

Original citation:

Kunc, Martin (2004) Simulating the evolution of industries using a dynamic behavioural model. In: 2004 International Conference of the System Dynamics Society, Oxford, UK, July 25 - 29. Published in: Proceedings of the 2004 International Conference of the System Dynamics Society

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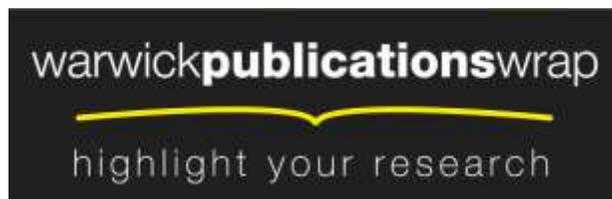
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Simulating the evolution of industries using a dynamic behavioural model *

Paper presented at the 2004 International System Dynamics Conference at Oxford, England

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* The research reported in this paper has been funded in part by the PhD Program at London Business School. Additional funding has been provided by the System Dynamics Group at London Business School

Abstract

Investment decisions determine that not only the evolution of industries is hard to forecast with certainty but also industries may have different dynamic behaviour and evolutionary paths. In this paper we present a behavioural framework to simulate the evolution of industries. Two factors determine the dynamic behaviour of an industry: managerial decision-making and the interconnected set of resources. Managerial decision-making significantly affects the dynamic behaviour of firms. Bounded rational managers define rates of asset stock accumulation to achieve a competitive advantage using different mental models. However, the set of interconnected internal and external resources existing at industry level affects the expected performance of the firms. Consequently, the effect of the feedback structure existing in the industry, which consists of managers in competing firms making similar decisions over the interconnected set of resources, determines that the dynamically contingent behaviour of firms influence on the industry evolutionary paths.

In our simulations, we found that simple managerial choices, such as the definition of a market share or an expected market size, lead to diverse firm and industry performances even though management of competing firms emphasises different sets of resources required to carry out their strategy.

Introduction

Porter (1998) suggests that investment decisions make not only hard to forecast with certainty the evolution of industries but also industries may evolve following different paths at different speeds. We propose a model to explore the effect of management decisions on the evolution and dynamic behaviour of competitive industries.

In this model, two main factors determine the performance and dynamic behaviour of an industry. First, firms are comprised by a set of interconnected internal and external resources. Firms as open systems not only acquire resources from their environment but also lose resources to competitors through competitive interactions (Warren, 2001; Warren, 2002). Consequently, organizational survival in competitive industries is based on the ability to acquire and maintain resources in an environment consisting of rival organizations, which compete for shared resources or own the resources required for surviving and prospering.

Second, managerial decision-making significantly affects the dynamics of firms. Management decisions to meet their strategic goals affect the system of resources of competing firms, thereby generating reactions that will influence later their own resources. External environments are not completely exogenous but are in part created by managers and their decisions. Consequently, firms have to fit into patterns of resource exchanges with other firms in the industry forming adaptive systems embedded in feedback process. Thus, the dynamic complexity of industries comprising interlocking resources suggests that differences in the way managers interpret this complexity, set priorities and guide resource building will affect relative firm performance and, finally, the dynamic behaviour in competitive industries.

This paper presents a framework to analyse the evolution and dynamic behaviour of competitive industries from a micro behavioural perspective. The paper has four parts: First, we conceptually describe the dynamic behavioural model of competitive industries; second, we present the set of managerial decision-making styles explored in the simulations; third, we

formalise the model and their results. Finally, we suggest future directions to expand the model.

A Micro Behavioural Model of Competitive Industries

The dynamic behavioural model consists of two main sectors: industries as feedback systems, and the firm-wide managerial decision-making processes.

Industries as feedback systems

The concept of industry describes an environment where firms develop their business supplying similar products or services to customers. Basically, an industry is a feedback system comprised by firms and a market. On the one hand, firms provide services or products to satisfy customers' requirements. On the other hand, potential customers have requirements that they try to satisfy with the most convenient product at the best possible price. Firms and customers interact over time through a process of adjustment between consumers' requirements and firms' products. While successful firms grow when an increasing number of potential customers accept and adopt their products; other firms have to abandon the industry when their products do not satisfy consumers' needs.

The dynamic interaction between firms and market are reflected by two feedback processes (figure 1) *market evolution* and *firm evolution* (Kunc, 2003). Market evolution is basically a balancing feedback loop. As firms collectively grow in the industry, they reduce the pool of potential customers until they reach the market saturation level. This pool of potential consumers is a natural limit to growth for industries unless firms diversify into new geographical markets or engage in product innovation to attract more consumers. Market size is directly related to the number of potential customers attracted by industry's products. The evolution of firms is a reinforcing process that drives successful firms. Successful firms attract customers and generate revenues that are invested in resources to capture more customers from

the pool of potential customers or from rivals. This reinforcing process is controlled through managerial investment decisions that regulate the development and configuration of the set of resources, and competitive actions aimed to capture customers in the same market.

INSERT FIGURE 1

While the feedback structure is important as it imposes operating constraints (practical rules for how resources work and combine to deliver products and services attractive to customers) on managers, we believe that the effect of operating policies (management decision-making processes that guide resource -asset stock- accumulation) are more relevant to the dynamic behaviour of industries because they regulate the reinforcing process that drives the dynamic behaviour of firms and, through the interconnected set of resources, of the industry.

Firm-wide managerial decision-making processes

In System Dynamics, management is viewed as the process of converting information into action. This conversion process is decision-making. As Forrester (1994) notes, “if management is the process of converting information into action, then management success depends primarily on what information is chosen and how the conversion is executed. The difference between a good manager and a poor manager lies at this point between information and action”. The difference between a high performing firm and a less-well performing rival also lies at this point, and, as a consequence of the feedback structure of the industry, the evolution of an industry also depends on the individual decision-making processes of the participants.

In our framework we build on this view of management by separating managerial decision-making into two distinct information-processing components. There is an operating

policy to control the acquisition and composition of resources, and there is strategic resource conceptualisation to define which resources the business really needs.

Operating policy is normally represented as purposive adjustment of asset stocks or resources through goal-seeking information feedback (Sterman, 2000; Morecroft, 2002). It is the essence of the feedback view of the firm. Decisions stemming from operating policy lead to corrective actions intended to close observed gaps between desired and actual resources. Defining and monitoring the gaps (shortages or excesses) in a firm's portfolio of resources is essentially an information processing activity. System dynamicists recognise that such information processing is imperfect, judgmental and behavioural and subject to the practical constraints of bounded rationality (Morecroft, 1985). Every manager has available a large number of information sources to determine the firm's resources. But each manager selects and uses only a small fraction of all available information. Through this behavioural decision-making process, managers collectively build and configure the resources for competing in the industry.

The process of strategic resource system conceptualisation is related to top managers' mental models of the intended resource system and the expected sources of competitive advantage. In other words, each manager has a blueprint in his or her mind of the system of asset stocks that drives performance and dynamic behaviour of the firm over time. Collectively these blueprints determine the resource building strategy as well as the markets in which the firm competes. As Senge (1999: 175) suggests "our mental models determine not only how we make sense of the world, but how we take action." Mental models affect what we see, and two people with different mental models can observe the same industry or even the same firm, and yet define the intended resource system differently.

Managerial decision-making styles explored in the simulations

While the decision-making styles of managers in an industry can be very different; we can classify them using Porter's (1985) "Generic Strategies" into three main styles: cost leadership, differentiation, and focus.

The sources of *cost leadership* are varied and depend on the structure of the industry, but they are generally economies of scale or highly productive operational processes. If a firm can achieve and sustain overall costs leadership, then it will achieve above-average profits provided it can charge prices at or near the industry average. However, a cost leader must also achieve parity or proximity relative to its competitors in their bases of differentiation to sustain an above-average performance. Product parity means that the price discount necessary to achieve an acceptable market share will not erode their cost advantage.

The second generic strategy is *differentiation*. Firms that use this strategy in the industry seek to be unique along some dimensions that are widely valued by buyers. Management selects some attributes considered to be important by the potential and actual consumers, and tries to position itself to meet their needs. Firms in this position may be able to charge a premium price. Differentiation can be based on the product itself, the marketing approach or other resources and attributes valued by consumers. An above-average performer using differentiation strategy must have their extra costs incurred for being unique well below the price premium charged. Consequently, a firm achieving differentiation must also aim to have cost parity or proximity relative to its competitors.

The third generic strategy is *focus*. This strategy is based on a narrow competitive scope in an industry. The firm selects a segment and adapts its strategy to serving exclusively this segment. The focus strategy may use the better of the two generic strategies according to what is demanded by customers in this segment. A focuser takes advantage of underperforming broad competitors in specific segments of customers instead of developing the market.

Based on the three types of managerial decision-making depicted before, we present in table 1 the expected differences in four key issues faced by most of the firms in any industry: market size, customers' requirements, sources (in terms of asset stocks that need to be developed) of competitive advantage, and competitors' reactions.

Key Issues	Cost Leader	Differentiation Leader	Focus
What is the expected market's size?	The expected market size is based on extrapolations of past market growth rate.	Market size is based on the number of consumers that the managers expect to attract with the product.	Market size is equal to the expected size of the target segment.
What are the requirements of potential customers?	Broad requirements in terms of product characteristics, but highly sensitive to price.	The consumers are highly demanding in terms of product characteristics and less sensitive to price.	Specific requirements in terms of price and product characteristics.
What is the set of resources necessary to satisfy customers' requirements and maintain a competitive advantage?	Management expect to build their competitive advantage by improving the efficiency of the existing operations. Thus, they allocate most of their investment to increase the effectiveness of their operational resources as a mean to reduce costs. Market share is a key goal for the achievement of economies of scale. However, they try to maintain close product parity with the differentiation leader.	Management believe that customers' requirements are mostly related to better products rather than lower prices. Consequently, management allocate most of the investment in the development of new product technology as a means to achieve a competitive advantage.	The set of resources is configured to satisfy the technological need of the target segment at lower price than the Differentiation leader.
How will the firms react to competitors' actions?	Management will increase their efforts to reduce costs without increasing the gap with their competitors' product.	Management will tend to further differentiate the product from competitors if they face competitive pressures.	Management will not lose product parity with the differentiation leader and will reduce price to attract customers.

