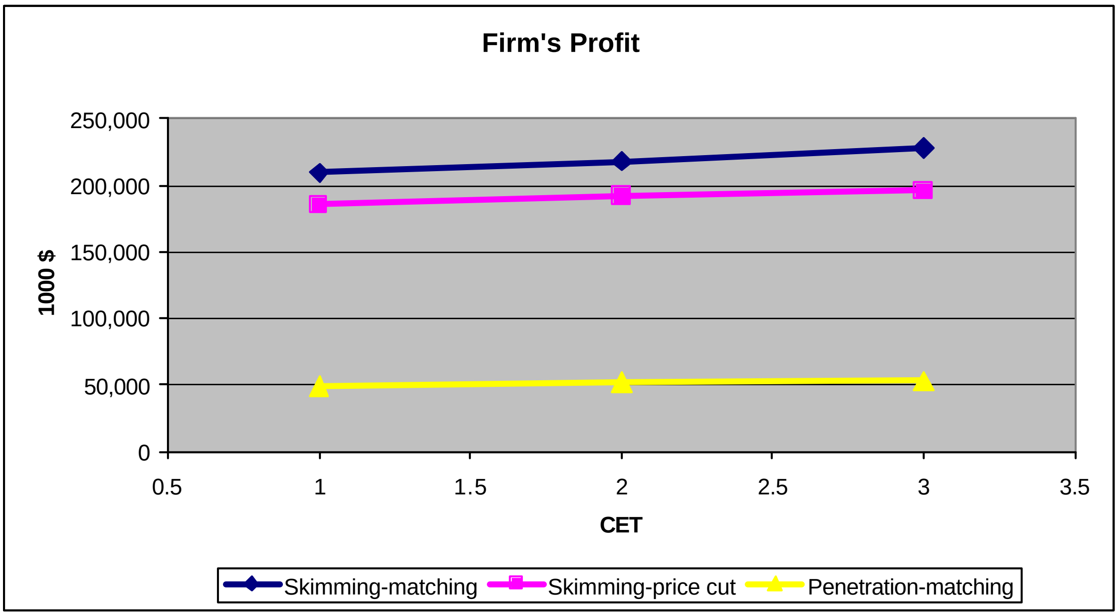

Figure 5-2 Firm’s profit under three scenarios (segment 2)

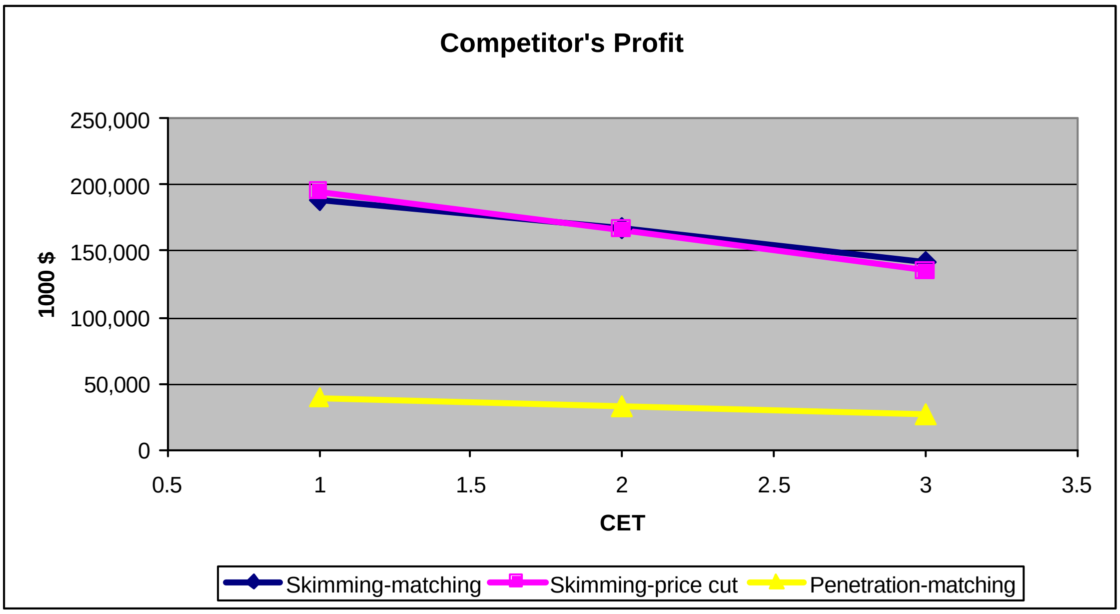

Figure 5-3 Competitor’s profit under three scenarios (segment 2)

The common point for the firm’s profit is the positive correlation with the entry time of the competitor, whereas from the competitor’s perspective there is a negative correlation. This means as the time lag increases the competitor looses profit while the firm wins.

The firm's profit level has the highest values for skimming-matching case among the scenarios. The underlying reason is keeping the high levels even after the entry of the competitor. If the competitor responds aggressively by decreasing the price level then the firm's profit decreases. In the final scenario, firm's profit level is very low due to small profit margins. When these three cases are considered from the competitor's perspective; both initial two scenarios are very profitable. In contrast to the firm, the second response results with the highest profit if the competitor enters the market in the first or second period. In the penetration-matching case, the profit level is low for both firms.

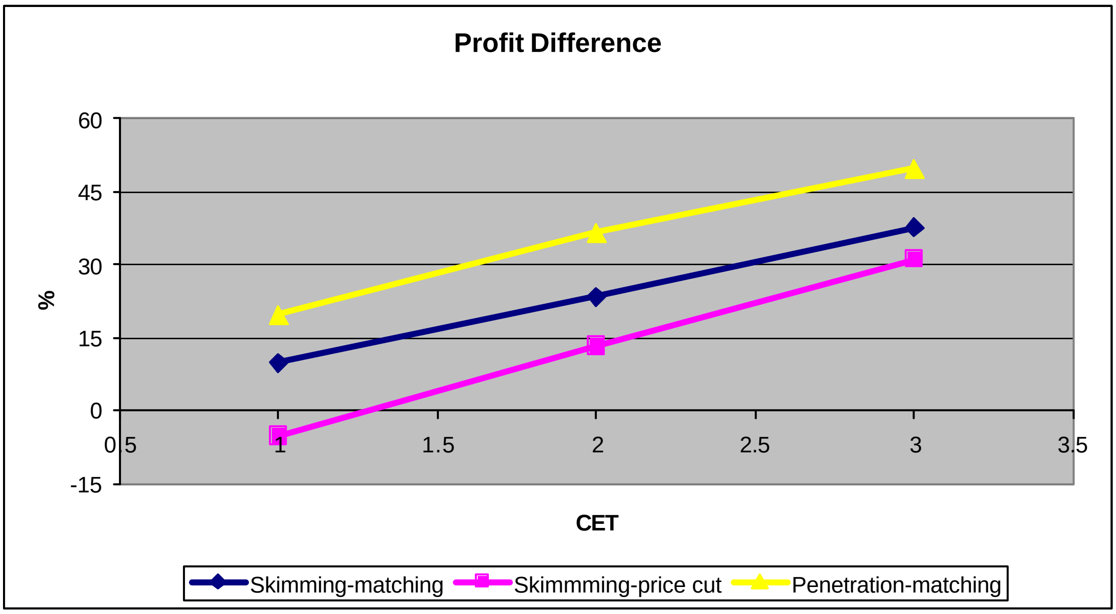

Figure 5-4 Profit difference under three scenarios (segment 2)

To make the inferences clear, firm's market share and profit difference are compared finally. The profit difference observed in penetration-matching scenario has the highest value among the others. In other words, this strategy is the best strategy in order to beat the competitor. However, the trade-off is with the decreasing profit levels. Skimming-price cut is another extreme in terms of profit ratio. In this case the competitor has the advantage, while still keeping the profit levels high. These conclusions are also supported by the firm's market share data (Figure 5-5).

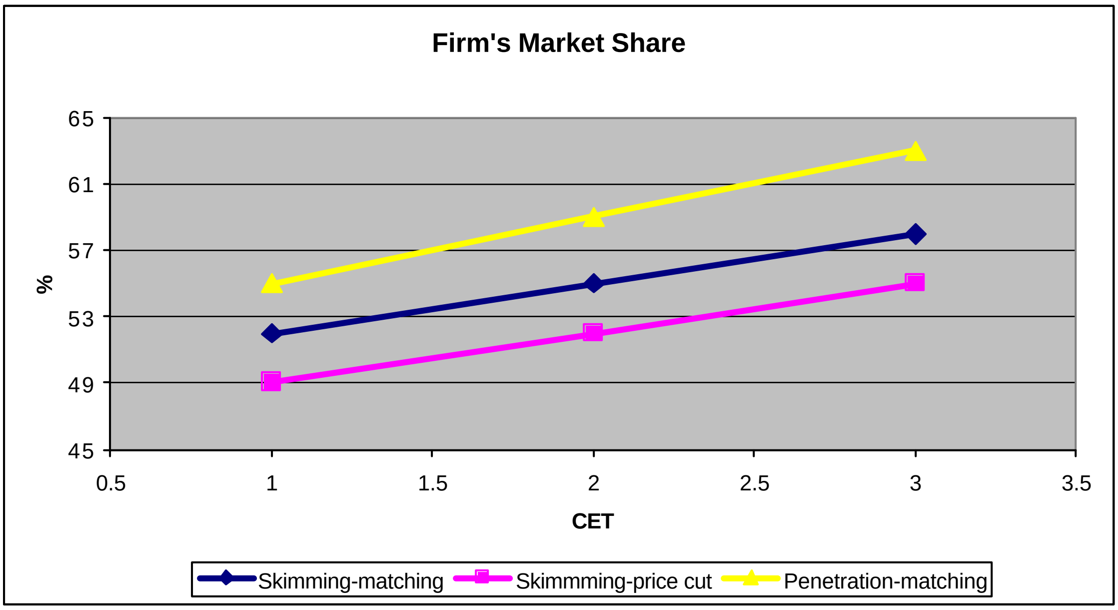

Figure 5-5 Firm's market share under three scenarios (segment 2)

In order to validate these results, testing them with a different segment would be appropriate in order to confirm. Therefore, in the next section the same design is applied to segment 3 and the results are discussed.

5.1.2. Pricing Scenarios for Segment 3

In skimming – matching scenario for segment 3, the initial price of the firm is set as 1800 and the competitor's price is defined dependent on this value and the rest of the parameters are kept the same.

Table 5-4 Results for skimming-matching case (segment 3)

Metrics / CET (year)	Firm's profit (1) (million $)	Competitor's profit (2) (million $)	Profit ratio ((1-2)/1) (%)	Firm's market share (%)
1	153,142.32	134,455.59	12.20	52.00
2	161,017.31	116,784.64	27.47	55.00
3	170,139.03	97,241.10	97.21	59.00

In the second scenario the firm's price is kept at 1800 and the competitor cuts this price approximately by 15 %.

Table 5-5 Results for skimming-price cut case (segment 2)

Metrics CET (year)	Firm's profit (1) (million $)	Competitor's profit (2) (million $)	Profit ratio ((1-2)/1) (%)	Firm's market share (%)
1	125,899.16	128,417.29	-2.00	49.00
2	129,775.60	103,584.30	20.18	52.00
3	138,313.30	81,422.95	41.13	57.00

In the final scenario, the firm set the price at a lower level (1300) and the competitor matches the price.

Table 5-6 Results for penetration-matching case (segment 2)

Metrics CET (year)	Firm's profit (1) (million $)	Competitor's profit (2) (million $)	Profit ratio ((1-2)/1) (%)	Firm's market share (%)
1	49,094.41	28,530.98	41.88	63.00
2	57,308.28	18,810.06	67.17	74.00
3	63,023.53	11,794.05	81.28	82.00

For market segment 3, firm's profit, competitor's profit, profit difference (%) and firm's market share are illustrated in Table 5-4 through Table 5-6 and in Figure 5-6 through Figure 5-9.

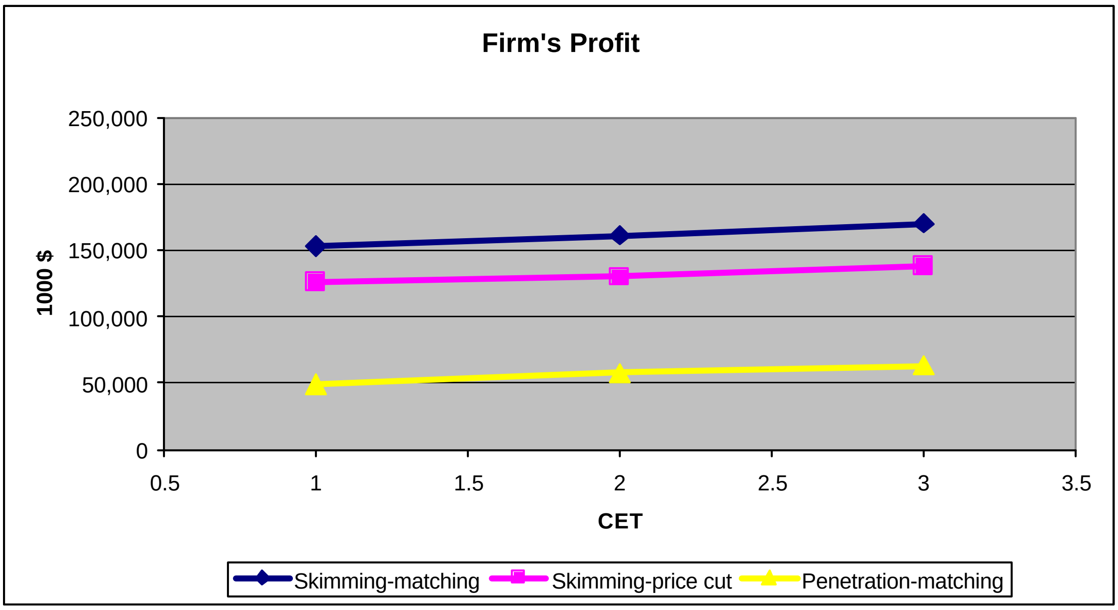

Figure 5-6 Firm's profit under three scenarios (segment 3)

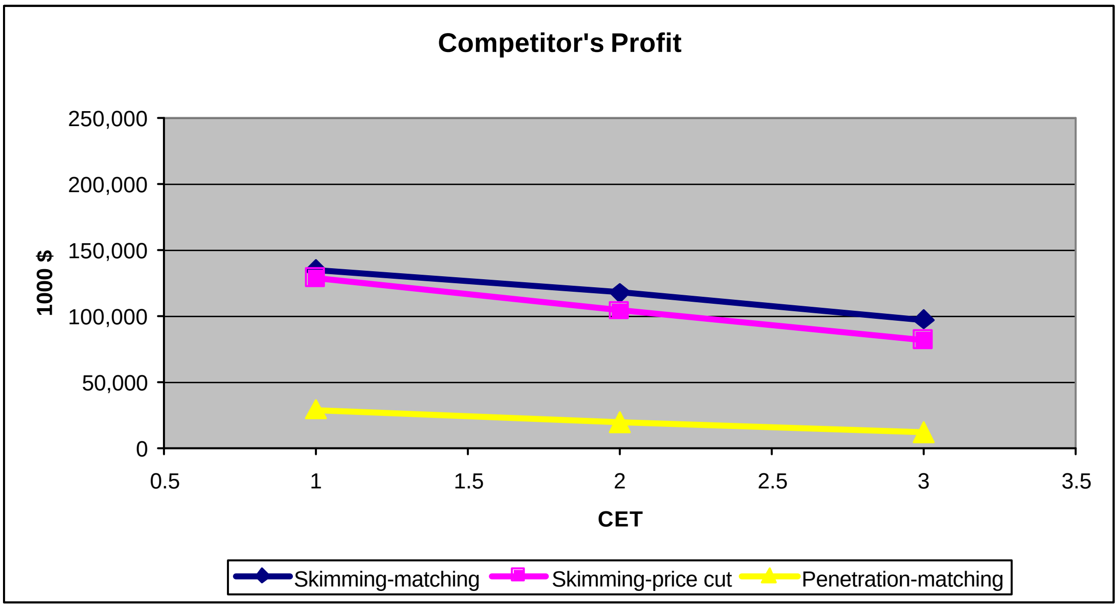

Figure 5-7 Competitor's profit under three scenarios (segment 3)