TABLE 1. Differences in decision-making styles using the Porter's (1985) generic strategies

Model Formalisation

The model addresses the dynamic behaviour of the industry by identifying the dynamic behaviour of individual competing firm and consumer response to firms' actions rather than using an aggregate view of the industry. In this model, firms have two main components: decision-making processes and a system of resources. The decision-making processes describe

decision functions as simple rules of thumb similarly to behavioural simulation models (Sterman, 1987, Morecroft, 1985b). The system of resources that constitutes the firms are based on the approach depicted in the dynamic resource-based view of strategy (Morecroft, 2000; Warren, 2002).

Consumer behaviour is based on literature related to the diffusion and adoption of innovations in heterogeneous populations (Mahajan, Muller, and Wind, 2000), and a simplified model of consumer choice.

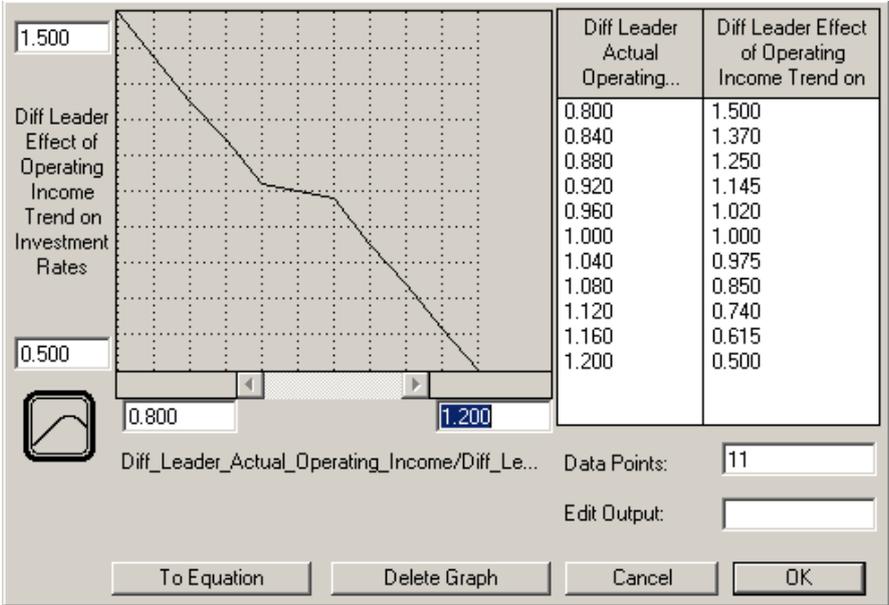
Firms

Firms in this model are assumed to be embedded in a reinforcing feedback process regulated by managerial decision-making processes. Figure 2 represents a simplified view of the structure of our simulated firms. Management focus its attention on sources of information related to the performance of the firm such as profits or market share to coordinate the sectors of the firm. There are four sectors that represent the main resources of our simulated firm: Financial, Technology, Operational and Market Development (Marketing). The financial sector contains one asset stock that symbolizes the financial resources of the firm. The technology sector contains two asset stocks: one corresponds to the product technology and the other indicates the level of productivity of the operational resources. The operational sector contains the asset stock that represents the capacity of the firm to provide products. Finally, the market development sector includes the marketing actions to attract customers such as price and advertising.

INSERT FIGURE 2

Financial Resources. The goal of the decision-making process in the financial sector is to maintain the rate of operating income over time (ratio actual operating income/established

operating income) rather than the level of the stock of financial resources. Management will allocate more financial resources to change the configuration of the source of competitive advantage (technology or operational resources productivity) if they fail to maintain the operating income over time as can be seen in the left hand-side part of the table function. If the rate of profits is considered to be satisfactory, management will reduce the allocation of resources to technology, as they believe they have achieved a satisfactory configuration of the product technology as can be see in the right-hand side of the table function (the stock and flow diagram and a full list of the equations of this sector are in the Appendix).



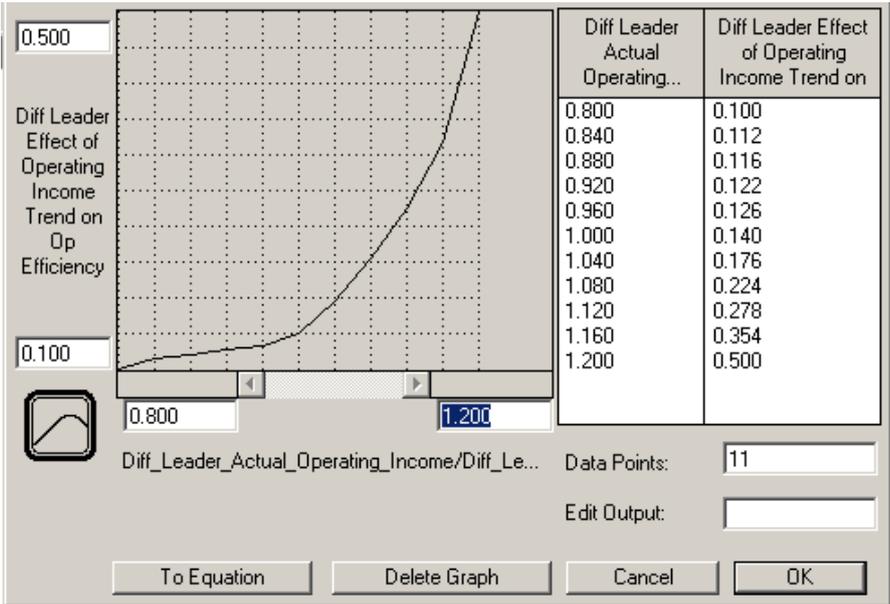
Effect of Goal Non-attainment in the Normal Rate of Investment in Technology

Technology resources. In this simplified model, the set of resources responsible for the competitive advantage and superior performance is the set of Technology Resources. Technology resources comprise two resources: Product Technology and Operational Efficiency. Product technology is the key resource for firms following a differentiation strategy, and operational efficiency is the key resource for firms following a cost leadership strategy.

This set of resources describes the technological level of the product portfolio and the operational efficiency level of the firm. For simplicity, we assume that the resource named ‘Product Technology’ represents an index of the level of the product characteristics that can be

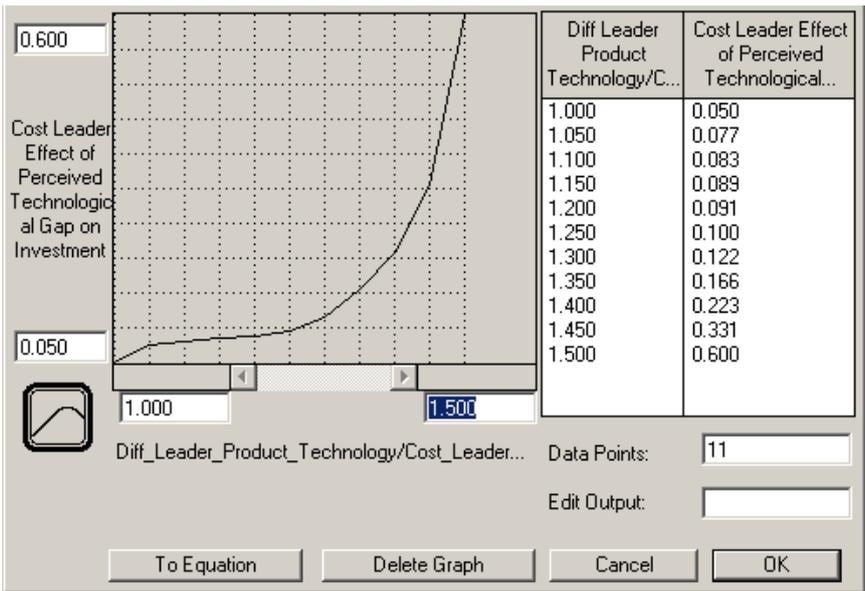
directly associated to the level of potential customers' requirements; for example, a product technology level of 100 is fairly close to cover all the possible customers' requirements, and, consequently, the firm may be able to attract a huge number of customers from the total available market. Moreover, a higher product technology level relative to its competitors' level will attract not only potential customers but also customers from existing competitors. Management change the level of the Product Technology through the investment of financial resources, which correspond to the allocation of resources to product development projects.

Management can also invest financial resources to increase the efficiency of the Operational resources. Operational Efficiency represents the cumulative efforts of the firm to refine the operating technology for the actual type of products. Operational Efficiency reflects the management efforts to reduce costs independently of the economies of scale achieved through Operational Resources. A firm following a differentiation strategy will invest financial resources in Operational Efficiency only when its management perceive that the actual Product Technology level is accepted in the market. Thus, the differentiation leader will invest more in Operational Efficiency when the operating income is increasing or stable to improve further the income generated as the next table function shows.



Effect of Operating Income Trend on the allocation of Financial Resources to Operational Efficiency

On the other hand, management following a Cost leader strategy believes that their main competitive advantage is to have the lowest cost. Consequently, management will invest more resources to increase the efficiency of its Operational Resources and less in the technology of the product. We assume this management style will allocate few resources to change the technology of its products because it erodes the gains obtained from investing in Operating Efficiency. However, if there is a widening gap between the Differentiation Leader’s product and its own product technologies, a cost leader firm will allocate more resources to promptly reduce the existing gap as can be observed in the next table function (see Appendix 1 for the equations and the stock and flow diagram).



Effect of Technology Gap in the Allocation of Financial Resources to Product Technology Development

We assume that the technologies are similar to all participants in the industry. For example, the effect of change in product technology affects similarly to the operational efficiency in both Cost and Differentiation Leader; the economies of scale achievable by both firms are identical; the rate of improvement of operational efficiency as well as the initial productivity per unit of Operational Resource are also similar; and, finally, the level of operational efficiency for a certain technology is limited. There are two reasons for this

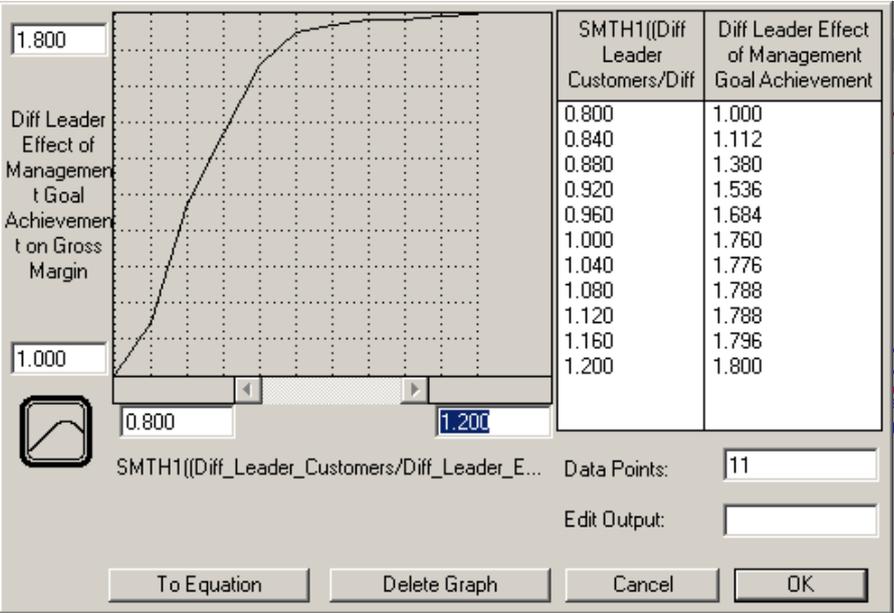
assumption. First, all resources are sourced from external and common suppliers to the industry. Second, we want to explore in these simulations the result of dissimilar managerial decision-making styles in a competitive industry, and not intrinsic differences in the set of resources.