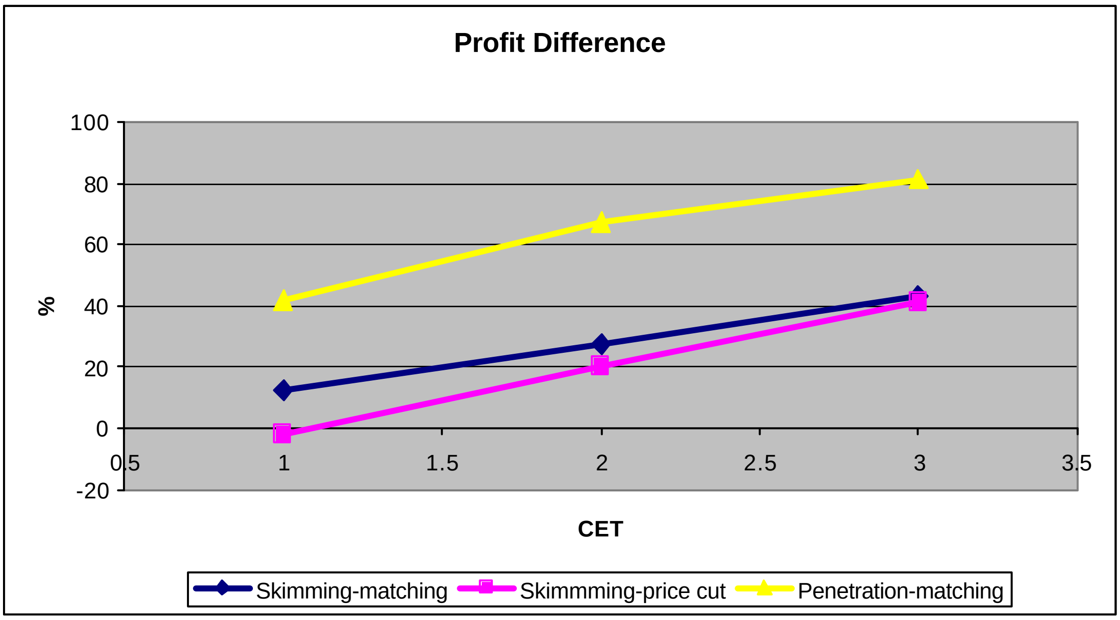

Figure 5-8 Profit difference under three scenarios (segment 3)

Based on the results for segment 2 and 3, it can be said that profit levels for case 1 and 2 are higher compared to that of case 3. This means skimming strategy brings a profit advantage to both of the firms. If the competitor responds aggressively, this leads to a little decrease in the profit level. On the other hand, this leads to an increase in the competitor's market share and profit. Finally, case 3, penetration pricing serves the purpose of reaching a large installed base and having a lower cost. This strategy results in lower costs and higher market share compared to the other two cases.

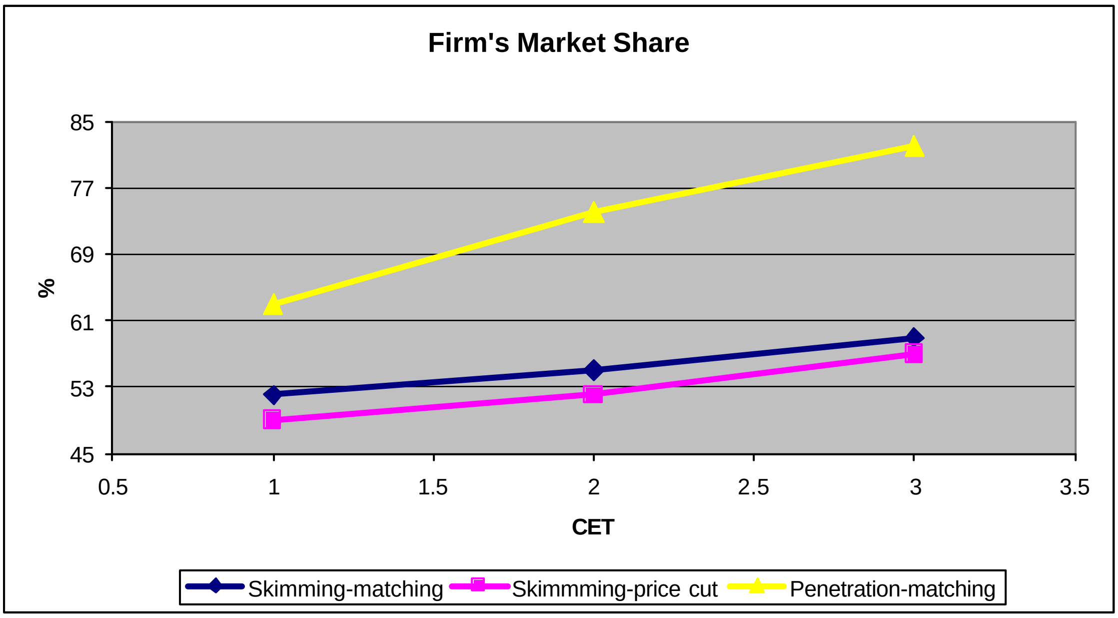

Figure 5-9 Firm’s market share under three scenarios (segment 3)

5.2. Product Launch Analysis in Monopoly and Duopoly Market Cases

In the second group of scenarios the new product launching strategies are discussed under different pricing strategies and different market structures (monopoly and duopoly). The scenarios are repeated for seven different launching times for the second product (at times 0, 2, 4, 6, 8, 10 and 50). Note that period 50 means not launching the product. In duopoly six different entry times for the competitor are also considered (0, 2, 4, 6, 8, and 10). These scenarios are run under three different pricing strategies. These pricing strategies are: (1) skimming, (2) skimming but the firm and the competitor (if present) make a discount for their first products by increasing cost sensitivity parameter after the launching of the second product and (3) penetration pricing. Each design is replicated for other group of segments in order to check the reliability of the scenarios. In the first group, the firm’s first product is launched to the second segment and second product is launched to the third segment, whereas in the latter one, the first product is launched to the third segment and the next product is launched to the fourth segment. This section is concluded with the comparison of the results under these two different segment combinations.

In each scenario total profit at the end of 12 years is calculated and used as the performance metric. The scenarios are also run for 24 years. However, since there was not a significant difference is observed, 12 years is preferred as the time horizon.

For each scenario group a label is defined that represents parameters. Table 5-7 illustrates an empty label.

Table 5-7 Empty label and definition box

Scenario ID:……			
Competitor		**Firm**	
CET:		*FET:*	
Segment:		Segment:	
Price:		Price:	
SPC:		SPC:	
SPCP:		SPCP:	
CET_2:		*FET_2:*	
Segment:		Segment:	
Price:		Price:	
SPC:		SPC:	
SPCP:		SPCP:	

FET(CET): Firm's (Competitor's) entry time.

FET_2 (CET_2): Firm's (Competitor's) second product's launch time.

SPC: Sensitivity of the price to the cost.

SPCP: Sensitivity of the price to the competitor's price.

Segment: Represents the market segment that the product is launched for.

Each scenario has an ID that defines the segment combination, environment and the pricing strategy. The first entity represents the segment combination (if 1 then 2&3, if 2 then 3&4). The second entity stands for the environment; monopoly or duopoly. Finally the third entity symbolizes the pricing strategy (can be S1, S2, or S3). For example, 1-DS3 means, in duopoly, the products are launched to segments 2 and 3, and the third pricing strategy is used.

5.2.1. Analysis in Monopoly

The three pricing strategies are applied in sequence and replicated for the second segment groups. First, the segments 2 and 3, then 3 and 4 are represented.

5.2.1.1. Analysis in Monopoly for the First Group of Segments

The results for the skimming pricing (without a discount) are illustrated with Table 5-8 and Figure 5-10.

Table 5-8 1-MS1 results

Scenario ID: 1-MS1					
Competitor		**Firm**		**FET_2**	**Firm's Profit**
CET:	50	*FET:*	0	0	292,665
Segment:		Segment:	2	2	286,599
Price:		Price:	800	4	258,839
SPC:		SPC:	0.02	6	242,494
SPCP:		SPCP:	-	8	240,534
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50	10	236,201
Segment:		Segment:	3	50	239,557
Price:		Price:	1800		
SPC:		SPC:	0.02		

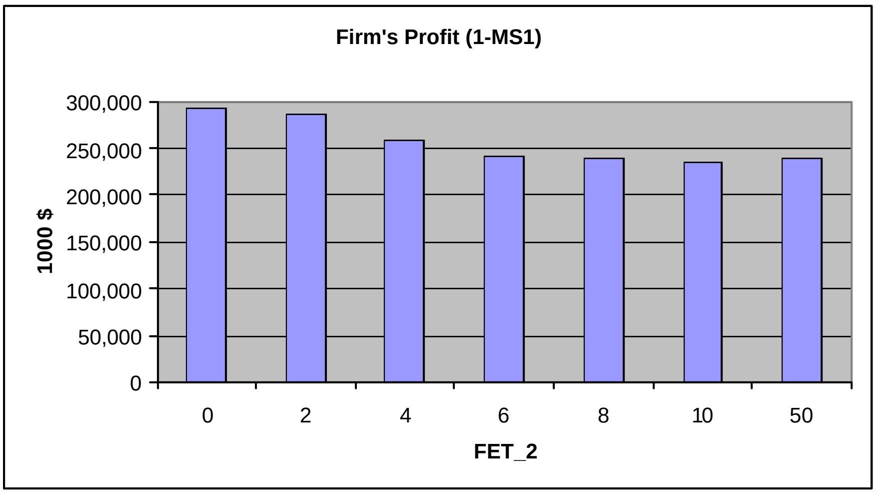

Figure 5-10 Firm's profit in 1-MS1

In this pricing strategy there is no pressure on the profit margin; in other words, the profit margin is high and is not affected from the entry of the new product (*FET_2*). Therefore, the best policy depends on the settings of the segments (segment size and profit margin). Under the first segment group, launching the second product seems as the best strategy. Postponing the launch time results with a decrease as can be seen from Figure 5-10. The underlying reason is the higher profit margin of the second product.

When the skimming strategy with a discount (with the entry of the second product) is used, the increase in the *FET_2*, first leads to a decrease then to an increase as illustrated in Figure 5-11 and Table 5-9. The firm should decide whether to launch the second product immediately or to postpone the launch. A simultaneous entry is advantageous, because the sales volume of the first product is high due to the decreased price and the profit margin of the second product is very high and the firm uses the advantage of this high margin during 12 years. However, if the second product enters to market in years 2, 4, or 6, the duration during which the firm uses the advantage of third segment's higher profit margin decreases. Furthermore, the first product's installed base does not reach a high level due to the high price. In that situation, the firm neither has the advantage of skimming strategy in a more profitable segment nor the high volume installed base that creates a high word of mouth effect. On the other hand, launching the second product at a late time becomes advantageous due to very high installed base in a very large segment. Note that the second product's entry decreases the size of segment 2 by 37.5 %. Since the second product's launch is postponed the segment keeps its beginning size. In this situation the firm may not be able to use the advantage of a high margin but instead has the advantage of a large and stable installed base. In summary, in one extreme the firm uses the advantage of high profit at a longer time, whereas in the other extreme the firm uses the advantage of a high installed base.

Table 5-9 1-MS2 results

Scenario ID: 1-MS2			
Competitor		**Firm**	
CET:	50	*FET:*	0
Segment:		Segment:	2
Price:		Price:	800
SPC:		SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	

FET_2	**Firm's Profit**
0	203,279
2	144,816
4	121,320
6	110,771
8	127,527
10	170,981
50	239,557

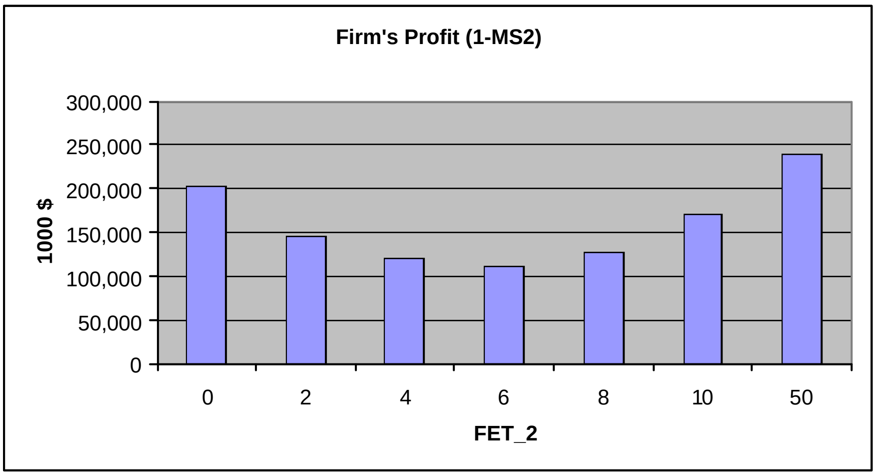

Figure 5-11 Firm's profit in 1-MS2

Table 5-10 1-MS3 results

Scenario ID:1-MS3			
Competitor		Firm	
CET:	50	*FET:*	0
Segment:		Segment:	2
Price:		Price:	700
SPC:		SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0, 2, 4, 6, 8, 10, 50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02

FET_2	Firm's Profit
0	201,688
2	150,992
4	122,192
6	92,644
8	73,977
10	57,223
50	55,444

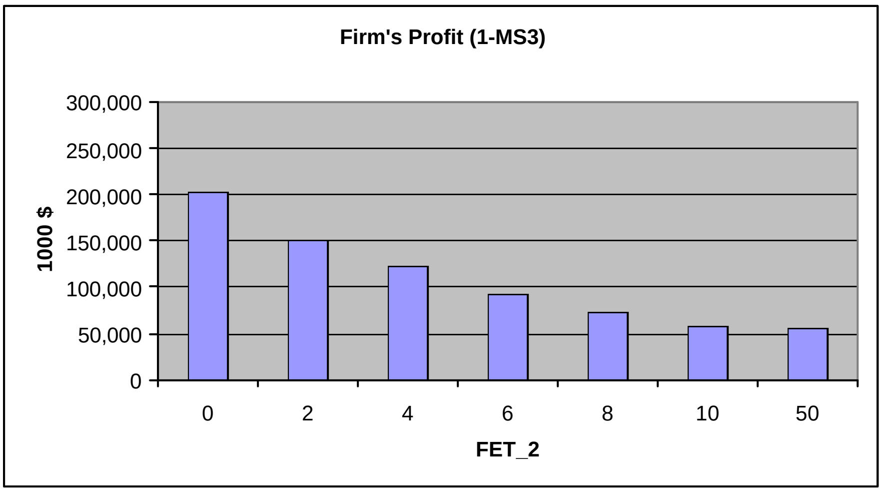

Figure 5-12 Firm's profit in 1-MS3

If the firm uses a penetration strategy, the best policy is launching the second product immediately since the high profit margin of the new product increases the firm's total profit. This is also supported by Figure 5-12 and Table 5-10.

5.2.1.2. Analysis in Monopoly for the Second Group of Segments

In the skimming price strategy the firm's first product's profit margin is kept at a high level. However, since the market size of segment four is very low, launching a product to that segment by allocating the capacity becomes a bad policy although the profit margin is higher. In summary, the best policy is to postpone the new launch and concentrate on the initial segment. Table 5-11 and Figure 5-13 display the results.