Operational Resources. We use the concept of Operational Resources to capture physical and human assets stocks that are necessary to provide the products requested by customers. Firms start with an initial endowment of resources that reflects their initial investments, and the development of these resources depends on the expectations that managers have about the evolution of the market. We assume that there is no backlog or infinite supply as well as any effect of lower supply than demand in the consumer behaviour. Consequently, we assume that the potential sales revenue (the unit sold to actual customers –repetitive buyers- and the unit sold to new customers –first buyers-) is reduced by the availability of volume produced (level of units of Operational Resources multiplied by the productivity per unit of operational resource), and any shortage in product availability will not affect the movement of customers between firms.

Finally, there are a series of additional assumptions related to Operational Resources. First, the level of Operational Resources determines the basic cost per unit of product, which is influenced by the effect of economies of scale. Second, when Operational Efficiency increases, the productivity per unit of operational resource also increases. Higher productivity reduces the real cost per unit of product and the amount to invest in expanding operational resources. Operational resources is subject to a normal depreciation rate; however, when firm changes its technology not only increases the normal depreciation rate due to technological obsolescence but also increases the cost of goods sold by reducing productivity and economies of scale.

Competitive Actions. While the set of resources is a source of the long-term competitive advantage, management also take short-term competitive actions. These short-term actions are related to the process of attraction of potential customers and competitors’ customers. In the model, we present two short-term actions: price adjustments and advertising expenditure.

We use a ‘cost + gross margin’ pricing policy. Thus, price adjustments, which are a result of the non-attainment of the market size goal, are implemented through the adjustment of the gross margin as can be observed in the next table function. While a reduction of the gross margin affects the profitability in the short term, two long-term strategic actions are also included in the model: cost reduction through better operational efficiency and improvement of product technology relative to competitors’ technology. Consequently, a reduction in price will attract more customers to improve the operating income in the long-term (if the discount does not exceed the benefit of more sales) and obtain resources to invest in cost reduction or technology improvement.



Effect of Market Size Goal non-attainment in the gross margin

Advertising expenditure helps to attract potential customers to the industry and expand the market. Thus, advertising is another short-term action that improves the long-term

perspective not only of the firm but also of the industry. (see in Appendix 1 the stock and flow diagram and the equations for these sector).

Finally, consumers use price, product functionality and advertising to define the best alternative to adopt, as a first buyer, and, later on, to replace the actual product as a repetitive buyer (Cost Leader, Differentiation Leader or Focus products).

To conclude, table 2 presents a summary of the main decisions existing in the behavioural model of the firm.

Management Decisions	Cost Leader	Differentiation Leader	Focus
<i>Financial Resources</i>	The objective is to maintain a stable operating income. If actual profit rate is lower than past profit rate, more financial resources will be allocated to the development of technology or operational efficiency.	The objective is to maintain a stable operating income. The evolution of profits determines the intensity of the resources allocated to technology development.	The objective is to maintain a stable operating income. The achievement of the expected market size determines the intensity of the investment in product technology.
<i>Technology Resources</i>	The configuration of Technology Resources is principally oriented to reduce costs by increasing operating efficiency. However, if there is an important gap with competitor's product, the resources are mostly used to reduce the gap with competitor's technology.	The source of competitive advantage is believed to be the development of new products. Consequently, the resources are mostly allocated to develop the product technology.	The technology goal is based on information about the requirements of the customers segment in terms of the technology of the product leader in the market (differentiation leader product).
<i>Operational Resources</i>	The expected size of the market, which is adjusted by an extrapolation of the actual market growth rate, determines the expansion rate of this asset stock.	Operational resources are developed over time based on the management's expected size of the market.	This participant does not have specific operational resources. We assume that it does not have specific manufacturing resources but a cost of sourcing the product from third parties.
<i>Competitive Actions</i>	Price: It aims to be lowest in market by reducing gross margin and costs of good. Advertising: lower budget than the differentiation leader.	Price: higher than average in market but it will tend to cut gross margin aggressively if the expected market size is not achieved. However, it will increase price very fast when expectations about market size achieved are fulfilled. Advertising: highly intensive.	Price: average in market. Advertising: no resources invested in advertising.

TABLE 2. Main decision-making processes existing in the behavioural model of the firm.

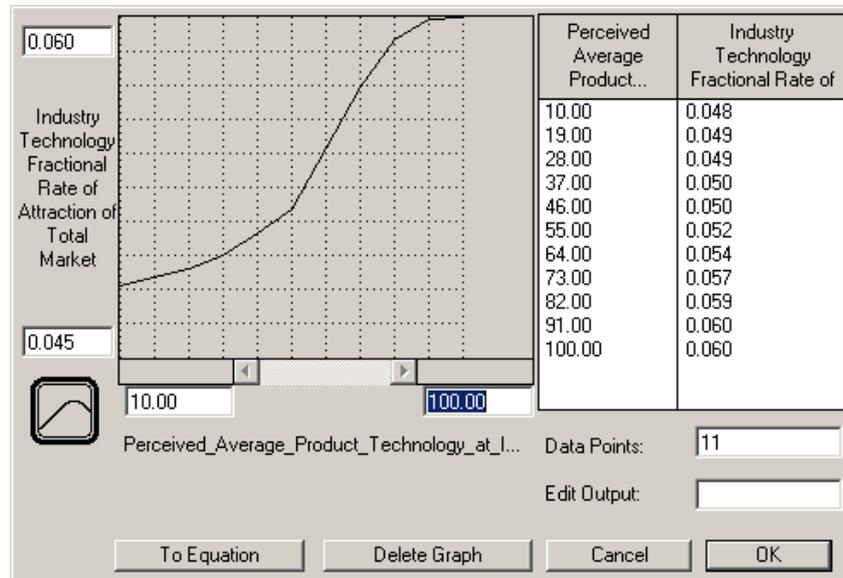
Market Sector

The simplest model of the evolution of markets over time is the Bass Diffusion Model (Bass, 1969). The Bass Diffusion Model has been extensively used in System Dynamics to describe the diffusion of innovations (Sterman, 2000). The basic version of the Bass Diffusion Model considers the diffusion process independently from the effects of firms' strategies (except Advertising) or the distribution of the customers' preferences. Some researchers have modified the model to portray customers' response to firms' actions; for example, Paich and Sterman (1993) presented a revised version using price adjustment to modify the size of the pool of potential customers.

The Bass Diffusion Model is an interesting starting point but it does not present consumers' decision-making process. For example, the model only considers consumers' decision-making processes homogeneous and driven mainly by word-of-mouth. However, customers consider other factors such as functionality and price before buying a product. While price is an important factor to influence consumer behaviour, it does not capture the most essential process during the evolution of industries: The match between customers' requirements in terms of product's functionality and the ability of firms in the industry to provide the best product that match these functionalities. Consequently, we include three modifications to the Bass diffusion model in our simulated market:

- First, the stock of potential customers, fixed in a Bass based model, may change over time as product functionality changes attracting others segments of people who have not been interested in the product yet. The function represents the process of attracting different segments of the total population as product technology evolves. When the industry improves their product technology (or product functionality), the proportion of the total population interested increases (and the fractional rate of attraction per time increases). However, the rate of growth of the industry diminishes over time, as few members of the

population remain without using the products of the industry. The next graph represents the table function that depicts the relationship between the average product technology at industry level and fractional rate of attraction over time of the industry.



Fractional Rate of Attraction of the Total Market

- Second, we have included behavioural variables to represent a basic consumer decision-making process at the adoption of a new product. A weighted value is obtained for each alternative (Cost Leader or Differentiation Leader alternatives) in function of the relative weights that heterogeneous customers (Price or Product functionality sensitive adopters) have about each dimension (price, product functionality or advertising) and the relative strength of each alternative in these dimensions with respect to the existing alternatives in the market (e.g.: Cost Leader product functionality compared to average product functionality). The components are then combined in an overall value for that alternative in terms of share of the potential customers that adopt any of the existing alternatives in the market (Cost Leader alternative or Differentiation Leader alternative). The next equation describes the process mentioned before for the Cost leader:

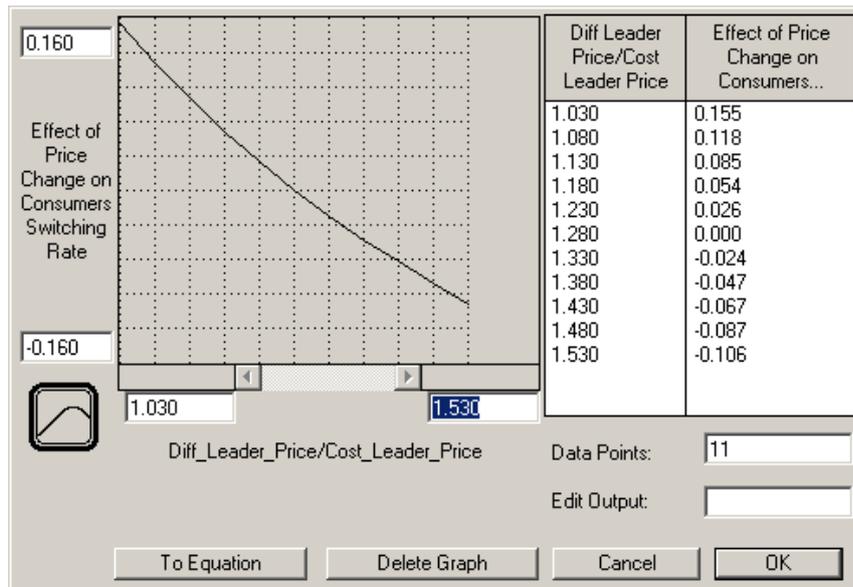
$$Adoption\ Rate\ for\ Cost\ Leader\ (i) = Price_Sensitive_Adopters * [\alpha_1 * (Product_Technology_i / \sum Product_Technology_{ij}) + \beta_1 * (Advertising_i / \sum Advertising_{ij}) + \gamma_1 * (Price_j / \sum Price_{ij})] +$$

$$\text{Functionality_Sensitive_Adopters} * [\alpha_2 * (\text{Product_Technology}_i / \sum \text{Product_Technology}_{ij}) + \beta_2 * (\text{Advertising}_i / \sum \text{Advertising}_{ij}) + \gamma_2 * (\text{Price}_i / \sum \text{Price}_{ij})]$$

Where $\alpha_1 + \beta_1 + \gamma_1 = 1$ and $\alpha_2 + \beta_2 + \gamma_2 = 1$ indicate the different weights that each type of adopter gives to each dimension to arrive a value for each alternative; and $\alpha_1 + \alpha_2 = 1$, $\beta_1 + \beta_2 = 1$ and $\gamma_1 + \gamma_2 = 1$ indicate the weight that each type of adopter gives to the different dimensions. A stock and flow diagram and the equations are included in appendix 1.