Table 5-11 2-MS1 results

Scenario ID: 2-MS1			
Competitor		**Firm**	
CET:	50	*FET:*	0
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Profit
0	382,919
2	371,145
4	365,237
6	376,687
8	407,593
10	455,634
50	476,020

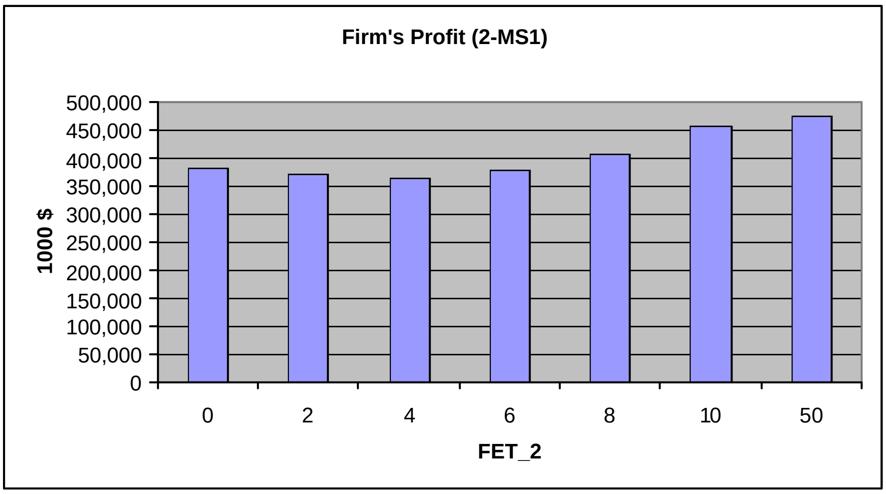

Figure 5-13 Firm's profit in 2-MS1

If the firm makes a discount with the entry of the new product, the firm's profit first decreases and then increases as the second product's entry time increases (Figure 5-14 and Table 5-12). The reason behind this is the same as in 1-MS2. In summary, the firm should launch the product in period zero or postpone the launch.

Table 5-12 2-MS2 Results

Scenario ID: 2-MS2			
Competitor		**Firm**	
CET:	50	*FET:*	0
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Profit**
0	210,328
2	187,922
4	174,435
6	182,121
8	225,503
10	313,545
50	476,020

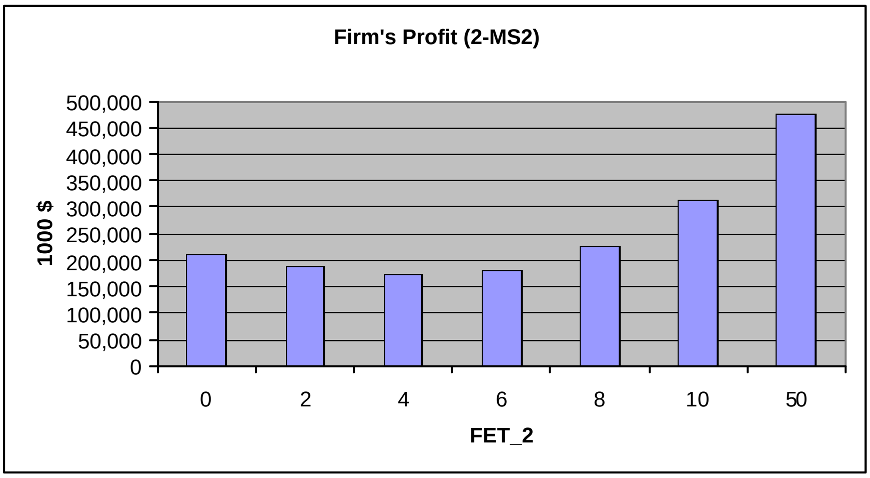

Figure 5-14 Firm's profit in 2-MS2

In the penetration strategy, launching the second product as early as possible is the best policy as supported by Figure 5-15 and Table 5-13. As mentioned in the previous group of segments, the high profit margin of the second products leads to an increase in the profit level.

Table 5-13 2-MS3 results

Scenario ID: 2-MS3			
Competitor		**Firm**	
CET:	50	*FET:*	0
Segment:		Segment:	3
Price:		Price:	1300
SPC:		SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Profit
0	212,609
2	188,370
4	167,611
6	148,558
8	134,605
10	124,039
50	120,716

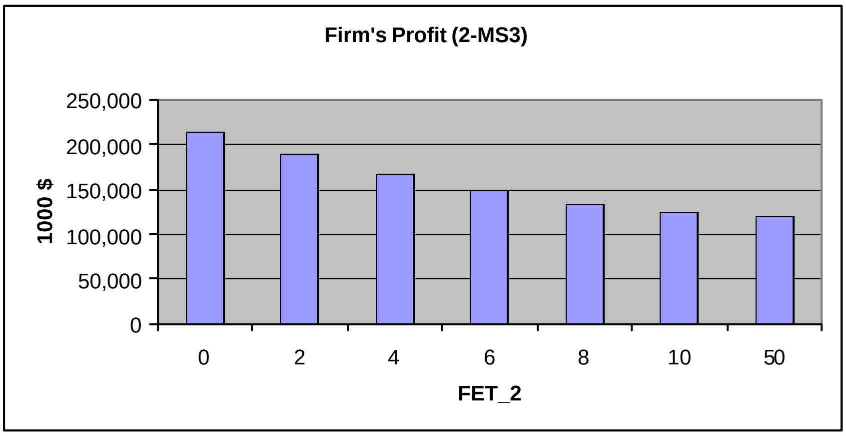

Figure 5-15 Firm's profit in 2-MS3

After explaining the results for two different segment combinations separately, comparing the results would be appropriate. The results observed for the skimming and a discount pricing strategy and the penetration pricing strategy follows the same trend. In the second (skimming-discount) strategy, in both cases, an early launch or a late launch is observed as the best policies. In the penetration, launching the second product as early as possible becomes the best strategy. However, for the second strategy the best policies do not match. In the first group the best policy is launching the product whereas in the second group the best policy is not launching the product immediately. The underlying reason is the high dependency to the segment parameters. This strategy is highly dependent on the market size and segment profitability because the profit margin is never forced to decrease to the cost level. Also note that there is no effect of the competitor. In summary, launching the second product becomes a good strategy for the first segment groups, since the profit margin is high (Figure 5-10). In contrast, postponing becomes a good strategy for the second group, since the profit reaches a relatively high level all contributed by segment 3 with no contribution of segment 4 (Figure 5-13).

5.2.2. Analysis in Duopoly

The three pricing strategies are applied in sequence and replicated for the second segment groups. Recall that the strategies are also replicated for different entry times of the competitor (*CET*). In this section the 3-D graphs that also illustrate the competitor's different entry times are provided both for the firm and the competitor.

5.2.2.1. Analysis in Duopoly for the First Group of Segments

The results for the first group of segments with the skimming price strategy are illustrated both with a table (Table 5-14) and 3-D graphs (Figure 5-16 and Figure 5-17).

From the firm's perspective, launching the second product is a profitable policy. As the competitor enters the market late the profit level of the firm increases. However, there may become some small fluctuations in the profit level. The reasons behind these fluctuations are the competitor's short-term effect on the firm's delivery delay, market segment parameters and installed base volume. Note that these fluctuations are very small and therefore negligible.

From the competitor's perspective, competitor's profit is decreasing as it enters the market later. The effect of firm's second product is more complex. As the firm introduces its second product at a later time this brings an advantage to the competitor. But, there is a sudden increase in the competitor's profit from period 0 (when the firm's second product enters in period 0) to 1 (when the firm's second product enters in period 0). Even if the competitor is not present in period 0 or 1, this difference is still valid. In Figure 5-17, this sudden increase can be seen from the left part of the surface.

If the competitor is not present in period 0, then why is it affected from the firm's earlier policy? The answer of this question is the stability of the environment. If the firm launches its second product simultaneously with the first product, then the firm would enter a stable environment. The market size would not differentiate at a later time with the entry of the second product. The market would reach its final composition at the beginning. In this situation the firm would not lose a part of its installed base and would not spend money for the people who will switch in the next periods. However, if the firm launches the second product in the first period, then it would lose a part of its installed base. In other words, it would lose a part of its competitive power. Therefore, this would increase the competitor's competitive power whenever it enters the market. Of course the effect would be higher in the earlier periods. The difference is less if the competitor enters in period 10, but it still exists. We define this situation as the start-up problem. Another issue is about the firm. Firm is not much affected from this situation, because in either case it will win by introducing a new product to a more profitable segment. In some situations the firm may increase its profit by launching in later periods. This a different start up problem that is based on segment parameters (as in 2-DS1).

Table 5-14 1-DS1 results

Scenario ID: 1-DS1			
Competitor		**Firm**	
CET:	0	*FET:*	0
Segment:	2	Segment:	2
Price:	800	Price:	800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp. Pr.**
0	284,046	100,284
2	280,288	166,516
4	240,154	164,183
6	211,539	167,220
8	197,060	175,992
10	194,365	189,399
50	203,626	203,626

Scenario ID:1-DS1			
Competitor		**Firm**	
CET:	2	*FET:*	0
Segment:	2	Segment:	2
Price:	750	Price:	800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp. Pr.**
0	288,039	82,622
2	283,747	141,574
4	246,513	137,003
6	221,030	136,660
8	208,113	142,928
10	206,830	154,399
50	217,874	167,260

Scenario ID: 1-DS1			
Competitor		**Firm**	
CET:	4	*FET:*	0
Segment:	2	Segment:	2
Price:	710	Price:	800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	293,260	57,070
2	288,401	99,628
4	252,798	99,830
6	232,960	95,098
8	224,637	96,713
10	225,728	104,707
50	233,559	115,375

Scenario ID: 1-DS1			
Competitor		**Firm**	
CET:	6	*FET:*	0
Segment:	2	Segment:	2
Price:	672	Price:	800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	293,862	31,918
2	288,824	57,646
4	258,640	57,488
6	240,468	56,719
8	237,812	53,194
10	240,443	57,066
50	240,553	65,180

Scenario ID: 1-DS1			
Competitor		**Firm**	
CET:	8	*FET:*	0
Segment:	2	Segment:	2
Price:	640	Price:	800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	294,206	12,632
2	287,596	24,596
4	261,132	24,225
6	244,777	23,591
8	241,780	22,437
10	240,408	22,493
50	240,483	26,980

Scenario ID: 1-DS1			
Competitor		**Firm**	
CET:	10	*FET:*	0
Segment:	2	Segment:	2
Price:	610	Price:	800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	292,843	1,448
2	286,916	4,578
4	259,451	4,283
6	243,228	3,971
8	241,342	3,537
10	240,085	3,601
50	239,916	4,942

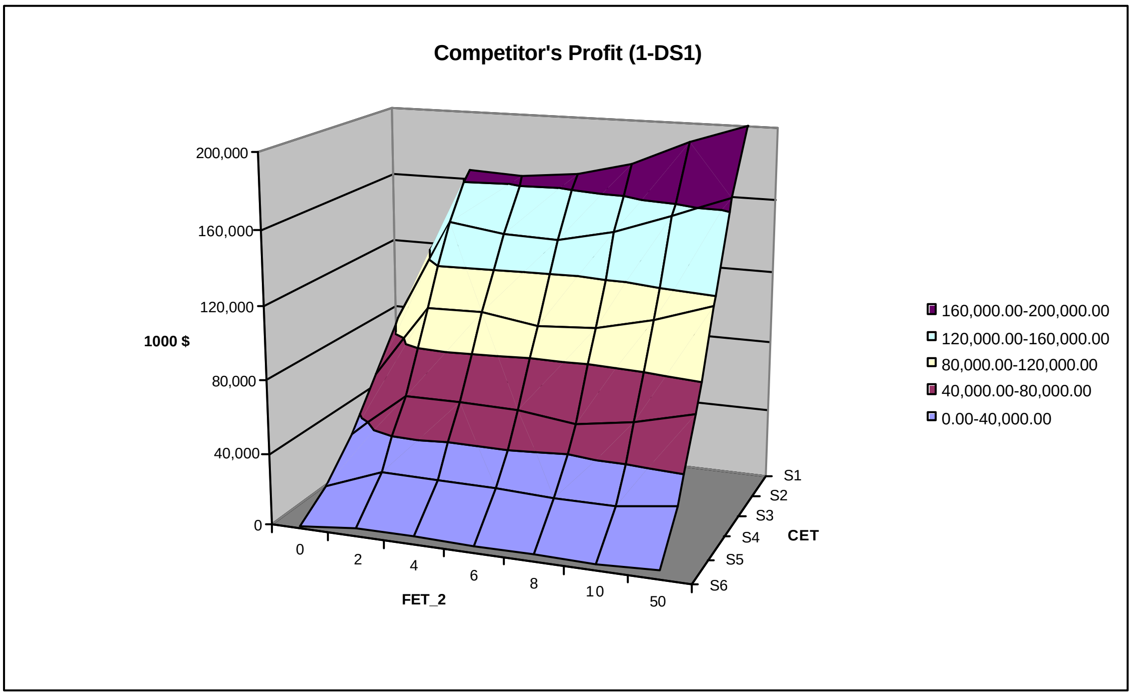

Figure 5-16 Firm's profit in 1-DS1

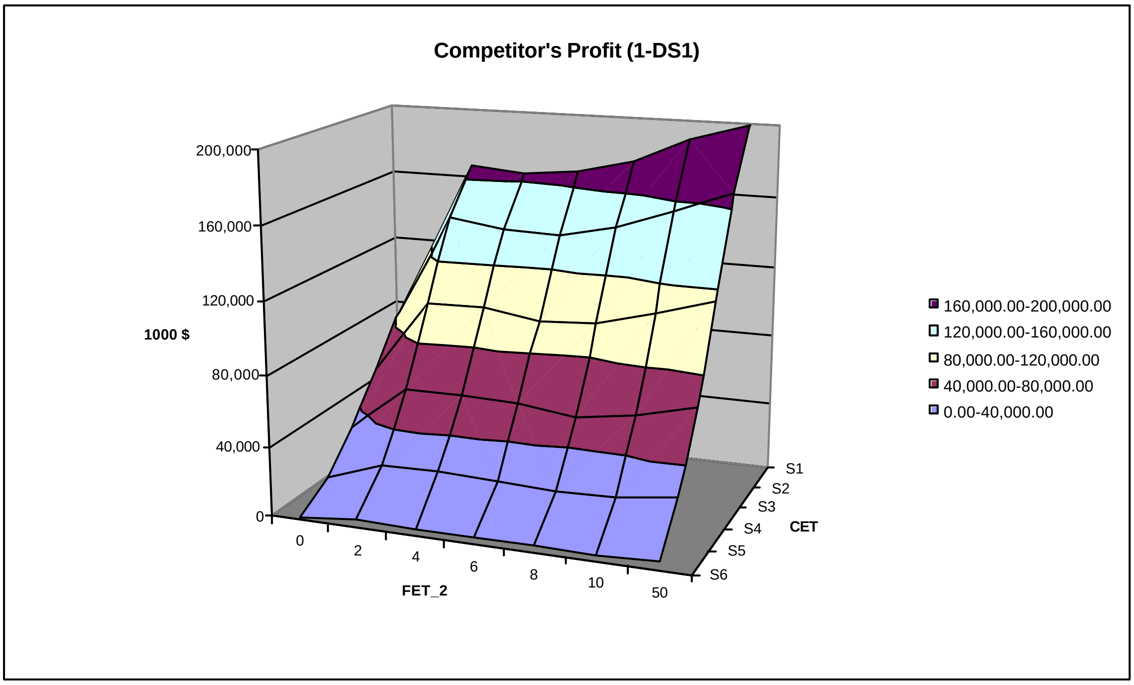

Figure 5-17 Competitor's profit in 1-DS1

In this scenario, the firm and the competitor use the skimming strategy, and the firm makes a discount just before the second product and the competitor makes a discount just after the second product by increasing the cost sensitivity parameters. Results are displayed in Table 5-15.

From the firm's perspective, as the competitor enters the market late the firm's profit first increases and then decreases. Up to 6th period the late entry will provide an advantage, however after this, it becomes a disadvantage. Because, in these time periods, presence of the competitor decreases the delivery delay effect of the firm, and the firm's demand increases. Another point is the launch of the second product. It is similar to that of in monopoly. The firm should either launch it in the early periods or later periods (Figure 5-18).

On the competitor's side, there is again a start up problem but it is smoother than that of the skimming price strategy scenario, because the profit margins are getting smaller and building a large installed base is easier. Also, as expected, the late entry of the competitor and the early launch of the firm's second product lead to a decrease in the competitor's profit (Figure 5-19).

Table 5-15 1-DS2 Results

Scenario ID:1-DS2			
Competitor		**Firm**	
CET:	0	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp. Pr.**
0	212,873	26,661
2	170,260	45,898
4	129,726	55,717
6	116,043	74,429
8	122,289	106,462
10	148,638	149,947
50	203,626	203,626

Scenario ID:1-DS2			
Competitor		**Firm**	
CET:	2	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	238,035	14,682
2	169,213	35,899
4	131,539	42,187
6	117,094	56,002
8	124,651	81,646
10	155,584	118,869
50	218,077	167,547

Scenario ID:1-DS2			
Competitor		**Firm**	
CET:	4	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	241,853	7,388
2	177,784	22,018
4	136,074	27,399
6	121,693	33,140
8	133,675	49,099
10	167,455	76,137
50	235,216	115,996

Scenario ID:1-DS2			
Competitor		**Firm**	
CET:	6	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	221,163	2,735
2	168,411	11,364
4	143,870	13,811
6	130,756	16,386
8	144,364	21,234
10	179,084	37,031
50	244,811	65,903

Scenario ID:1-DS2			
Competitor		**Firm**	
CET:	8	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	220,895	-90
2	166,617	4,020
4	145,674	4,939
6	132,008	5,803
8	149,261	6,837
10	186,034	10,379
50	241,982	27,446

Scenario ID:1-DS2			
Competitor		**Firm**	
CET:	10	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	213,946	-1,922
2	157,907	-571
4	134,752	-444
6	125,575	-277
8	141,597	-13
10	186,374	133
50	240,080	5,041

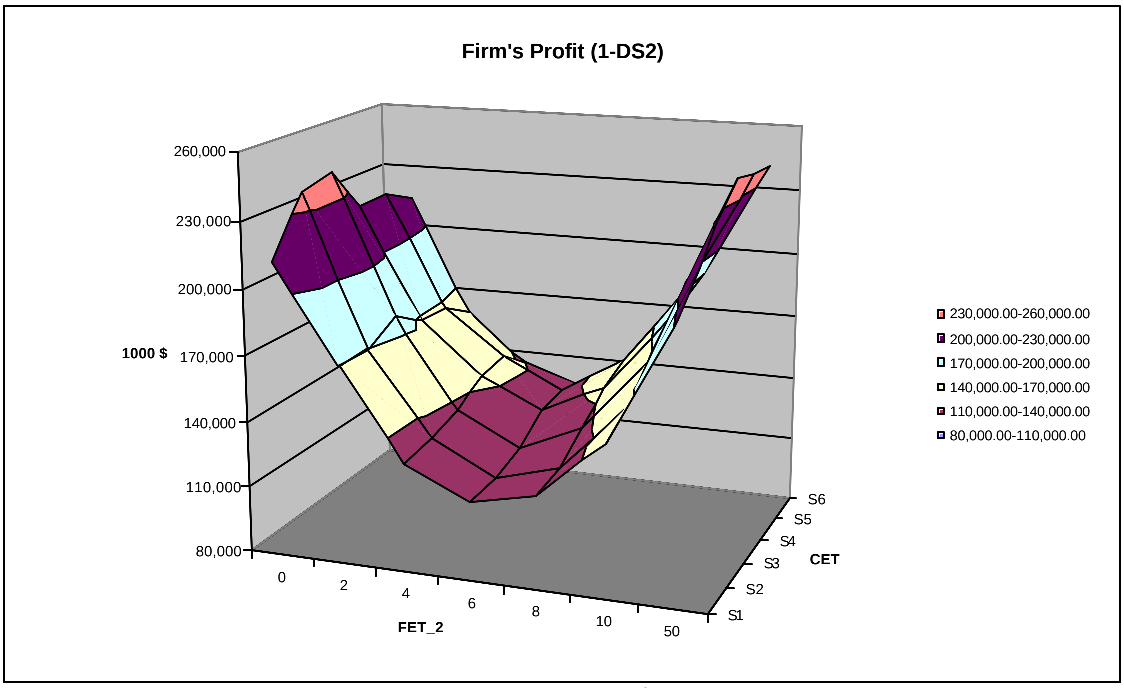

Figure 5-18 Firm's profit in 1-DS2

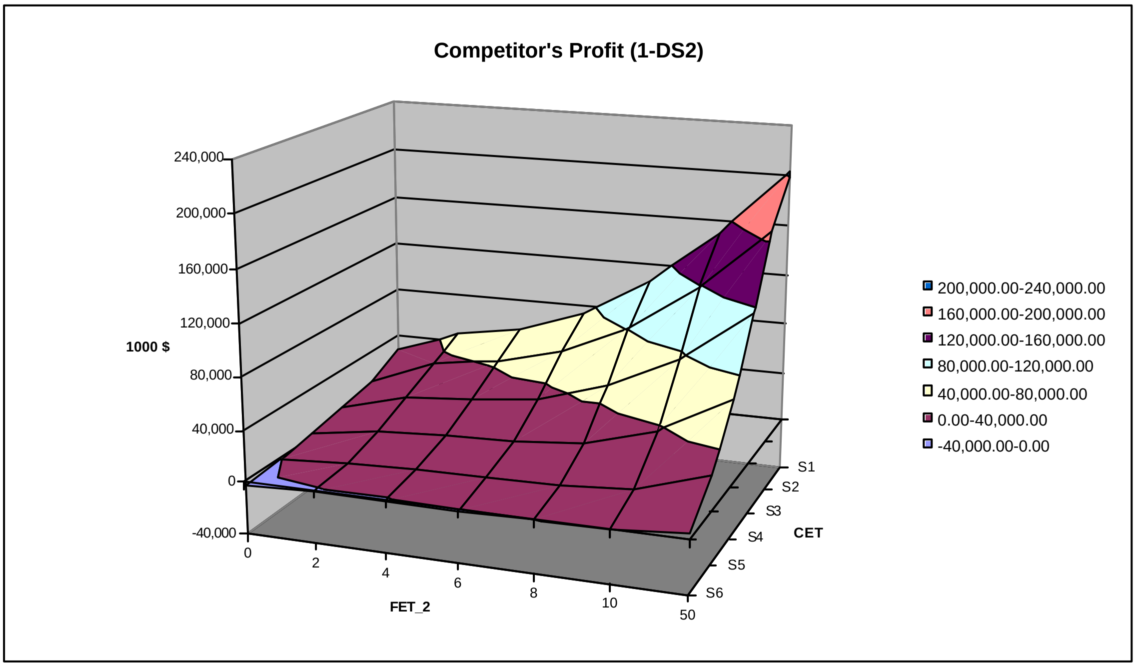

Figure 5-19 Competitor's profit in 1-DS2

In the penetration strategy, the firm's and the competitor's profit levels are low as can be seen from Table 5-16. From the firm's perspective, as the competitor enters the market late the firm's profit first increases and then decreases similar to the previous scenario. The early launch of the second product brings a great profit advantage to the firm (Figure 5-20).

There is again a start up problem for the competitor. But in this case it is not smooth as in the previous case. The prices are still low and it is also easy to build a high volume installed base. However, the number of people who would switch will increase. This leads to a sharp start up problem in this case. Note that after the start up problem the competitor's profit level is not affected much from the entrance time of the second product. The underlying reason is the large number of potential customers due to the low price levels. Finally, the competitor's profit decreases as its entrance time increases (Figure 5-21).

Table 5-16 Results in 1-DS3

Scenario ID: 1-DS3			
Competitor		**Firm**	
CET:	0	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	700
SPC:	0.5	SPC:	0.5
SPCP:	0.02	SPCP:	0.02
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp Pr.**
0	212,398	26,861
2	162,002	41,362
4	115,578	40,491
6	84,405	40,971
8	63,547	42,577
10	49,468	44,440
50	45,795	45,795

Scenario ID: 1-DS3			
Competitor		**Firm**	
CET:	2	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	700
SPC:	0.5	SPC:	0.5
SPCP:	0.02	SPCP:	0.02
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp Pr.**
0	219,653	14,000
2	166,297	30,993
4	123,732	27,092
6	93,289	27,134
8	69,881	29,455
10	54,533	31,575
50	51,796	32,880

Scenario ID: 1-DS3			
Competitor		**Firm**	
CET:	4	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	700
SPC:	0.5	SPC:	0.5
SPCP:	0.02	SPCP:	0.02
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	217,001	7,198
2	162,574	18,521
4	122,964	17,242
6	92,976	16,751
8	72,547	17,209
10	57,671	18,944
50	53,673	20,607

Scenario ID: 1-DS3			
Competitor		**Firm**	
CET:	6	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	700
SPC:	0.5	SPC:	0.5
SPCP:	0.02	SPCP:	0.02
CET_2:	50	*FET_2:*	0-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	214,521	2,575
2	163,350	9,522
4	121,797	8,074
6	93,904	8,303
8	73,412	8,213
10	58,827	9,116
50	55,163	10,405

Scenario ID: 1-DS3			
Competitor		**Firm**	
CET:	8	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	700
SPC:	0.5	SPC:	0.5
SPCP:	0.02	SPCP:	0.02
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	204,394	-130
2	154,200	3,317
4	122,148	2,466
6	93,564	2,259
8	73,976	2,449
10	58,446	2,829
50	58,444	3,774

Scenario ID: 1-DS3			
Competitor		**Firm**	
CET:	10	*FET:*	0
Segment:	2	Segment:	2
Price:		Price:	700
SPC:	0.5	SPC:	0.5
SPCP:	0.02	SPCP:	0.02
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	3
Price:		Price:	1800
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	201,836	-1,927
2	151,029	-815
4	122,257	-1,084
6	92,710	-1,252
8	74,011	-1,255
10	57,223	-1,115
50	55,444	-666

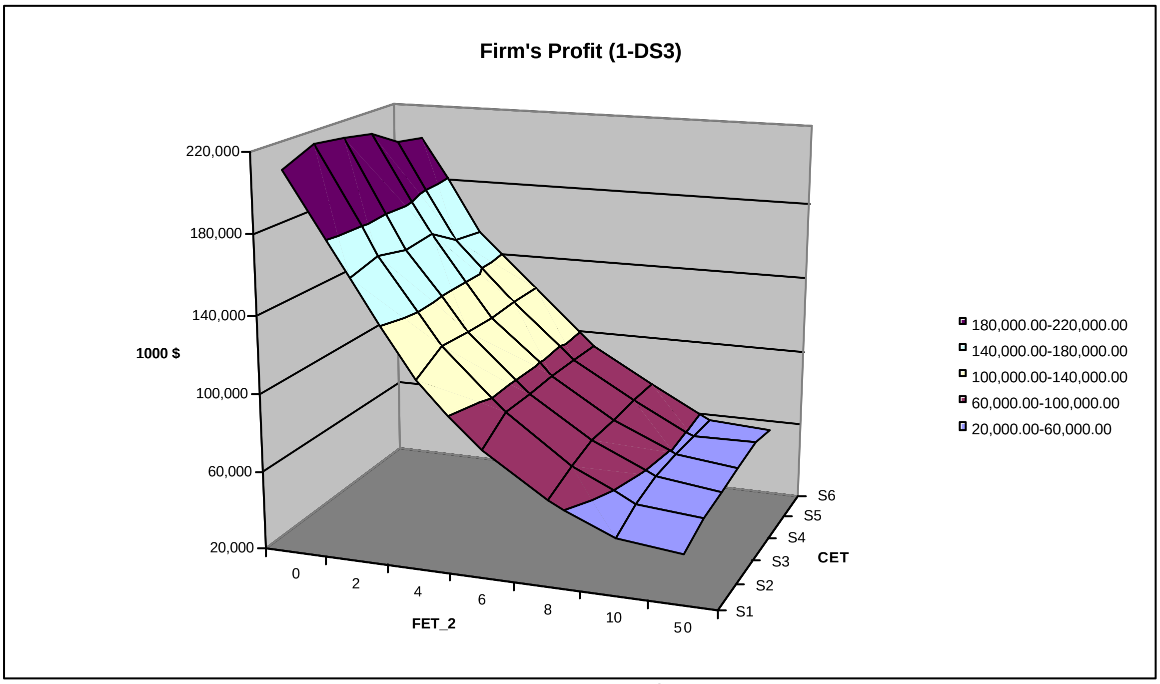

Figure 5-20 Firm's profit in 1-DS3

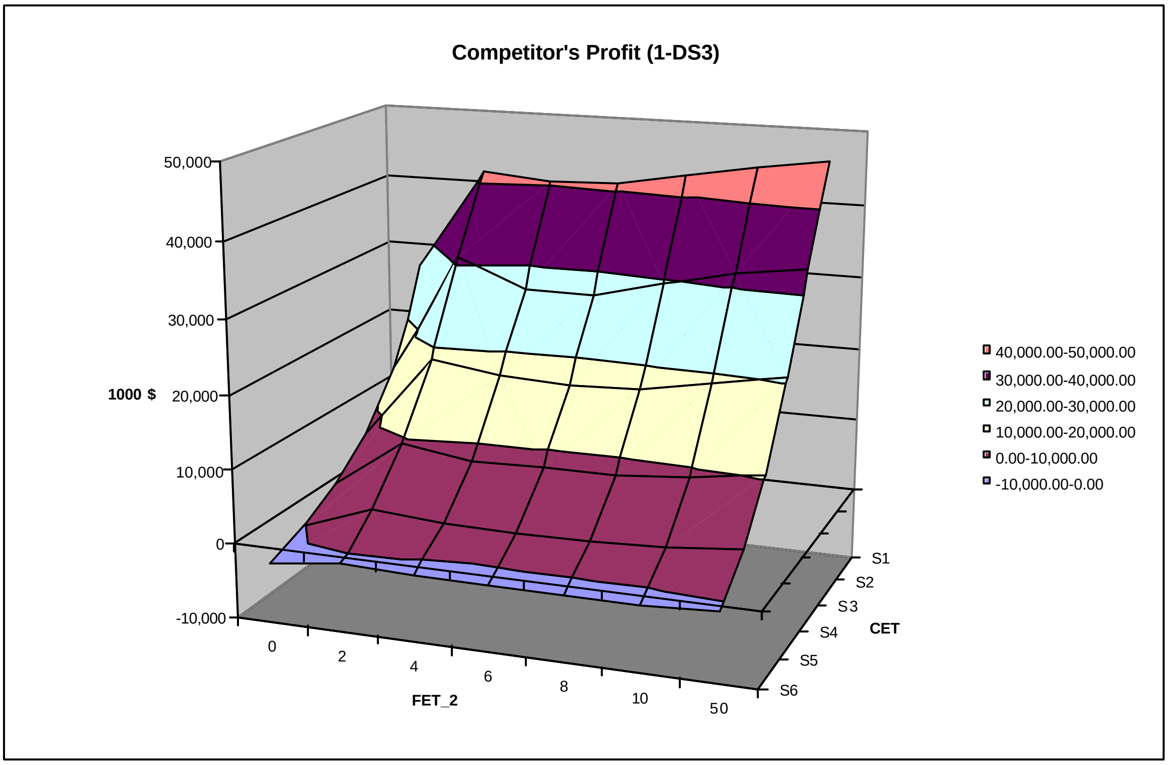

Figure 5-21 Competitor's profit in 1-DS3

5.2.2.2. Analysis in Duopoly for the Second Group of Segments

From the firm's perspective, launching the second product is a profitable policy. As the competitor enters the market late the profit level of the firm increases at the same level as for in the first group of segments. However, there is an apparent start up problem for the firm in this case. The start up problem is different from the other cases. In this case firm's start up problem arises in period 2. In this case, if the firm launches the second product to the market, the profit is maximized (Figure 5-22). Note that the numeric results are represented in Table 5-17.

From the competitor's perspective, the competitor's profit is decreasing as it enters the market later. There is a start up problem similar to the first group of segments. Finally, as in every scenario, late entry results in less profit (Figure 5-23).