- Third, customers may change the product as competitors offer better products for the same price or a lower price for the same product technology. The movement of customers between firms in the industry is regulated by a long-term perception of the relative position of each alternative (cost leader alternative or differentiation leader alternative) in each dimension (price or product technology). For example, customers may perceive as ‘natural’ situations where the prices of the differentiation leader is 28% higher than the cost leader but only if the differentiation leader’s product is at the same time 28% better than the product of the cost leader. Whenever firms in the industry change these perceived relationships, customers will respond by switching to the firm that offers the best combination of price and product technology. If the rival does not react promptly, it may find itself out of the market. For simplicity, we do not model the effect of learning processes at consumer level that may change the ‘natural’ relationships between alternatives in a certain dimension. The table function represents the price relationship and its effects in terms of percentage of customers per unit of time moving from one firm to the other when the actual price ratio is different than the neutral price.

Appendix 1 contains all the equations and stock and flow diagram representing the decision-making processes of customers.



Long-term customers perceived price ratio between Differentiation Price and Cost Leader Price

Results of the Simulation

The natural distribution of the customers – the industry in equilibrium

The industry has three firms that each of them follows one of the three decision-making styles: Cost Leadership, Differentiation Leadership and Focus. The total population is equally divided among people willing to buy products according to their functionality given a certain price – which is not necessarily the lowest- (functionality sensitive adopters), and willing to buy products at the lowest price given a certain level of product functionality (price sensitive adopters). In the first simulation, we left the initial conditions (price and product functionality) fixed during all the simulation. Figure 3 presents the evolution of the market during the simulation. Lines 1 and 2 represent the evolution of the number of customers captured by each leader. Since the proportion of people sensitive to price and to product functionality is equal, both leaders captured the same number of customers achieving equilibrium. Line 3 represents the number of customer of Focus. Focus did not capture any customer because its product technology and its price were not attractive enough to capture customers from the leaders.

INSERT FIGURE 3

Figure 4 presents the evolution of price and operating income for the two leaders during the period of the simulation. The price and operating income of the Differentiation Leader were higher than the Cost Leader price and operating income because it could charge a premium price for a better product.

INSERT FIGURE 4

Industry with only Cost Leader and Differentiation Leader

Now, we simulated the industry with only two participants: a Cost Leader and a Differentiation Leader. Figure 5 shows the evolution of the market. We can observe that the market reaches equilibrium after quarter 130 with Differentiation Leader having 57% of the market. Both leaders reached equilibrium when the product of the differentiation leader was 60% better than cost leader product at a price 70% higher than cost leader price. At these price and product technology values the number of customers who chose to switch based on product functionality is similar to those customers who switched based on price. Consequently, the net movement of customers between firms is zero.

INSERT FIGURE 5

We will analyze the simulation from quarter 1 to quarter 132 to identify the reasons behind the success of the differentiation leader and demise of the cost leader. Figure 6 shows the evolution of price and operating income for both leaders. We observe that the differentiation leader reduced its price aggressively at the beginning of the industry trying to

attract more customers than the cost leader. However, differentiation leader rose its price too soon as it perceived that the number of customers would keep increasing. Consequently, most of the initial adopters were attracted by Cost Leader lower price. Cost leader obtained a huge increase in the rate of operating profits surpassing Differentiation Leader operating income by quarter 20, and the technological gap started to decrease as Cost Leader have more resources to invest in technology. The Cost leader was helped by the pricing policy followed by the Differentiation Leader, which maintained a wide gap with the price of the Cost Leader and a small product technology difference. Only when the Differentiation Leader reduced its price to match the price of the cost leader, Differentiation leader's operating profits rose because it attracted customers back. Only by quarter 50, the Differentiation Leader operating income trend was definitively positive and growing over time because it has more resources to increase the product technology and charge a higher price. On the other hand, Cost Leader management continued reducing its price in order to attract the customers lost. However, this policy only eroded more its declining operating income reducing its ability to invest in the reduction of the technological gap with Differentiation leader as figure 7 displays.

INSERT FIGURE 6

While an increasing operating income allowed the Cost Leader management to close the technological gap with Differentiation leader technology and employed the cost advantage for the first 50 quarters, Cost Leader management lessened its ability to close the gap as they continued reducing its prices when its market share was diminishing after quarter 50 as figure 7 shows.

INSERT FIGURE 7

In conclusion, Differentiation Leader aggressive price reduction at the beginning of the industry helped it to achieve a huge market share; however, management propensity to raise price without offering a more improved product corroded this initial advantage and customers' long-term price relationship between alternatives drove customers to Cost Leader's product. Cost Leader continuous pricing reduction exploited the huge differentiation leader price to attract customers. This huge improvement in market share created some future problems for the Cost Leader. As Cost Leader management used past market share achieved as the source of information for defining its prices, management started reducing its price when the differentiation leader reaction eroded Cost Leader market share. This competitive response from Cost Leader management destroyed the source –operating income- to sustain its long-term cost advantage as it lost product technology parity entering into a reinforcing process.

Adding more complexity to the industry, not only a Cost and a Differentiation Leader but also a firm with a Focus strategy

The industry now has three participants: Cost Leader, Differentiation Leader and Focus. Figure 8 presents the evolution of the market segments including a firm following a focus strategy. We can observe that the market reaches equilibrium after quarter 160 with the Differentiation Leader having 57% of the market. The market reached equilibrium between both leaders as the firm following a focus strategy almost disappeared from the market. The equilibrium occurred when the number of customers switching due to lower price was equal to the customers switching due to better technology. Thus, we will concentrate on the first 160 quarters of the simulation.

INSERT FIGURE 8

Figure 9 shows that the main competitive action of the Focus competitor was to drastically reduce its price (line 3) in order to attract customers from Cost Leader and Differentiation Leader. Focus' alternative represented a better technology at the same price for Cost Leader's customers and it was a similar product technology at a much lower price for Differentiation Leader's customers. After Focus management achieved its expected market size, it increased its price to the same level of Cost Leader. However, Focus management could not sustain the continuous price reduction trend established by Cost Leader due to its smaller size. Moreover, Cost Leader and Differentiation Leader investments in technology determined that the product technology offered by the leaders was better than the product technology available in Focus. From quarter 80, Focus started losing customers to both leaders, and finally it almost disappeared by quarter 160. Such as Porter (1985) suggested Focus was trapped in the middle and it could not sustain any specific competitive advantage.

INSERT FIGURE 9

In conclusion, Focus in the industry contributed to reduce the divergences between the Leaders. Focus acted as a buffer between both leaders in the industry as it absorbed part of the effects of their competitive actions (see figure 10).

INSERT FIGURE 10

Key Findings

- While we cannot suggest that managers mental models are either cost or differentiation oriented, we can observe in this simulation how bounded rational managerial decision-making processes may make very bad decisions because their goal setting process did

not consider the complexity of the feedback structures and the consequences of interconnected set of resources.

- In the simulations, we can observe how the interconnection between functional areas of a company may influence its performance over time as it generates competitors' reactions that erode the effectiveness of appropriate decision-making process.
- The existence of three or more firms in an industry increased the intensity of competitive actions, especially those from the leaders, because the third firm acted as a buffer or delay between the competitive action and the results obtained. This situation resulted in a higher attrition rate of financial resources to sustain the competitive advantage.
- The dynamics of the industry did not change significantly when we tested different proportions of the customers sensitive to price or product functionality, but we obtained quite different results when we changed the market share goal of the firms.

Final Considerations

Managers face very complex investment decisions due to uncertainties about customer acceptance, market size, technology, actions of competitors, and a dynamic complex feedback system. In addition, the complexity of a system of interrelated stocks and the information feedback structure of the industry raises managerial decision-making process as one of -if not- the most important variable to manipulate the evolution of an industry.

This paper attempts to analyse the influence of managerial decision-making on the evolution of industries, and more specifically on the dynamic behaviour of three key components of any industry: the rate of growth of the firms, the evolution of the market, and technology development. Porter (1991) suggests that firms can achieve superior competitive positions due to two factors: established conditions and pure managerial choices. Established

conditions may be a good factor when we are analysing established industries; however, in some circumstances, established conditions can be overcome from managerial actions such as the simple actions observed in the simulations. Pure managerial choices, such as the definition of a market share, lead to the assembly of particular resources required to carry out the strategy. However, managerial choices can lead to non-desired consequences because of the complexity of the environment and the cognitive limitations of the managers, especially when there are different conceptualisations of the set of resources and the competitive actions.

We realise that the model has its limitations in terms of the decision-making processes described and other relationships used in the model as well as the results obtained. However, we believe that the model as a metaphor for illustrating the balancing and reinforcing processes at firm level and its consequences in the dynamic behaviour of industries is very useful.