Table 5-17 Results in 2-DS1

Scenario ID: 2-DS1			
Competitor		**Firm**	
CET:	0	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp. Pr.**
0	196,748	79,326
2	210,526	121,784
4	181,287	120,943
6	159,123	122,908
8	145,848	128,158
10	141,653	137,379
50	147,578	147,578

Scenario ID: 2-DS1			
Competitor		**Firm**	
CET:	2	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp. Pr.**
0	201,723	63,936
2	218,444	99,492
4	189,400	97,170
6	167,915	97,056
8	155,620	100,499
10	153,030	107,760
50	160,688	116,662

Scenario ID: 2-DS1			
Competitor		**Firm**	
CET:	4	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	209,659	43,875
2	232,290	67,513
4	201,799	68,037
6	181,093	65,567
8	170,676	66,467
10	170,502	70,850
50	180,046	77,364

Scenario ID: 2-DS1			
Competitor		**Firm**	
CET:	6	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	217,917	24,705
2	245,934	37,949
4	215,234	38,212
6	193,328	37,975
8	184,797	36,442
10	187,323	38,292
50	199,474	41,945

Scenario ID: 2-DS1			
Competitor		**Firm**	
CET:	8	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	224,435	10,059
2	256,200	16,005
4	225,336	16,130
6	203,262	15,996
8	194,235	15,464
10	198,676	15,150
50	213,570	17,097

Scenario ID: 2-DS1			
Competitor		**Firm**	
CET:	10	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	0.02	SPC:	0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp. Pr.
0	228,217	994
2	261,649	2,678
4	230,711	2,712
6	208,545	2,668
8	199,441	2,486
10	203,907	2,206
50	220,908	2,772

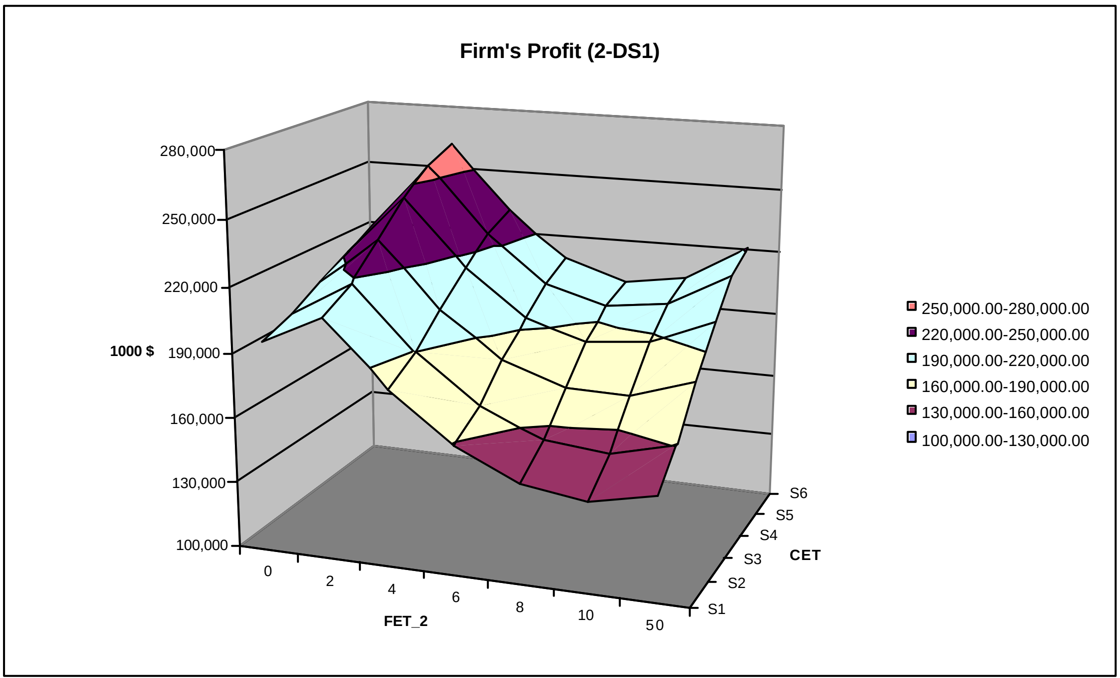

Figure 5-22 Firm's profit in 2-DS1

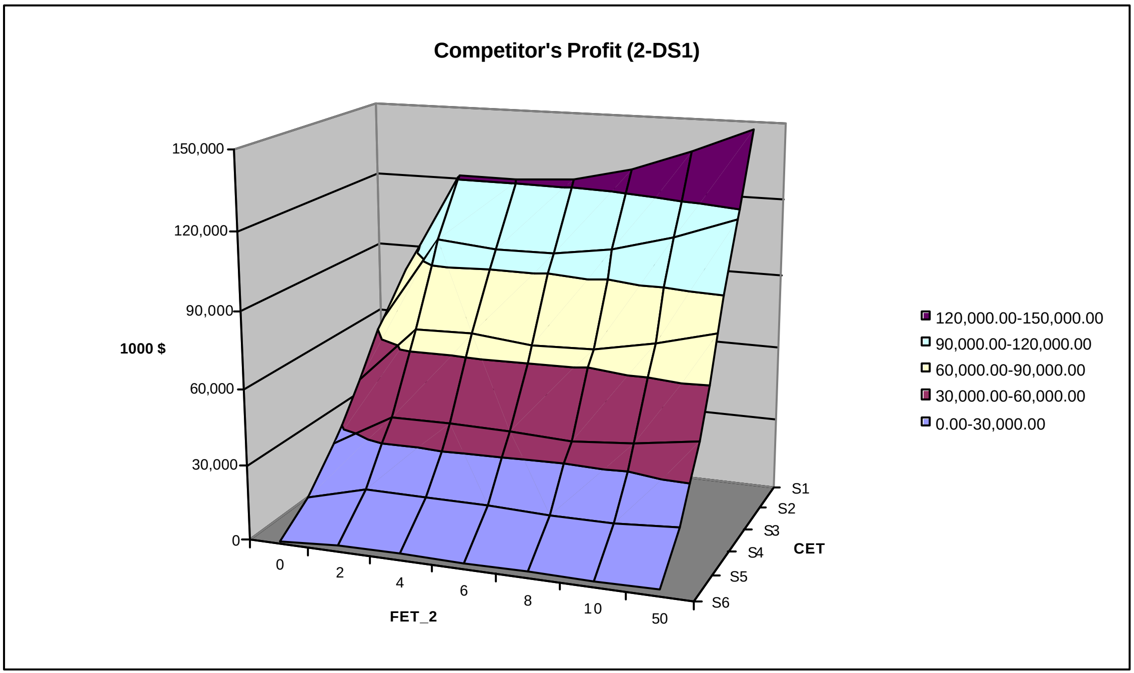

Figure 5-23 Competitor's profit in 2-DS1

In the skimming and discount scenario, as the competitor enters the market late, the firm's profit first increases and then decreases as in the first group of segments as illustrated in Table 5-18 and Figure 5-24. Up to 6th period the late entry will provide an advantage, however, after this point, it becomes a disadvantage for the firm. Because, in these time periods, presence of the competitor decreases the delivery delay effect of the firm, and firm's demand increases. Launching the second product is profitable for the firm in the early periods and in the late ones.

From the competitor's perspective, there is again a start up problem but it is smoother compared to that of the skimming price strategy scenario as can be seen from Figure 5-25. The underlying reasons are stated in 1-DS2. Similar to the other scenarios, the late entry of the competitor and the early launch of the firm's second product lead to a decrease in the competitor's profit.

Table 5-18 Results in 2-DS2

Scenario ID: 2-DS2			
Competitor		**Firm**	
CET:	0	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp. Pr.**
0	142,070	23,877
2	130,062	37,064
4	108,464	47,043
6	97,516	63,397
8	99,366	86,805
10	112,927	116,398
50	147,578	147,578

Scenario ID: 2-DS2			
Competitor		**Firm**	
CET:	2	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	**Firm's Pr.**	**Comp Pr.**
0	150,520	13,061
2	133,731	24,785
4	107,891	34,772
6	97,377	48,523
8	100,556	68,854
10	113,357	90,714
50	138,024	109,151

Scenario ID: 2-DS2			
Competitor		**Firm**	
CET:	4	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	157,226	4,898
2	145,120	10,686
4	116,477	16,965
6	106,555	24,639
8	110,764	38,098
10	131,108	56,062
50	180,067	77,337

Scenario ID: 2-DS2			
Competitor		**Firm**	
CET:	6	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	160,754	607
2	153,198	3,101
4	124,740	6,119
6	109,886	9,301
8	116,279	16,015
10	140,798	27,532
50	199,530	42,124

Scenario ID: 2-DS2			
Competitor		**Firm**	
CET:	8	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	162,536	-1,442
2	158,187	-500
4	131,283	609
6	115,765	1,894
8	117,358	3,143
10	146,356	8,062
50	213,607	17,287

Scenario ID: 2-DS2			
Competitor		**Firm**	
CET:	10	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1800
SPC:	Time >F2-1 Then 0.5 Else 0.02	SPC:	Time >F2-1 Then 0.5 Else 0.02
SPCP:	0.2	SPCP:	0.2
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	163,530	-2,470
2	157,759	-2,204
4	132,916	-1,949
6	118,886	-1,625
8	120,753	-1,295
10	145,661	-997
50	213,312	1,243

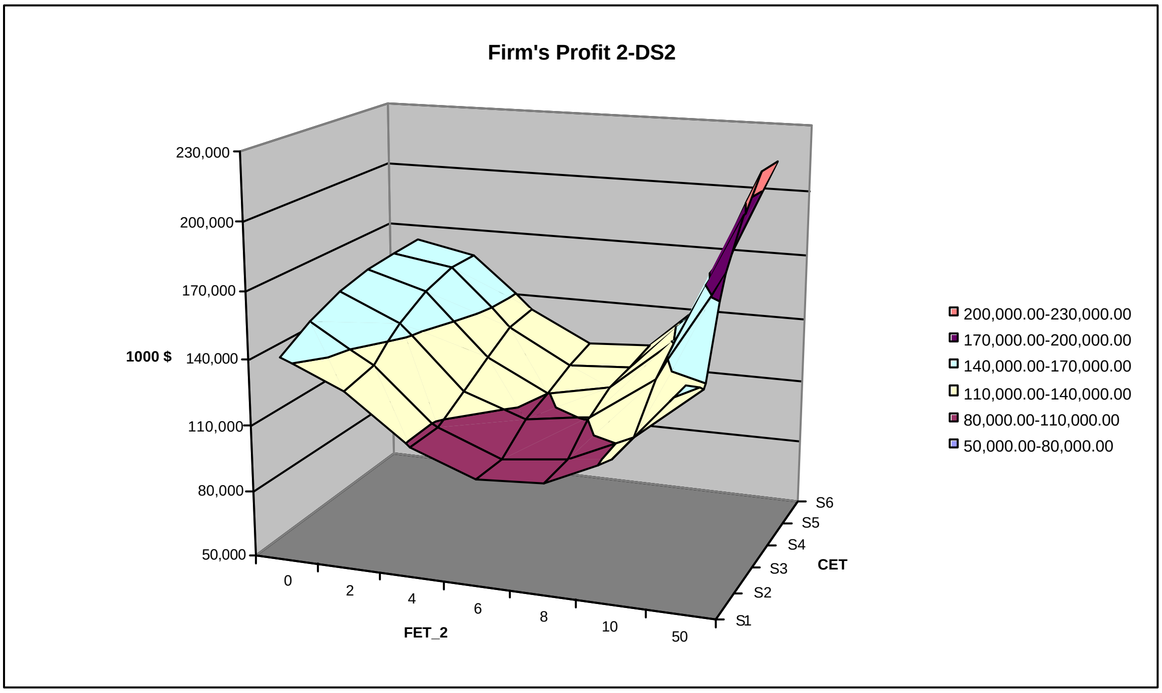

Figure 5-24 Firm's profit in 2-DS2

In the penetration strategy, as the competitor enters the market late, the firm's profit first increases and then decreases. From the competitor's perspective, there is again a major start up problem for the competitor. After the first period the competitor's profit does not fluctuated much. As a final issue, the competitor's profit decreases as it enters later. The results are displayed in Table 5-19 and Figure 5-26 and Figure 5-27.

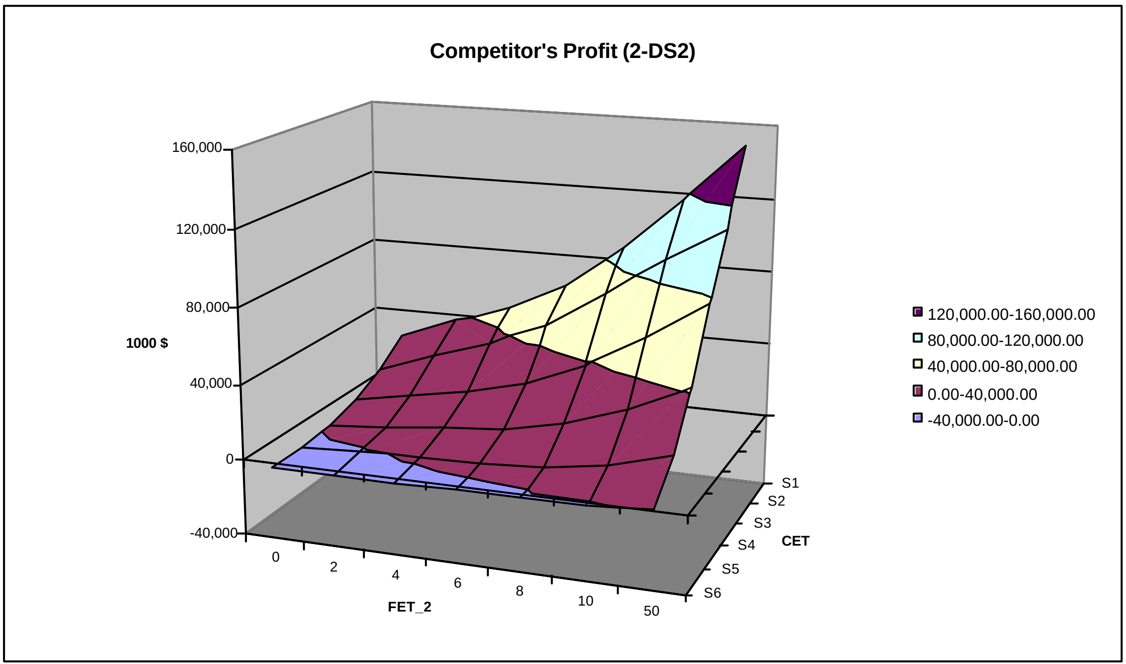

Figure 5-25 Competitor's profit in 2-DS2

Table 5-19 Results in 2-DS3

Scenario ID: 2-DS3			
Competitor		**Firm**	
CET:	0	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1300
SPC:	0.5	SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	141,686	24,265
2	123,695	35,365
4	94,859	34,975
6	71,462	35,443
8	54,387	36,737
10	42,557	38,286
50	39,627	39,627

Scenario ID: 2-DS3			
Competitor		**Firm**	
CET:	2	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1300
SPC:	0.5	SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	151,172	12,470
2	137,670	19,164
4	110,029	17,145
6	87,168	16,649
8	70,669	17,248
10	59,609	18,098
50	57,323	18,795

Scenario ID: 2-DS3			
Competitor		**Firm**	
CET:	4	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1300
SPC:	0.5	SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	157,670	4,581
2	146,992	7,667
4	118,593	7,018
6	96,153	5,859
8	79,907	5,976
10	69,138	6,438
50	67,018	6,826

Scenario ID: 2-DS3			
Competitor		**Firm**	
CET:	6	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1300
SPC:	0.5	SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	161,055	471
2	151,741	1,772
4	123,040	1,472
6	100,208	962
8	84,094	787
10	73,455	1,029
50	71,451	1,264

Scenario ID: 2-DS3			
Competitor		**Firm**	
CET:	8	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1300
SPC:	0.5	SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	162,621	-1,488
2	153,869	-960
4	125,024	-1,082
6	101,946	-1,289
8	85,811	-1,390
10	75,236	-1,273
50	73,287	-1,110

Scenario ID: 2-DS3			
Competitor		**Firm**	
CET:	10	*FET:*	0
Segment:	3	Segment:	3
Price:		Price:	1300
SPC:	0.5	SPC:	0.5
SPCP:		SPCP:	-
CET_2:	50	*FET_2:*	0-2-4-6-8-10-50
Segment:		Segment:	4
Price:		Price:	3500
SPC:		SPC:	0.02
SPCP:		SPCP:	-

FET_2	Firm's Pr.	Comp Pr.
0	163,296	-2,480
2	154,756	-2,304
4	125,863	-2,343
6	102,687	-2,406
8	86,507	-2,446
10	76,000	-2,420
50	74,089	-2,314

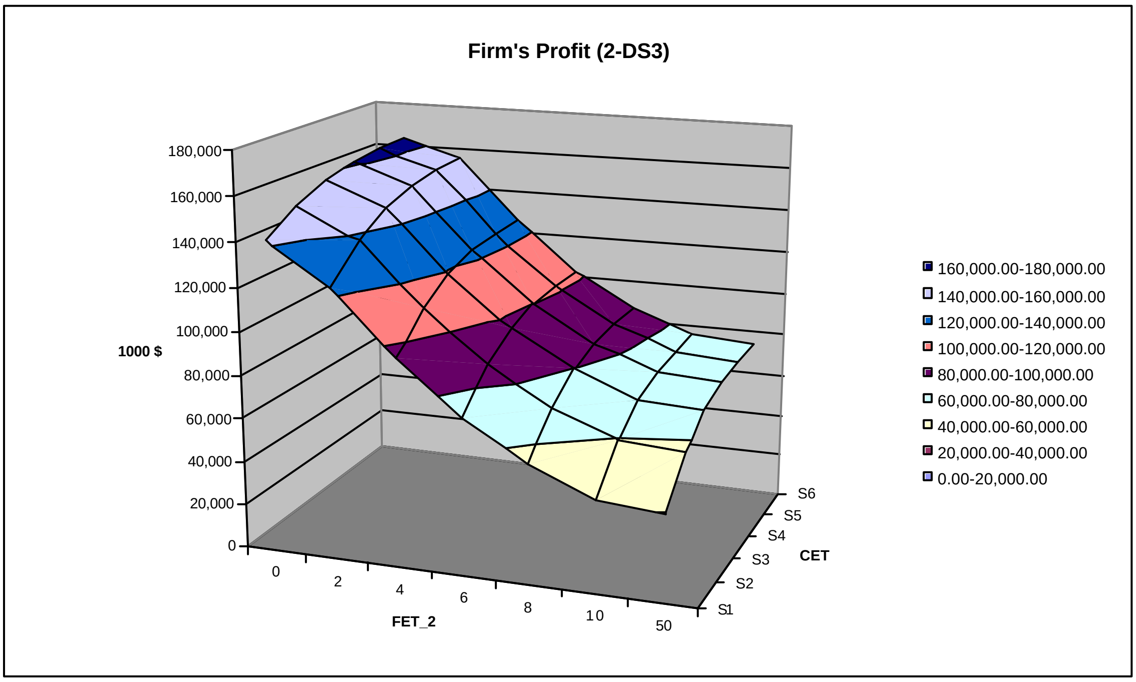

Figure 5-26 Firm's profit in 2-DS3

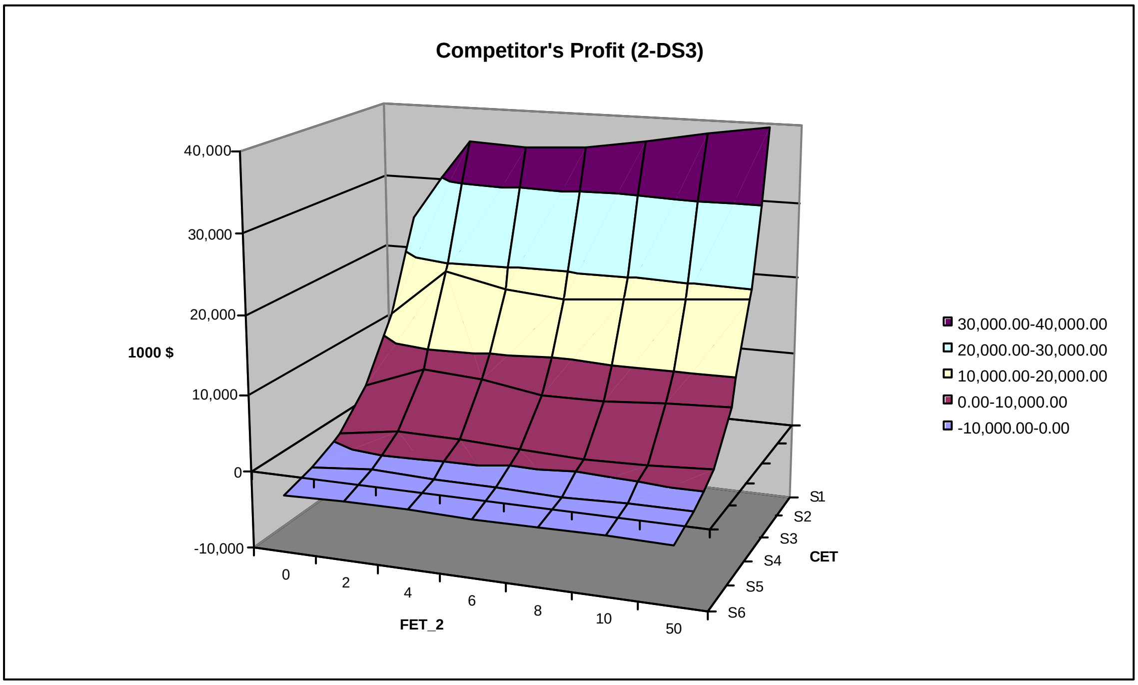

Figure 5-27 Competitor's profit in 2-DS3

After explaining the results for two different segment combinations separately, comparing the results would be appropriate.

For the skimming price strategy: launching the second product is a profitable policy from the firm's perspective. As the competitor enters the market late, the profit level of the firm increases. Also the competitor's profit is decreasing as it enters the market later and there is a start up problem. These points are common in both segment combinations. However, the start up problem for the firm is much more significant and different in the second segment combination. (2-DS1)

In the second pricing strategy (skimming and then a discount) all observations are common for both of the segment groups. In brief; from the firm's perspective, as the competitor enters the market late the firm's profit first increases and then decreases. Similar to this result, launch of the second product is advantageous in the early periods or in later periods. From the competitor's perspective, there is again a start up problem (smoother than that of the skimming price strategy scenario) and the late entry of the competitor and the early launch of the firm's second product lead to a decrease in the competitor's profit.

In the penetration strategy, the observations overlap. As the competitor enters the market late, the firm's profit first increases and then decreases. There is a major start up problem for the competitor's and as the competitor enters late its profit decreases as in other scenarios.

In conclusion, the results observed in every scenario (for different pricing strategies) in two segment groups have similar patterns and, these observations reinforce the reliability of the results.

5.2.3. Comparing Monopoly and Duopoly

In this section, the comparison is performed first based on the pricing strategies. Then, the common points observed in all of the pricing strategies are summarized.

In the skimming strategy, in monopoly, two different successful polices have been observed: Launching is observed for the first group of segments whereas not launching is observed for the second group of segments. In duopoly, with the increasing competition in all segment combinations launching is observed as the best policy.

The presence of the competitor has different effects based on the entry time for the first group of segments. If the competitor enters in the early periods, this leads to a decrease in the firm's profit, because in the introduction phase especially for the skimming strategy there is a high competition. However, if the competitor enters late, this results in an increase in the firm's profit due to the temporary relaxation in the firm's delivery delay. In the second group of segments no matter when the competitor enters, at any time the presence of the competitor decreases the firm's profit due to higher competition (compared to the first group of segments).

The last observation for the skimming strategy is the following: In monopoly the first group of segments, the profit levels are lower than those of the second group of segments. However, in duopoly the inverse is valid.

In the skimming and discount strategy, the increase in the launch time of the second product first leads to a decrease and then an increase in the firm's profit. This observation is common both for monopoly and duopoly.

The presence of the competitor increases the firm's profit in the first segment combination due to the decrease in the delivery delay and second product's price cut effect. However, in the second group of the segments presence of the competitor decreases the profit seriously.

In monopoly, the profit levels are lower than those of the second group of segments. However, in duopoly they are higher as in the skimming strategy.

In the penetration price strategy, launching the second product is observed as the best policy for all segment combinations.

The presence of the competitor has different effects as in the skimming strategy. It either keeps the profit at the same level or increases. The underlying reasons are the same as in the first pricing strategy. The presence of the competitor leads to a decrease in the second group of segments independent from the entry time.

Finally, as observed in the rest of the pricing strategies, the profit levels are lower than those of the second group of segments. In contrast, they are higher in duopoly.

There are some common points observed independent from the pricing strategies. Does the presence of the competitor decrease the prices always? In other words, in duopoly, are the profits higher or lower than in monopoly? The answers of these questions are dependent on the amount of the competition. In all pricing strategies, in the second segment combination the presence of the competitor always result in a decrease in profits in duopoly, because the competition is higher due to the smaller segment size. However, for the first segment combinations a generalization is not possible.

The final common observation is about the total profits of segment combinations. Should the firm play in the first segment combination or in the second segment combination in order to maximize its profit? In monopoly, playing in the second segment combinations provide higher profit levels. However in duopoly, due to a high level of competition in the second group of segments, playing in the first group of segments results in a higher profit level.

6. CONCLUSIONS AND FUTURE RESEARCH

The purpose of this study is to build a representative dynamic model in order to investigate a duopoly competition in the durable household goods market. Representative dynamic models are essential since to test various scenarios becomes easier and cheaper with such models. System dynamics is preferred as the methodology due to its wide capabilities.

The modules that are to be included in the model are decided initially. After drawing the boundaries, each module is developed separately based on an extended literature survey and interviews with the thesis advisor and an expert. The separately developed and tested modules are integrated employing proper connections. The model is further extended so as to support the entry of new products and different entry times to the market. After this phase, the modeling of the market structure is completed and the parameter estimation phase is started. The model is validated through the procedure that is suggested by Barlas (1996).

Finally, the scenarios are developed that are to be tested in the model. First the various pricing strategies are run in duopoly and then various second product entry strategies are considered.

In the first group of scenarios the firm can apply two different pricing strategies: (1) skimming pricing and (2) penetration pricing. As a response to the skimming pricing, the competitor either matches the price or cuts the price (aggressive response). On the other hand, as a response to the penetration strategy the competitor matches the price, since the price levels are already very low. This design is replicated for the different entry times of the competitor. The major conclusions obtained from the first group of scenarios are as follows:

- Consistent results are obtained for both segments

- Profit levels are high both in skimming-matching and skimming-price cut scenarios compared to that of the case in which penetration pricing strategy is used.
- If the competitor responds aggressively, this leads to a small decrease in the profit level. On the other hand, this leads to an increase in the competitor's market share and profit.
- Penetration pricing serves the purpose of reaching a large installed base and having a lower cost. This strategy results in lower costs and higher market share compared to the other two cases.

In the second group of scenarios the new product launching strategies are discussed under different pricing strategies and different market structures (monopoly and duopoly). The scenarios are repeated for seven different launching times for the second product and for the competitor's first product (only in duopoly analysis). These scenarios are run under three different pricing strategies. These pricing strategies are: (1) skimming, (2) skimming but the firm and the competitor (if present) make a discount for their first products by increasing cost sensitivity parameter after the launching of the second product and (3) penetration pricing. Each design is replicated for other group of segments in order to check the reliability of the scenarios. The major findings are stated as follows:

- In general, the results observed in every scenario in two segment groups have similar patterns.
- For the skimming price strategy: launching the second product is a profitable policy from the firm's perspective. As the competitor enters the market late, the profit level of the firm increases. Also the competitor's profit is decreasing as it enters the market later.
- In the second pricing strategy, from the firm's perspective, as the competitor enters the market late the firm's profit first increases and then decreases due to the temporary relaxation in the delivery delay. Launch of the second product is advantageous in the early periods or in later periods. From the competitor's perspective, the late entry of the competitor and the early launch of the firm's second product lead to a decrease in the competitor's profit.

- In the penetration strategy, as the competitor enters the market late, the firm's profit first increases and then decreases. As the competitor enters late its profit decreases as in other scenarios.

- In monopoly, launching the product to the second segment combinations provide higher profit levels. However in duopoly, due to a high level of competition in the second group of segments, playing in the first group of segments results in a higher profit level.

For future research, the model can be extended from different aspects: (1) The first order delay can be removed from the delivery. (2) The backlog stock can be modeled as a separate stock and this one delta time can be removed. (3) Learning curve effect can be handled in a different manner, using industry experience and general cost decrease expectations that are stated in the contracts in various industries. (4) A new product development module can be included to the model as a new module. (5) Cash flow can be included, and (6) the model can be extended to an oligopolistic market.

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APPENDICES

Appendix A: Simulation results for FAE_i and WOMi design

(Total 11 simulations: Run# 8 and 11 are displayed in the text)