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Figures

FIGURE 1. Conceptual representation of the Micro Behavioural Model of the Evolution of Competitive Industries

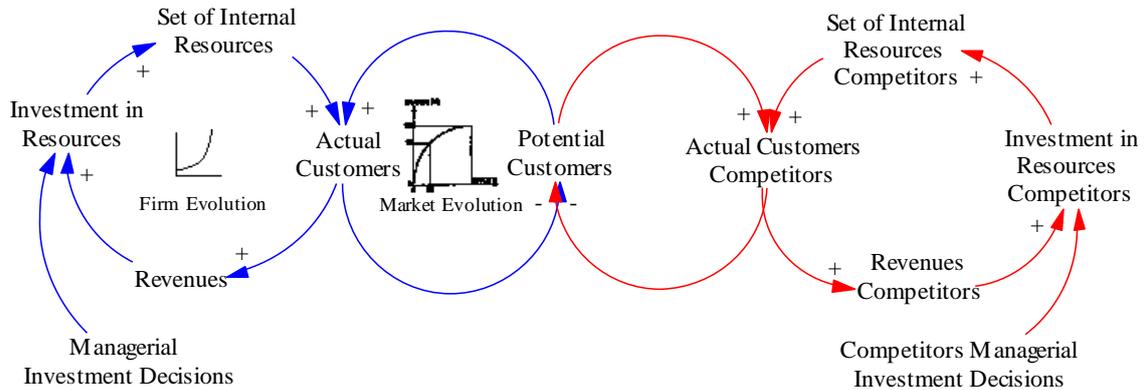


FIGURE 2. Simplified Behavioural Model of the Firm

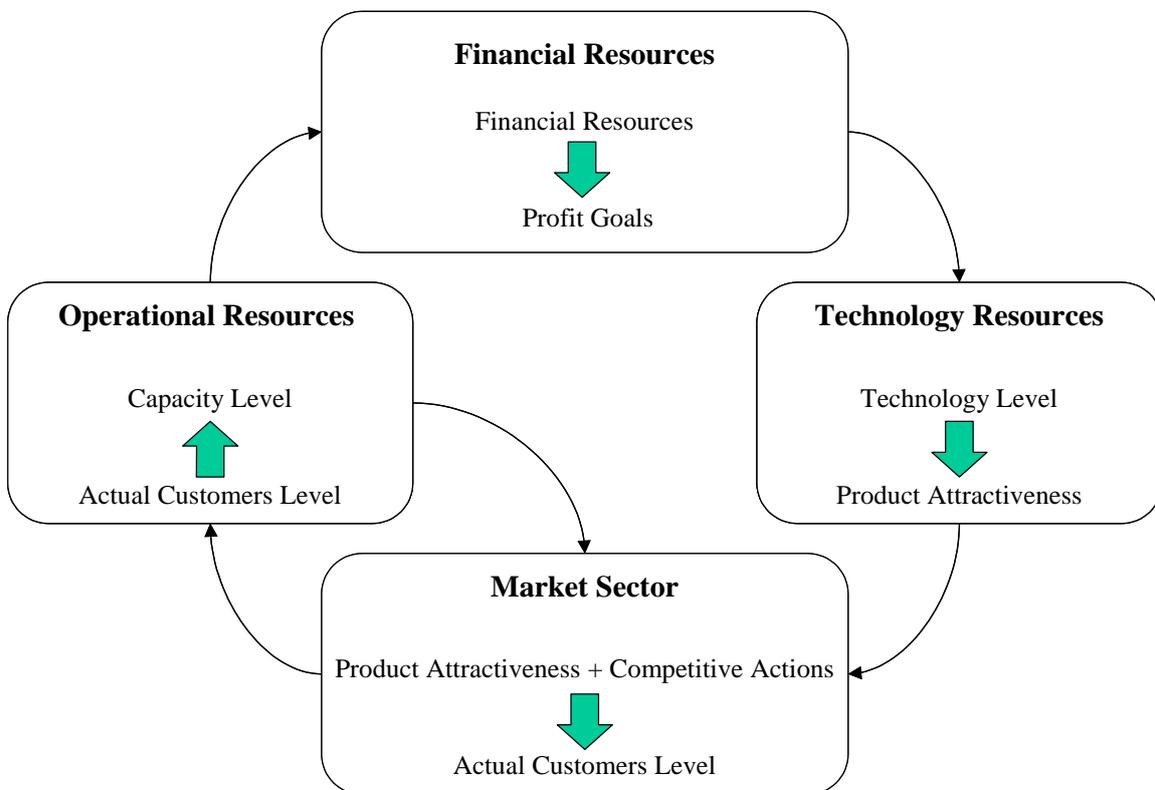




Figure 3. Market evolution under the initial conditions – Industry equilibrium

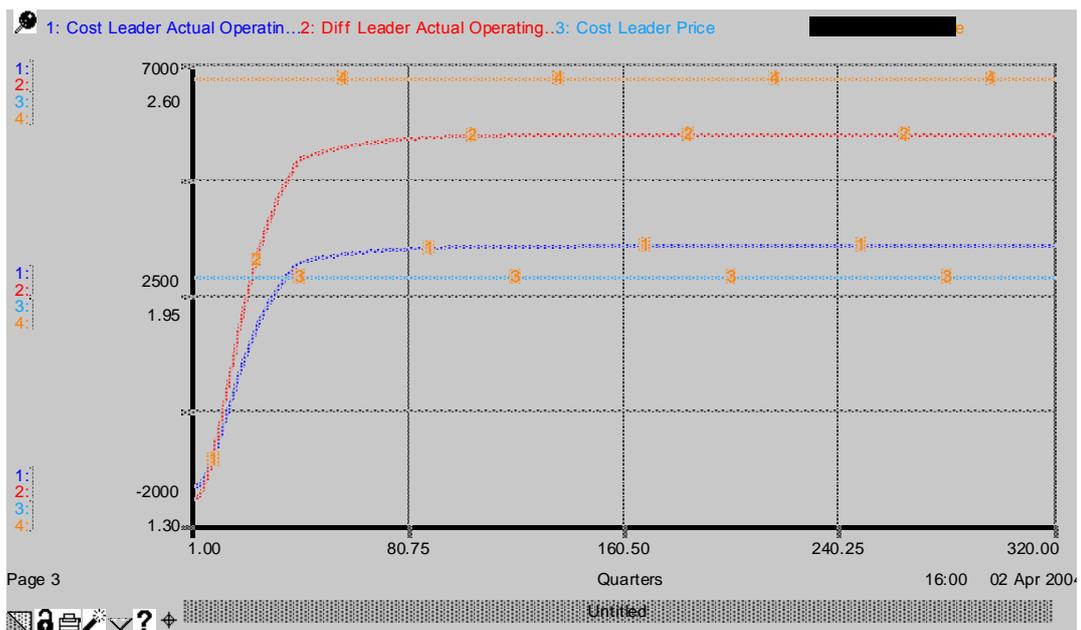


Figure 4. Cost Leader operating income (line 1) and price (line 3) and Differentiation Leader operating income (line 2) and price (line 4).

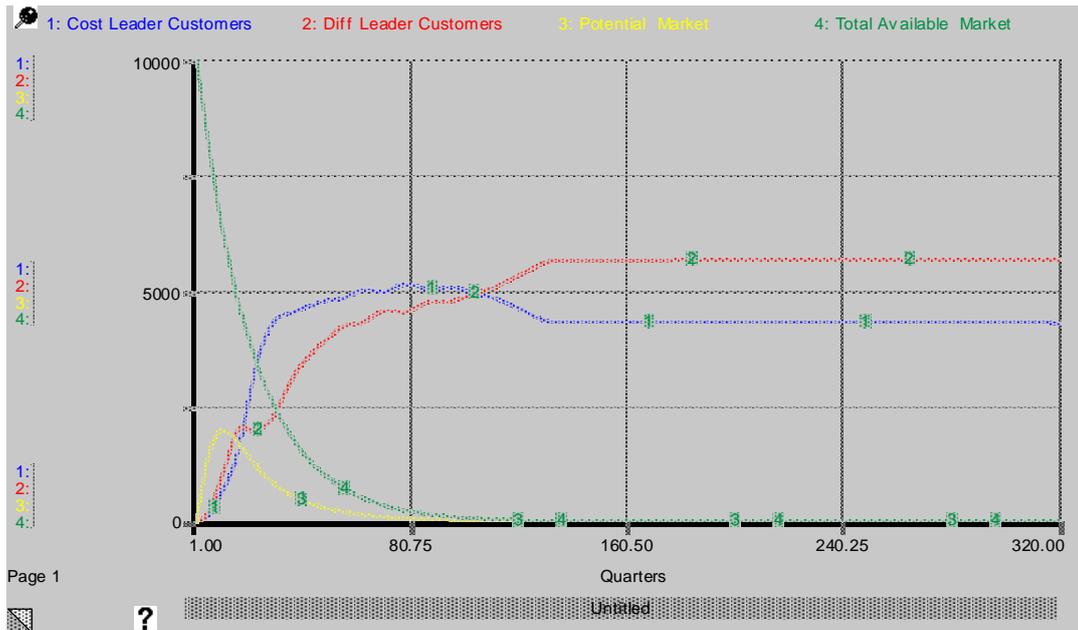


FIGURE 5. Market Evolution with only a Differentiation (line 2) and Cost Leader (line 1).

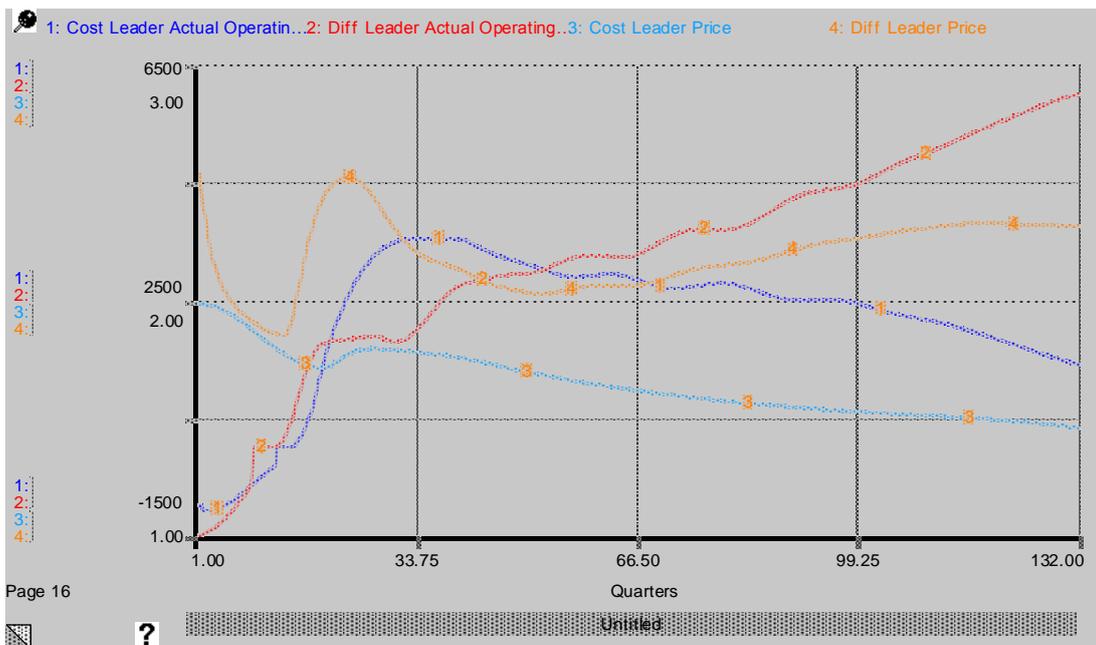


Figure 6. Cost Leader operating income (line 1) and price (line 3) and Differentiation Leader operating income (line 2) and price (line 4).