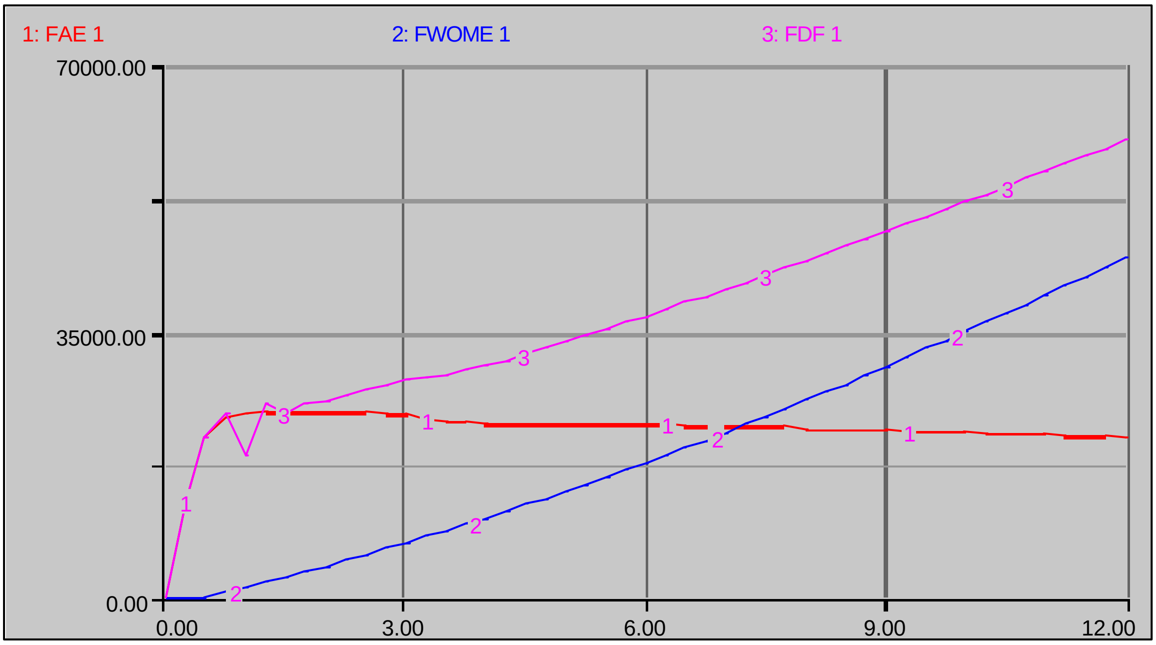

Figure A-1 Run #: 1

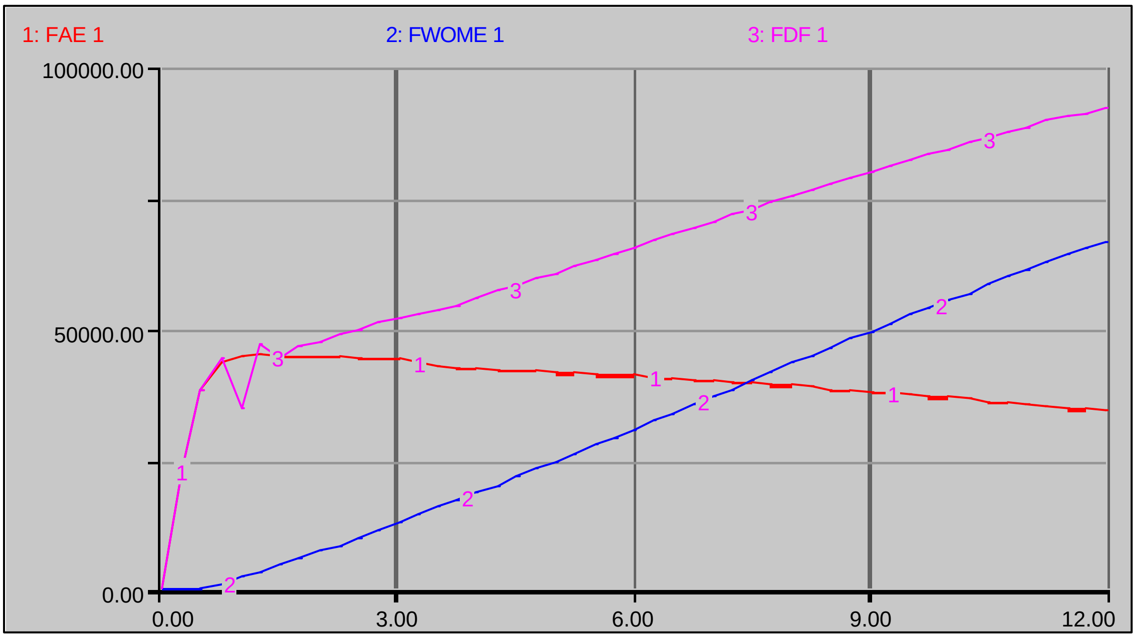

Figure A-2 Run #: 2

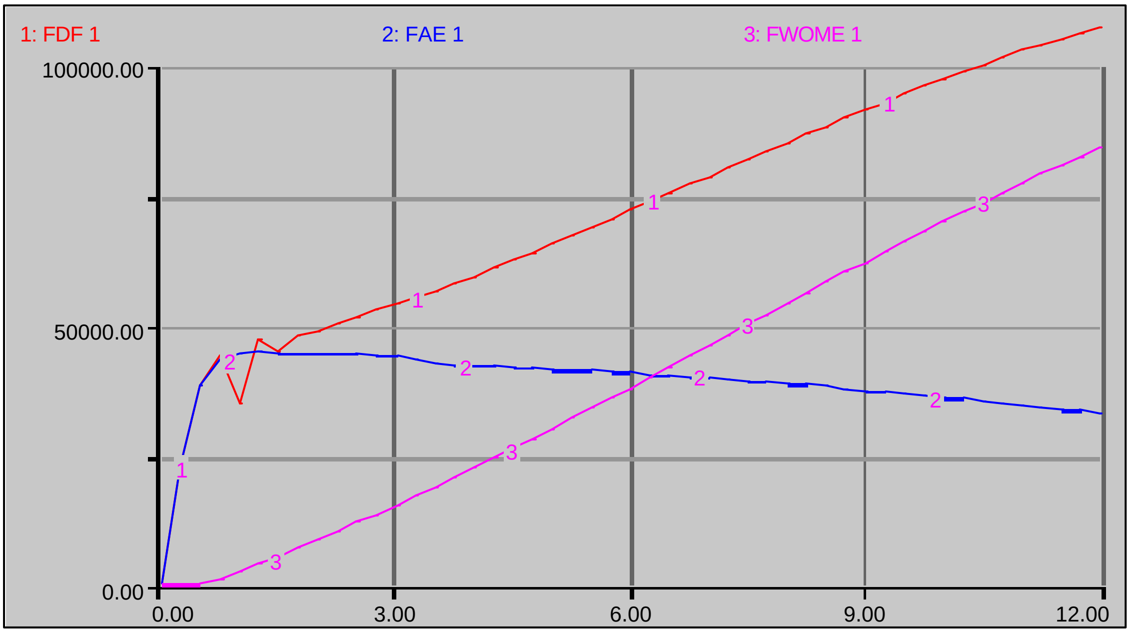

Figure A-3 Run #: 3

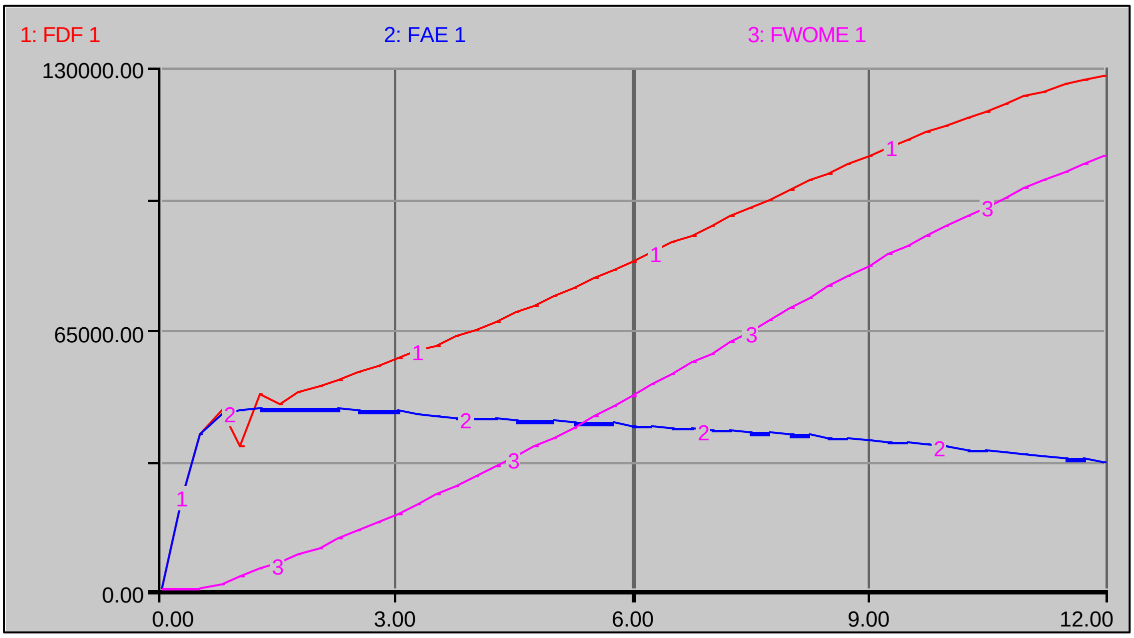

Figure A-4 Run #: 4

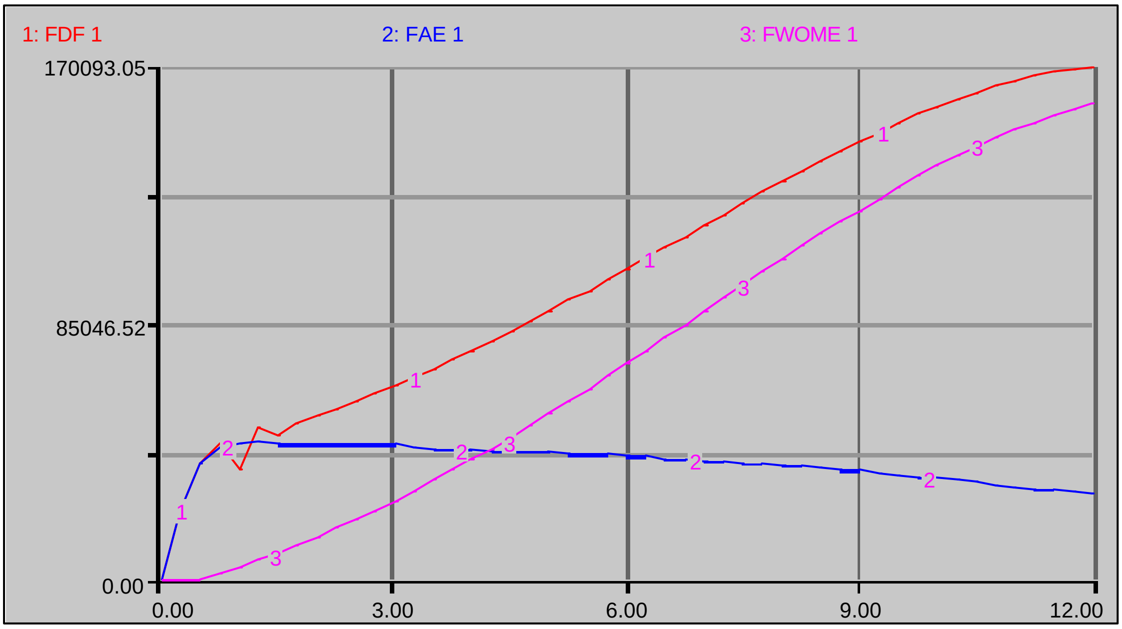

Figure A-5 Run #: 5

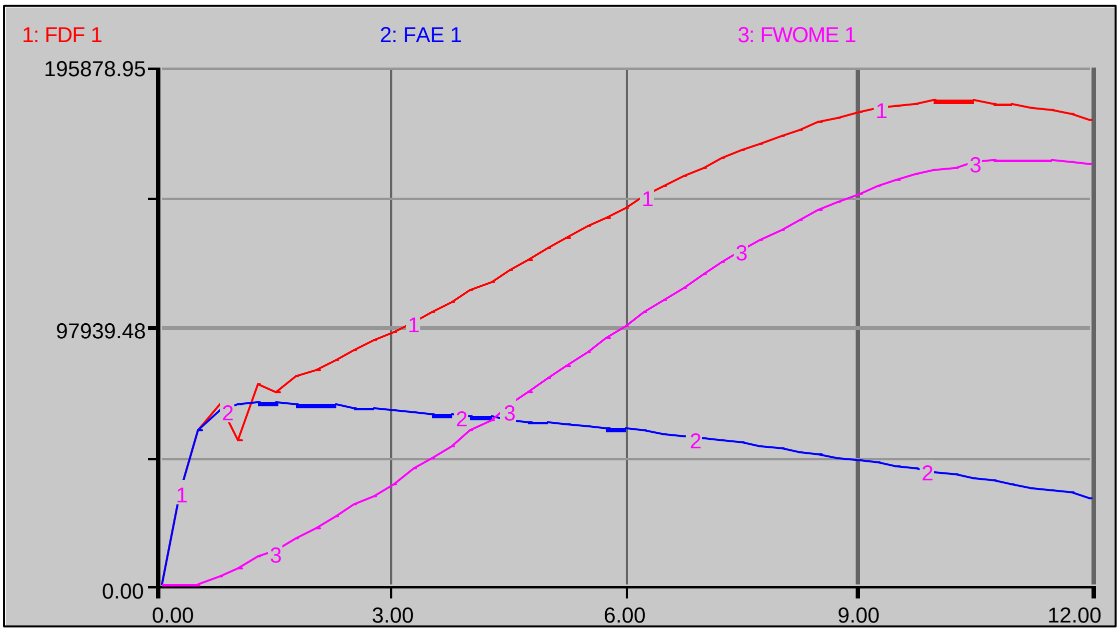

Figure A-6 Run #: 6

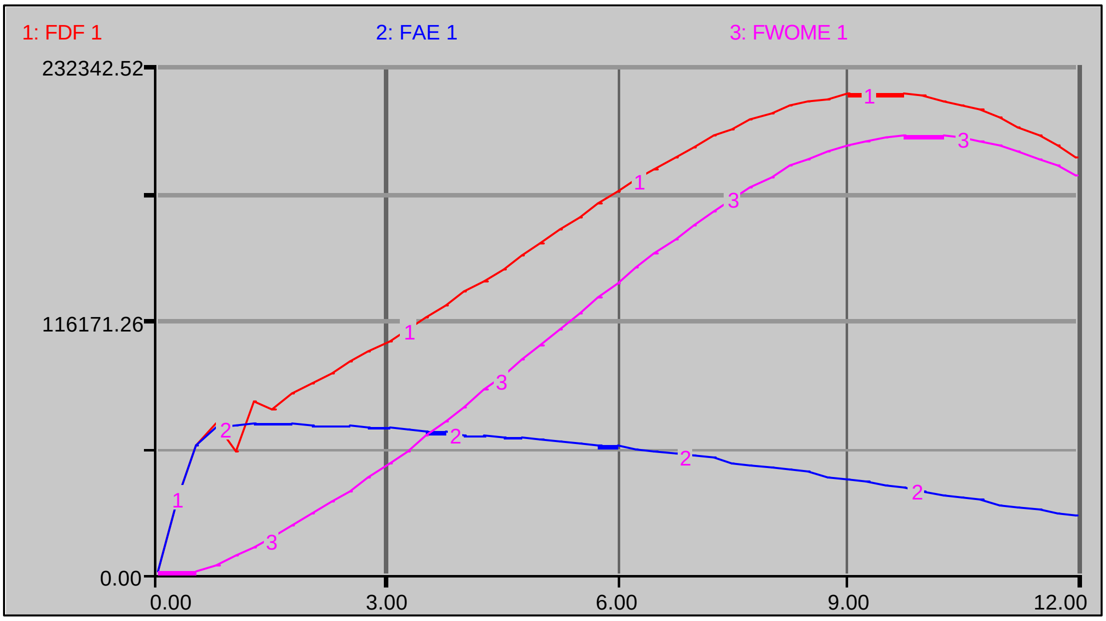

Figure A-7 Run #: 7

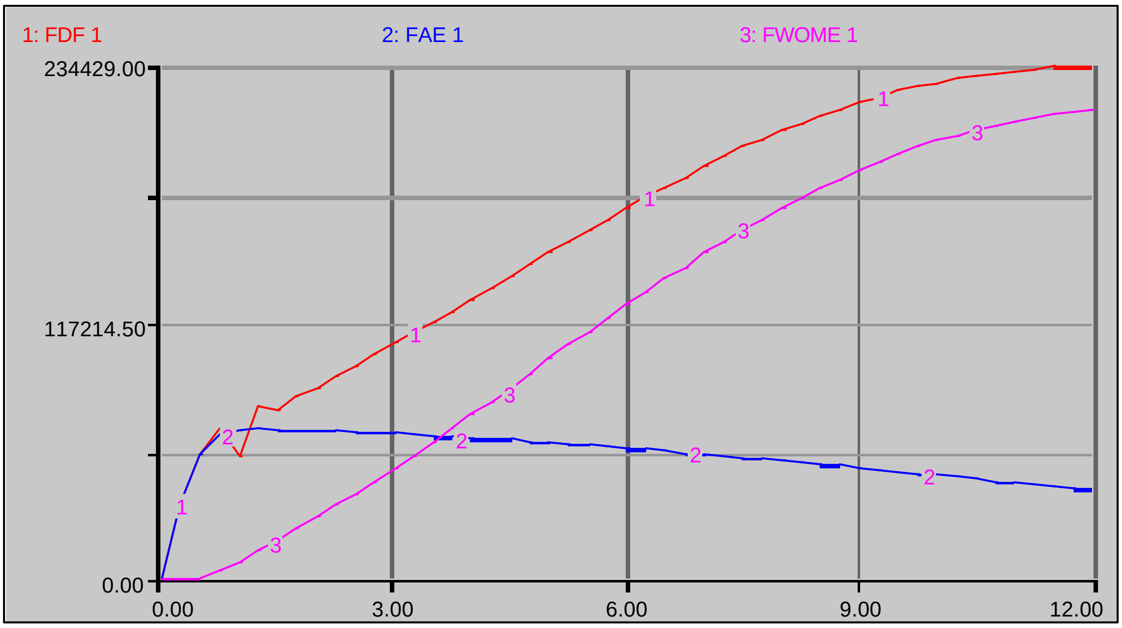

Figure A-8 Run #: 9

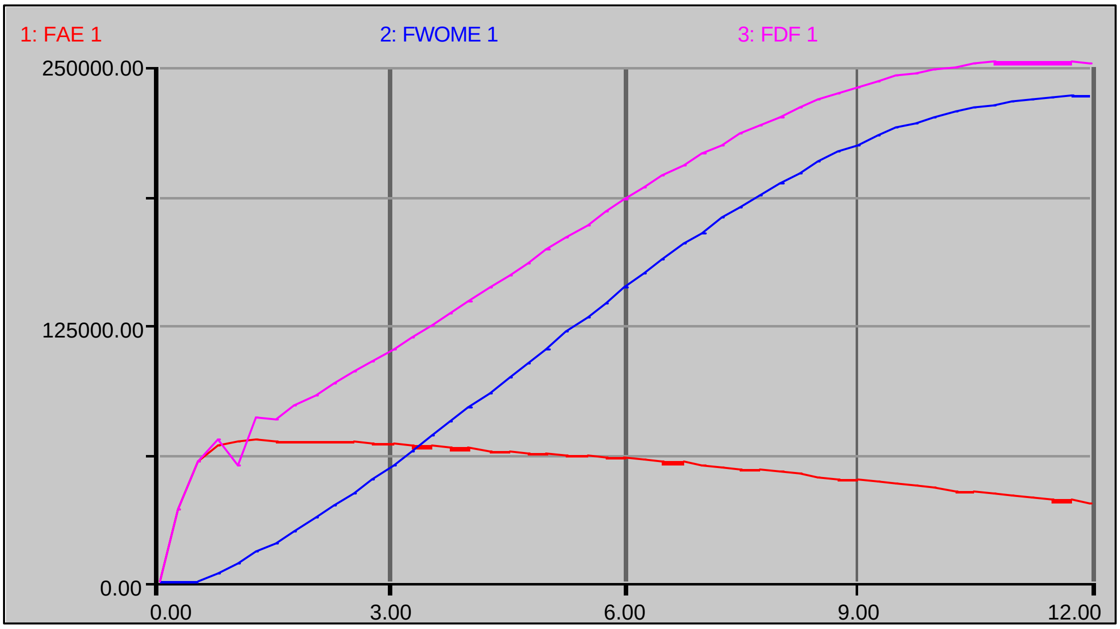

Figure A-9 Run #: 10

Appendix B: FAE_i sensitivity analysis results

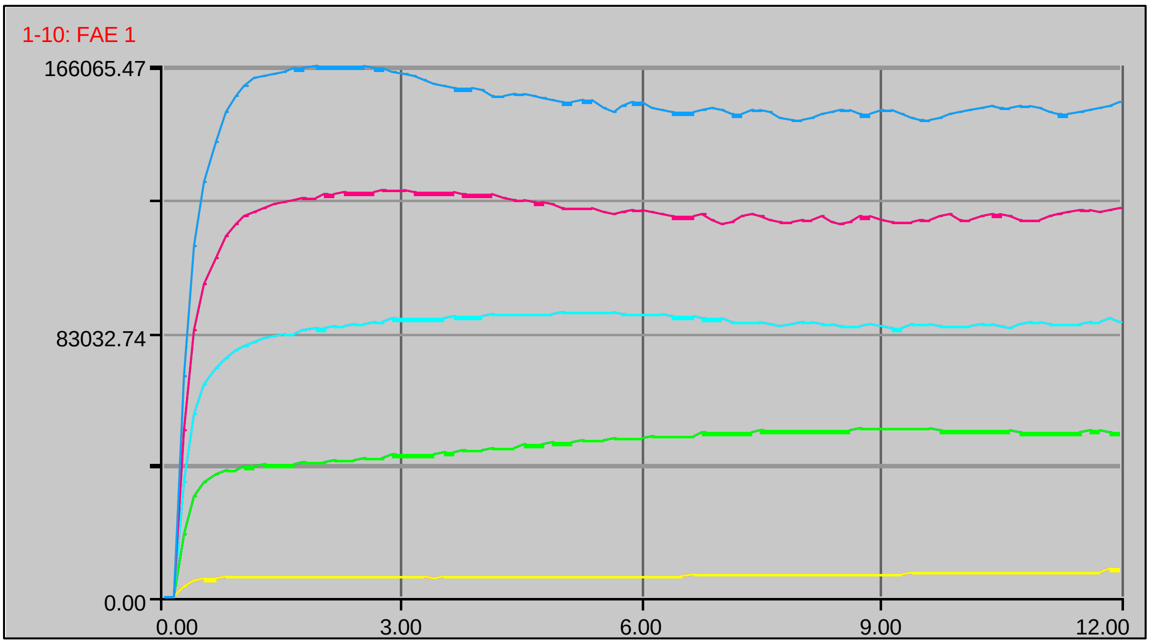