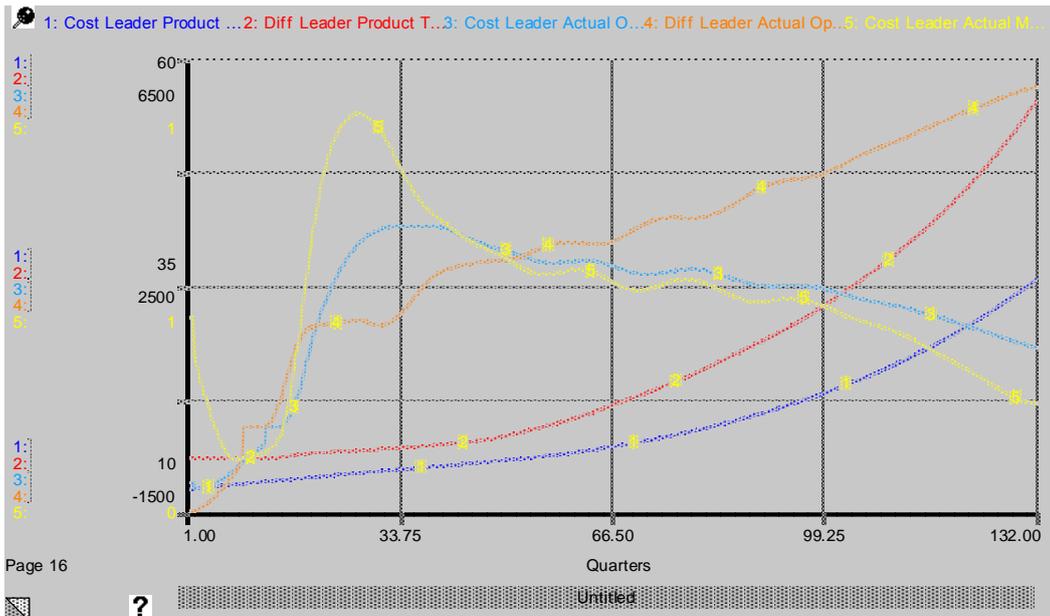


Figure 7. Cost Leader technology (line 1) and operating income (line 3) and Differentiation Leader product technology (line 2) and operating income (line 4).

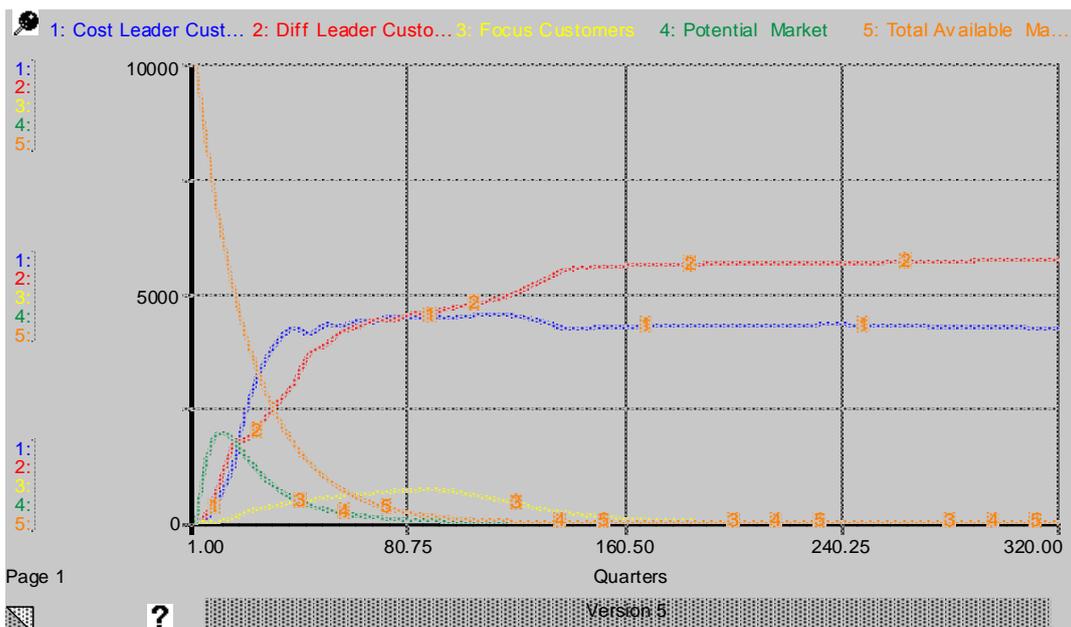


Figure 8. Evolution of the market with three firms: cost leader (line 1), differentiation leader (line 2) and focus (line 3).



Figure 9. Cost Leader price (line 1), Differentiation Leader Price (line 2), and Focus price (line 3) and market share (line 4)

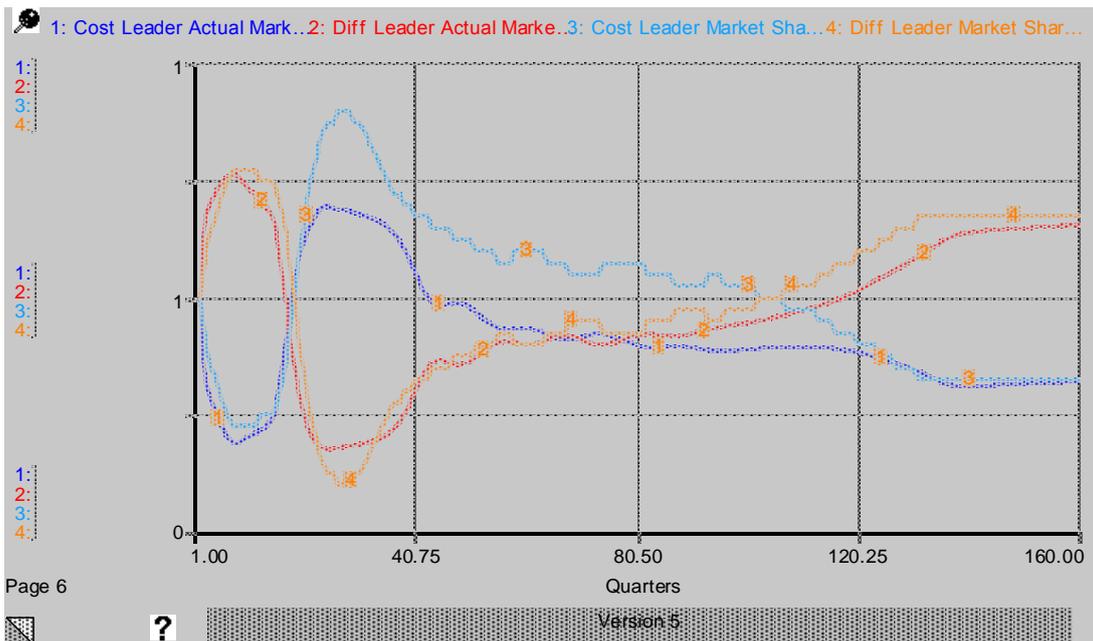
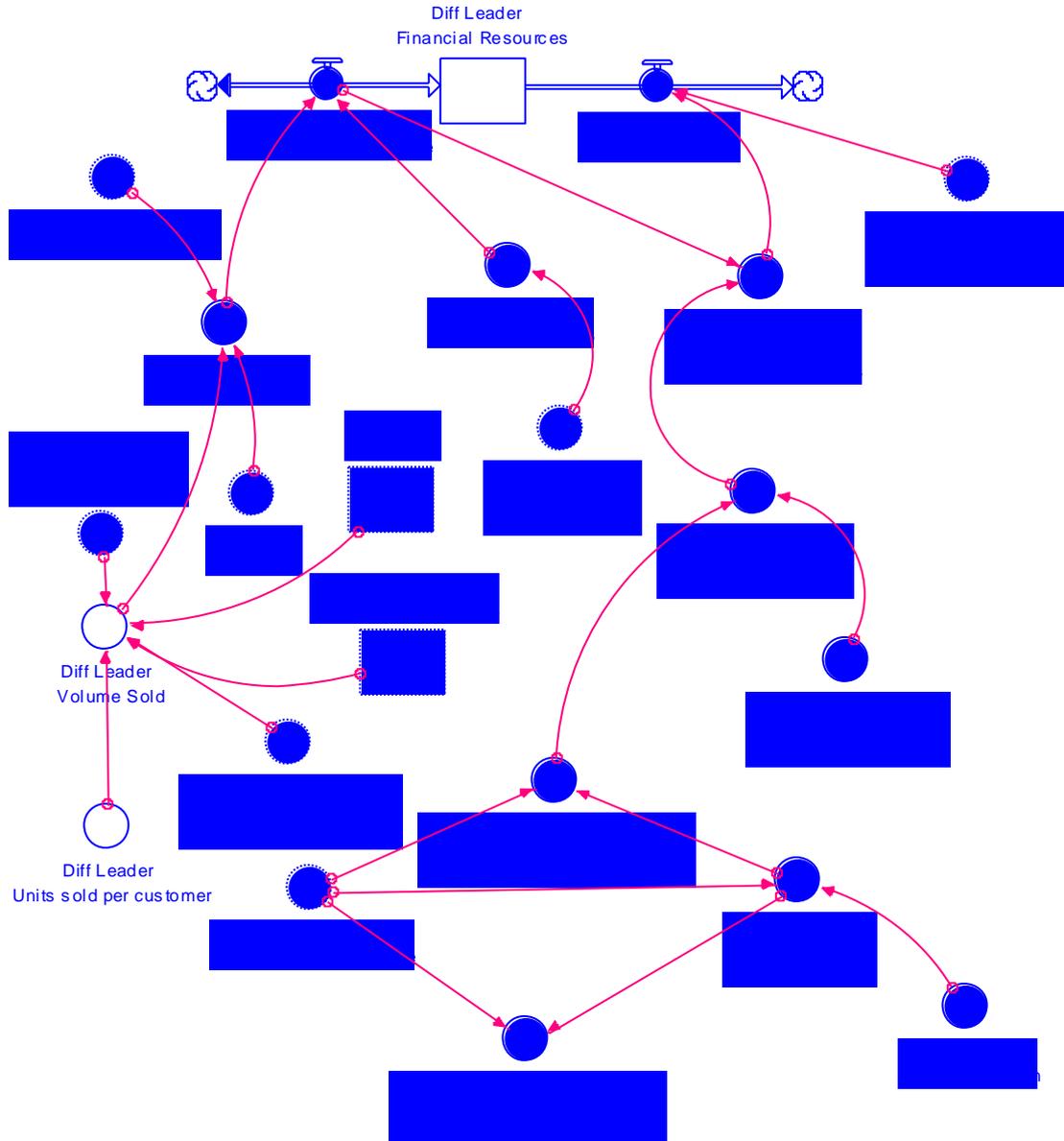