Figure B-1 FAE_i sensitivity analysis results I

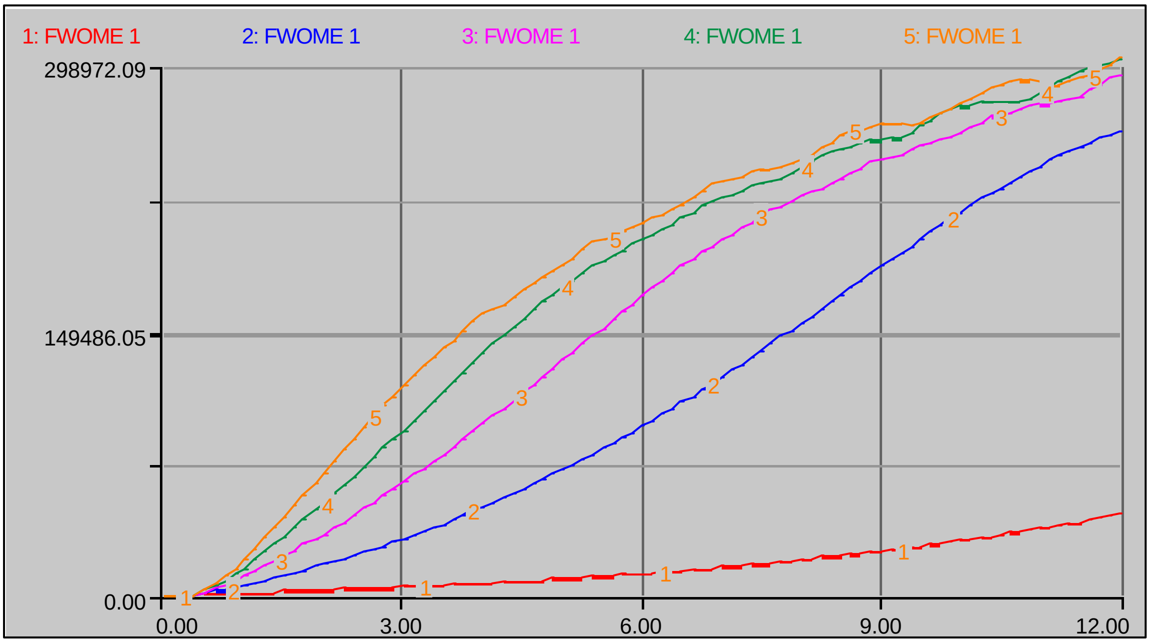

Figure B-2 FAE_i sensitivity analysis results II

Appendix C: WOMi sensitivity analysis results

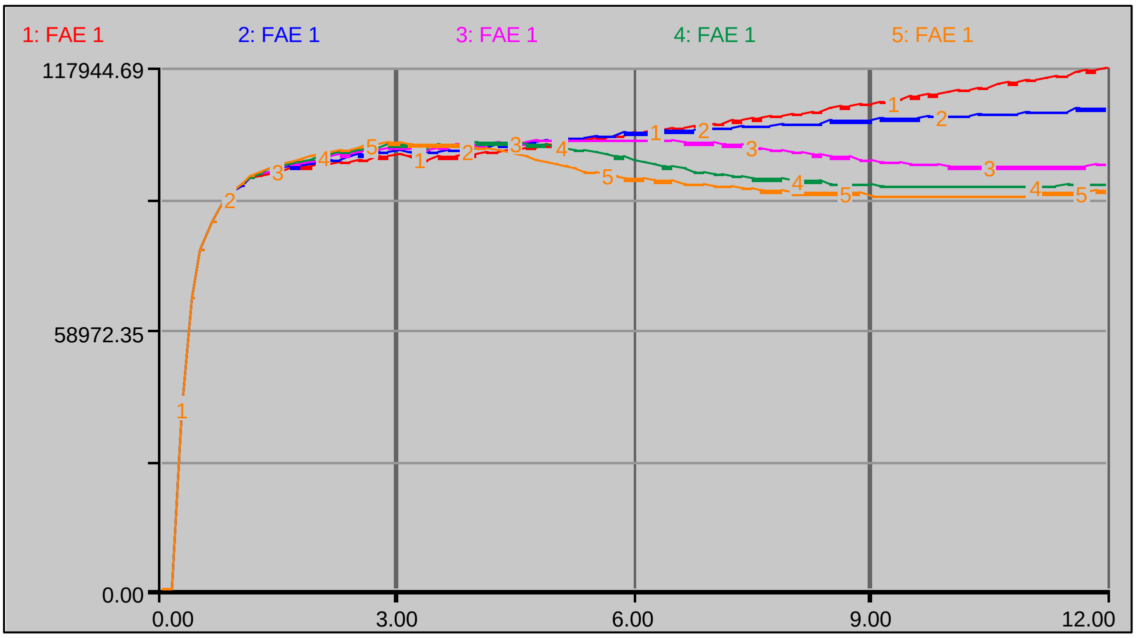

Figure C-1 WOMi sensitivity analysis results I

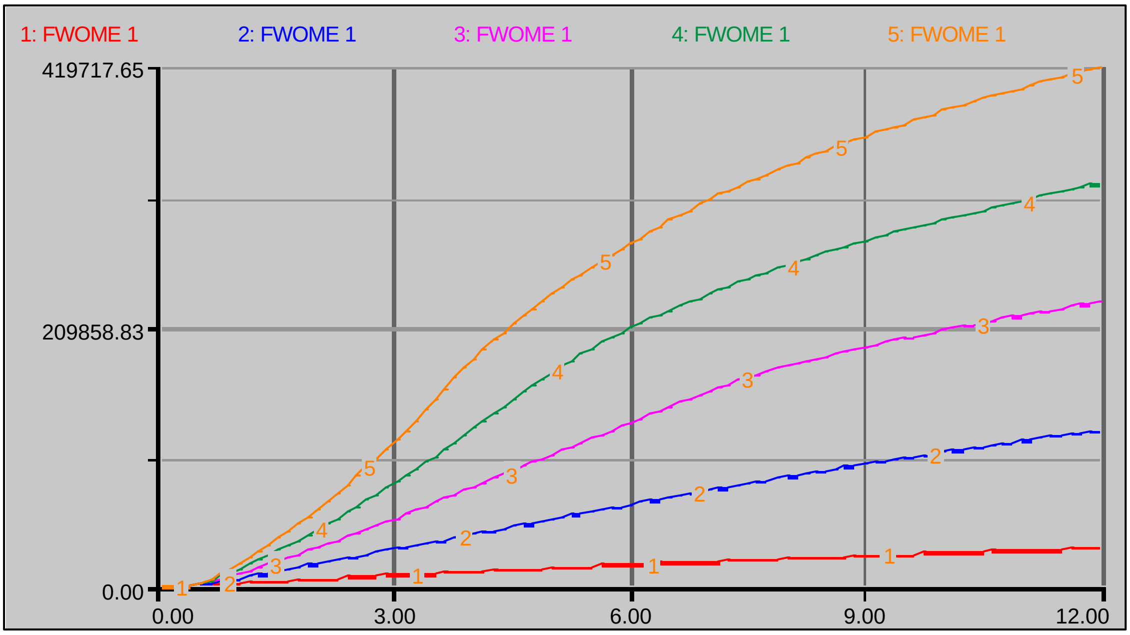

Figure C-2 WOMi sensitivity analysis results II

Appendix D: Learning curve strength sensitivity analysis results

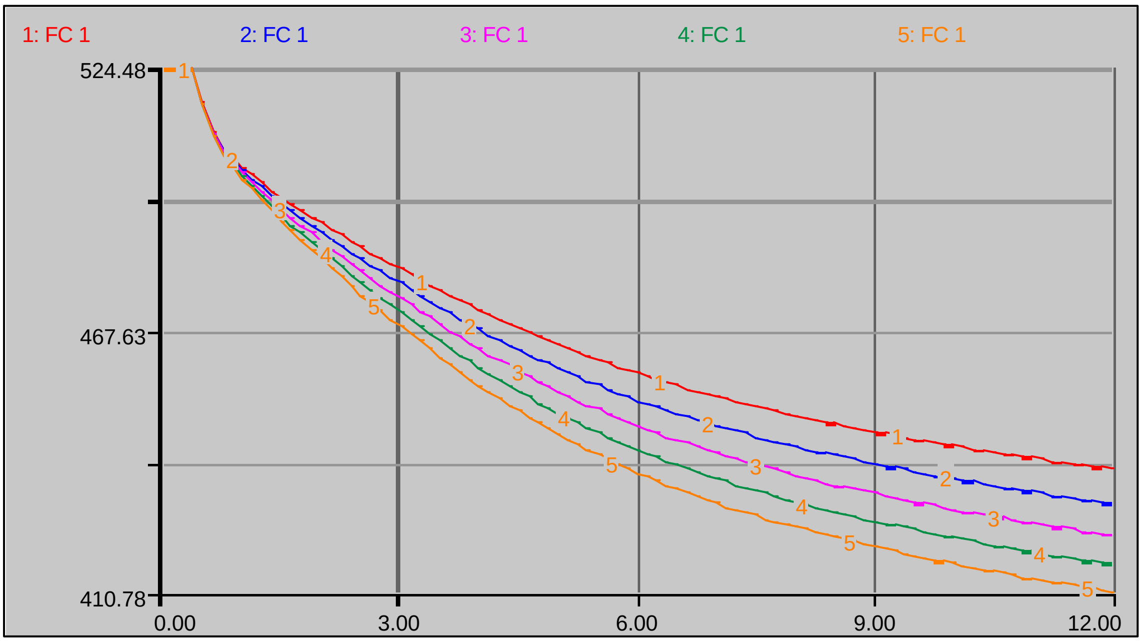

Figure D-1 Learning curve strength sensitivity analysis results I

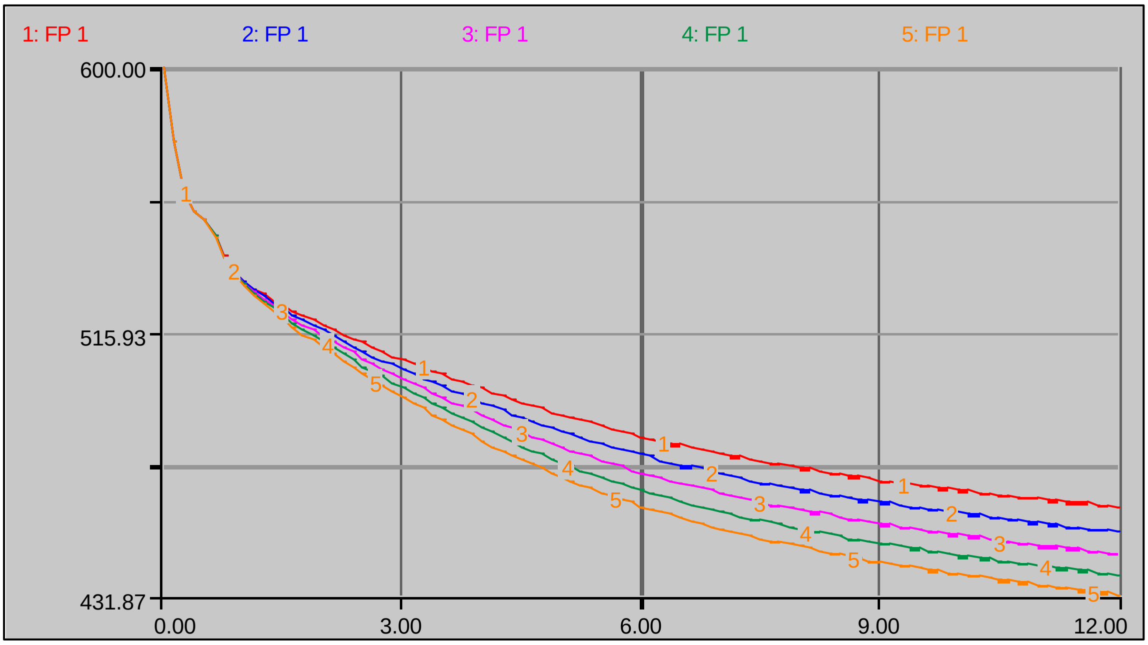

Figure D-2 Learning curve strength sensitivity analysis results II

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