Figure 10. Cost Leader market share with Focus (line 1) and without Focus (line 3), and Differentiation Leader market share with Focus (line 2) and without Focus (line 4)

Appendix 1

FINANCIAL SECTOR



$$\text{Diff_Leader_Financial_Resources}(t) = \text{Diff_Leader_Financial_Resources}(t - dt) + (\text{Diff_Leader_Actual_Operating_Income} - \text{Diff_Leader_Actual_Investments}) * dt$$

INIT Diff_Leader_Financial_Resources = 10000

INFLOWS:

$$\text{Diff_Leader_Actual_Operating_Income} = \text{Diff_Leader_Margin_Contribution} - \text{Diff_Leader_Operating_Expenses}$$

OUTFLOWS:

$$\text{Diff_Leader_Actual_Investments} = \text{Diff_Leader_Investment_Rate_in_Operational_Resources} + \text{Diff_Leader_Investment_Allocation_in_Technology_Resources}$$

$$\text{Diff_Leader_Actual_Investment_Rate_in_Technology} =$$

$$\text{Diff_Leader_Normal_Investment_Rate_in_Technology} * \text{Diff_Leader_Effect_of_Operating_Income_Trend_on_Investment_Rates}$$

Diff_Leader_Established__Operating_Income =
 SMTH1(Diff_Leader_Actual_Operating_Income,Diff_Leader_Planning_Horizon)
 Diff_Leader_Investment_Allocation_in_Technology_Resources =
 Diff_Leader_Actual_Operating_Income*Diff_Leader_Actual_Investment_Rate_in_Technology
 Diff_Leader_Normal_Investment_Rate_in_Technology = 0.1
 Diff_Leader_Planning_Horizon = 8
 Diff_Leader__Operating_Expenses = Diff_Leader_Normal_Advertising_Expenditure
 Diff_Leader__Margin_Contribution = (Diff_Leader_Price-
 Diff_Leader_Unit_Costs_of_Goods_Sold)*MIN((Diff_Leader_Customers+Differentiation_Leader_Adoption_
 Rate),Diff_Leader_Operational_Resources*Diff_Leader_Actual_Productivity_per_Unit_of_Operational_Reso
 urce)
 Diff_Leader_Effect_of_Operating_Income_Trend_on_Investment_Rates =
 GRAPH(Diff_Leader_Actual_Operating_Income/Diff_Leader_Established__Operating_Income)
 (0.8, 1.50), (0.84, 1.37), (0.88, 1.25), (0.92, 1.15), (0.96, 1.02), (1.00, 1.00), (1.04, 0.975), (1.08, 0.85), (1.12,
 0.74), (1.16, 0.615), (1.20, 0.5)
 Diff_Leader_Effect_of_Operating_Income_Trend_on_Op_Efficiency =
 GRAPH(Diff_Leader_Actual_Operating_Income/Diff_Leader_Established__Operating_Income)
 (0.8, 0.1), (0.84, 0.112), (0.88, 0.116), (0.92, 0.122), (0.96, 0.126), (1.00, 0.14), (1.04, 0.176), (1.08, 0.224),
 (1.12, 0.278), (1.16, 0.354), (1.20, 0.5)

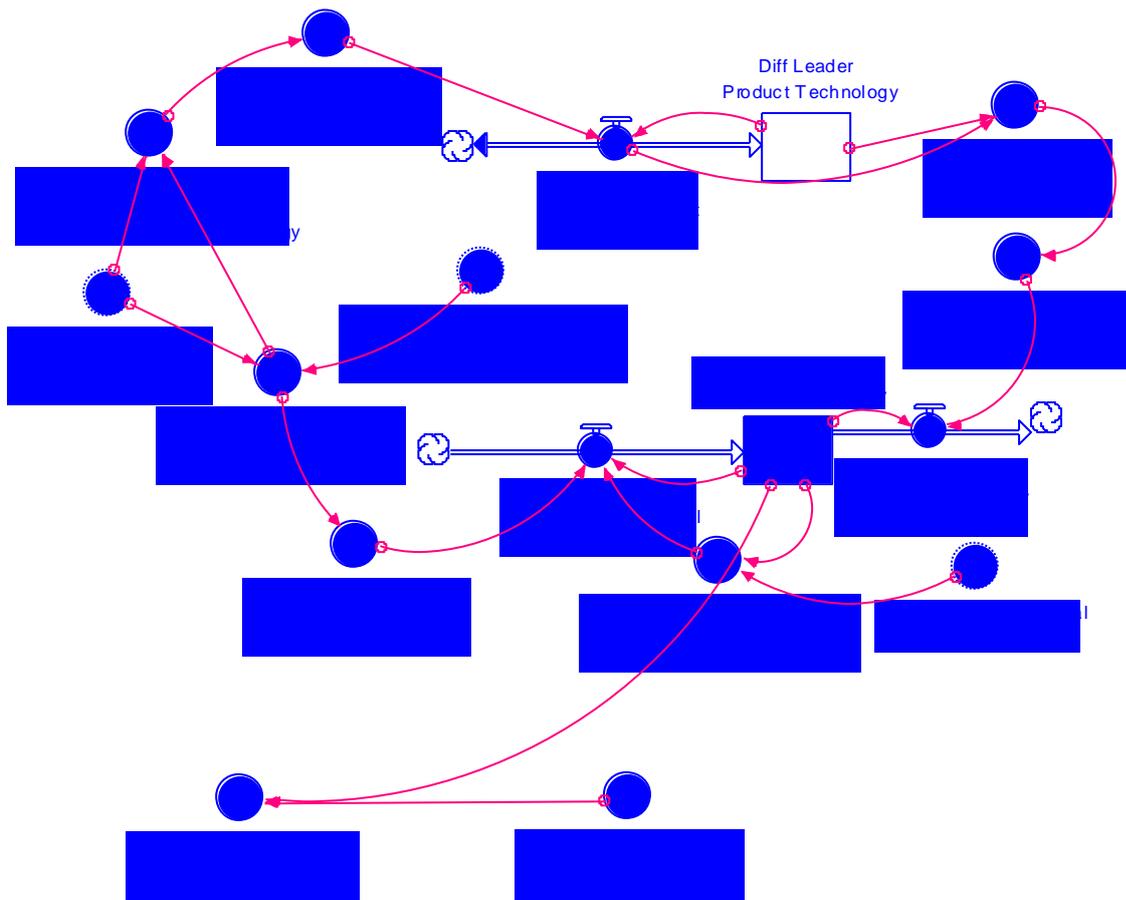
Cost_Leader_Financial_Resources(t) = Cost_Leader_Financial_Resources(t - dt) +
 (Cost_Leader_Actual_Operating_Income - Cost_Leader_Actual_Investments) * dt
 INIT Cost_Leader_Financial_Resources = 10000
 INFLOWS:
 Cost_Leader_Actual_Operating_Income = Cost_Leader__Contribution_Margin-
 Cost_Leader__Operating_Expenses
 OUTFLOWS:
 Cost_Leader_Actual_Investments =
 Cost_Leader_Investment_Allocation_in_Technology_Resources+Cost_Leader_Investment_Rate_in_Oper
 ational_Resources
 Cost_Leader_Actual_Investment_Rate_in_Technology =
 Cost_Leader_Normal_Investment_Rate_in_Technology*Cost_Leader_Effect_of_Operating_Income_Trend_o
 n_Investment_Rates
 Cost_Leader_Established__Operating_Income =
 SMTH1(Cost_Leader_Actual_Operating_Income,Cost_Leader_Planning_Horizon)
 Cost_Leader_Fraction_of_Resources_invested_in_Op_Efficiency = 1-
 Cost_Leader_Effect_of_Perceived_Technological_Gap_on_Investment
 Cost_Leader_Investment_Allocation_in_Technology_Resources =
 Cost_Leader_Actual_Operating_Income*Cost_Leader_Actual_Investment_Rate_in_Technology
 Cost_Leader_Normal_Investment_Rate_in_Technology = 0.1
 Cost_Leader__Contribution_Margin = (Cost_Leader_Price-
 Cost_Leader_Unit_Costs_of_Goods_Sold)*MIN((Cost_Leader_Customers+Cost_Leader_Adoption_Rate),
 Cost_Leader_Operational_Resources*Cost_Leader_Actual_Productivity_per_Unit_of_Operational_Resource)
 Cost_Leader__Operating_Expenses = Cost_Leader_Advertising_Expenditure_Level
 Cost_Leader_Effect_of_Operating_Income_Trend_on_Investment_Rates =
 GRAPH(Cost_Leader_Actual_Operating_Income/Cost_Leader_Established__Operating_Income)
 (0.8, 1.50), (0.84, 1.37), (0.88, 1.25), (0.92, 1.15), (0.96, 1.02), (1.00, 1.00), (1.04, 0.975), (1.08, 0.85), (1.12,
 0.74), (1.16, 0.615), (1.20, 0.5)

Focus Management Goal and Financial Resources

Focus_Financial_Resources(t) = Focus_Financial_Resources(t - dt) + (Focus_Actual_Operating_Income -
 Focus_Actual_Investments) * dt
 INIT Focus_Financial_Resources = 5000
 INFLOWS:
 Focus_Actual_Operating_Income = Focus_Contribution
 OUTFLOWS:
 Focus_Actual_Investments = Focus_Actual_Investment_in_Technology
 Focus_Actual_Investment_in_Technology =

$\text{Focus_Financial_Resources} * \text{Focus_Investment_in_Technology_Normal_Rate} * \text{Focus_Effect_of_Market_Size_Achievement}$
 $\text{Focus_Contribution} = (\text{Focus_Price} - \text{Focus_Unit_Cost_of_Goods_Sold}) * (\text{Focus_Customers} + \text{Segment_Customers_Driven_by_Functionality_Switching_Rate} + \text{Segment_Customers_Driven_by_Price_Switching_Rate})$
 $\text{Focus_Investment_in_Technology_Normal_Rate} = 0.1$
 $\text{Focus_Effect_of_Market_Size_Achievement} = \text{GRAPH}(\text{Focus_Customers}/\text{Focus_Estimated_Size_Market_Segment})$
 (0.8, 1.50), (0.84, 1.41), (0.88, 1.31), (0.92, 1.18), (0.96, 1.10), (1.00, 1.00), (1.04, 0.86), (1.08, 0.685), (1.12, 0.62), (1.16, 0.56), (1.20, 0.5)
 $\text{Focus_Estimated_Size_Market_Segment} = \text{GRAPH}(\text{TIME})$
 (1.00, 10.0), (12.9, 195), (24.8, 335), (36.7, 495), (48.6, 615), (60.5, 720), (72.4, 825), (84.3, 905), (96.2, 965), (108, 995), (120, 1000)
 $\text{Focus_Expected_Rate_of_Change_in_Product_Technology} = \text{GRAPH}(\text{Focus_Actual_Investment_in_Technology})$
 (0.00, 0.00), (100, 0.00555), (200, 0.0101), (300, 0.0135), (400, 0.0172), (500, 0.021), (600, 0.0243), (700, 0.0268), (800, 0.0286), (900, 0.0297), (1000, 0.03)
 $\text{Focus_Short_term_Gross_Margin} = \text{GRAPH}(\text{Focus_Customers}/\text{Focus_Estimated_Size_Market_Segment})$
 (0.8, 0.6), (0.84, 0.681), (0.88, 0.795), (0.92, 0.939), (0.96, 1.03), (1.00, 1.10), (1.04, 1.15), (1.08, 1.17), (1.12, 1.19), (1.16, 1.20), (1.20, 1.20)

TECHNOLOGY SECTOR



$$\begin{aligned}
 \text{Diff_Leader_Operational_Efficiency}(t) = & \text{Diff_Leader_Operational_Efficiency}(t - dt) + \\
 & (\text{Diff_Leader_Increase_in_Operational_Efficiency_Rate} - \\
 & \text{Diff_Leader_Operational_Efficiency_Decrease_Rate}) * dt
 \end{aligned}$$

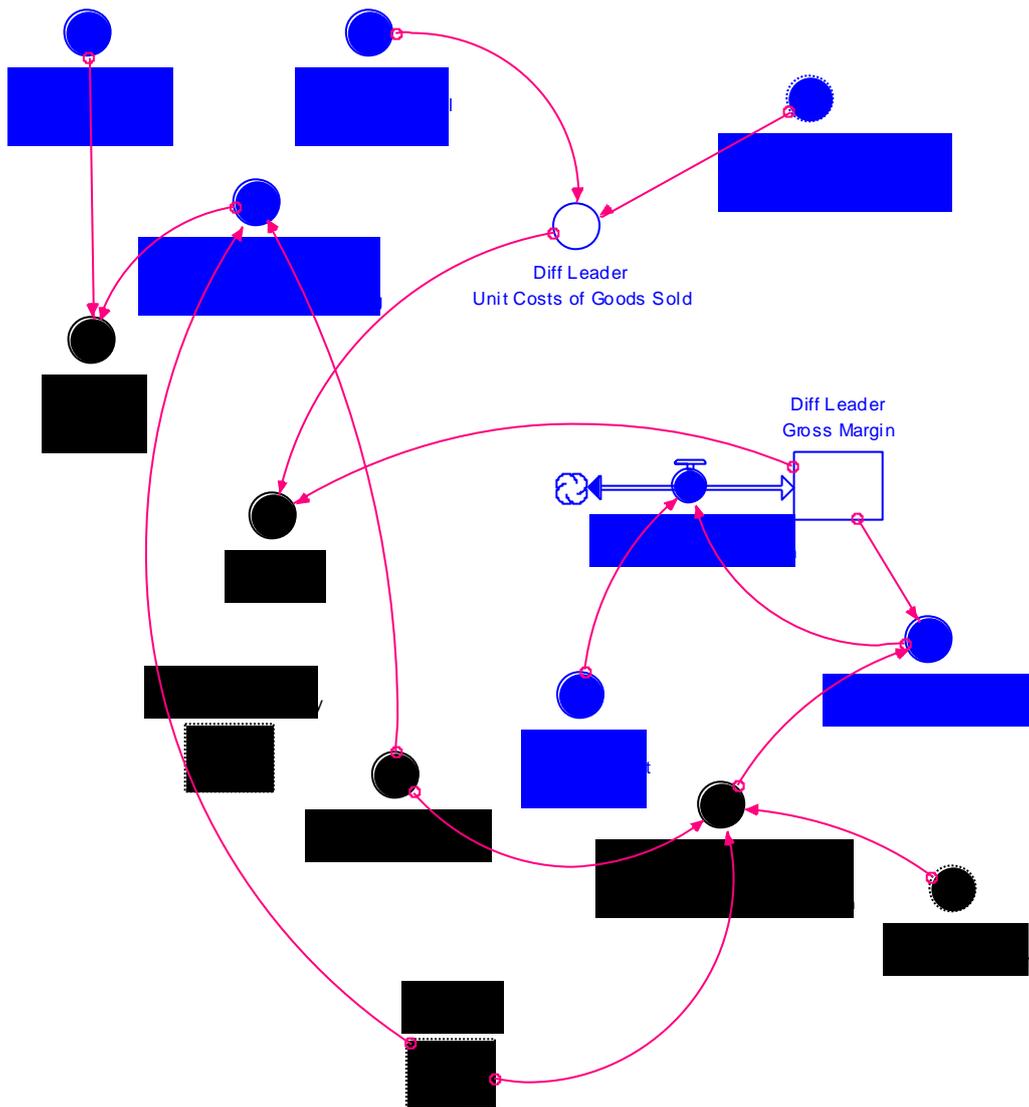
INIT Diff_Leader_Operational_Efficiency = 1
 INFLOWS:
 Diff_Leader_Increase_in_Operational_Efficiency_Rate =
 (Diff_Leader_Operational_Efficiency*Diff_Leader_Operational_Improvements_Increase_Rate)*Effect_of
 _limit_in_Technological_Efficiency_over_Improvements_2
 OUTFLOWS:
 Diff_Leader_Operational_Efficiency_Decrease_Rate =
 Diff_Leader_Operational_Efficiency*Diff_Leader_Technology_Change_Effect__on_Operational_Efficien
 cy
 Diff_Leader_Product_Technology(t) = Diff_Leader_Product_Technology(t - dt) +
 (Diff_Leader_Change_in_Product_Technology_Rate) * dt
 INIT Diff_Leader_Product_Technology = 16
 INFLOWS:
 Diff_Leader_Change_in_Product_Technology_Rate =
 Diff_Leader_Product_Technology*Diff_Leader_Expected_Rate_of_Change_in_Product_Technology
 Differentiation_Leader_Product_Technology_Relative_Change =
 Diff_Leader_Change_in_Product_Technology_Rate/Diff_Leader_Product_Technology
 Diff_Leader_Financial_Resources_allocated_to_Op_Improvement =
 Diff_Leader_Investment_Allocation_in_Technology_Resources*Diff_Leader_Effect_of_Operating_Income_T
 rend_on_Op_Efficiency
 Diff_Leader_Financial_Resources_allocated_to_Product_Technology =
 Diff_Leader_Investment_Allocation_in_Technology_Resources-
 Diff_Leader_Financial_Resources_allocated_to_Op_Improvement
 Diff_Leader_Expected_Rate_of_Change_in_Product_Technology =
 GRAPH(Diff_Leader_Financial_Resources_allocated_to_Product_Technology)
 (0.00, 0.00), (100, 0.00555), (200, 0.0101), (300, 0.0135), (400, 0.0172), (500, 0.021), (600, 0.0243), (700,
 0.0268), (800, 0.0286), (900, 0.0297), (1000, 0.03)
 Diff_Leader_Operational_Improvements_Increase_Rate =
 GRAPH(Diff_Leader_Financial_Resources_allocated_to_Op_Improvement)
 (0.00, 0.0005), (100, 0.00325), (200, 0.0065), (300, 0.011), (400, 0.0148), (500, 0.0203), (600, 0.031), (700,
 0.0403), (800, 0.0452), (900, 0.0495), (1000, 0.05)
 Diff_Leader_Technology_Change_Effect__on_Operational_Efficiency =
 GRAPH(Differentiation_Leader_Product_Technology_Relative_Change)
 (0.00, 0.00), (0.1, 0.0005), (0.2, 0.0025), (0.3, 0.0045), (0.4, 0.0075), (0.5, 0.013), (0.6, 0.0203), (0.7, 0.0288),
 (0.8, 0.037), (0.9, 0.0445), (1, 0.05)
 Effect_of_limit_in_Technological_Efficiency_over_Improvements_2 =
 GRAPH(Diff_Leader_Operational_Efficiency/Maximum_Technological_Efficiency)
 (0.00, 1.00), (0.1, 0.995), (0.2, 0.975), (0.3, 0.925), (0.4, 0.81), (0.5, 0.63), (0.6, 0.46), (0.7, 0.355), (0.8, 0.2),
 (0.9, 0.075), (1, 0.00)

Cost_Leader_Operational_Efficiency(t) = Cost_Leader_Operational_Efficiency(t - dt) +
 (Cost_Leader_Increase_in_Operational_Efficiency_Rate -
 Cost_Leader_Operational_Efficiency_Decrease_Rate) * dt
 INIT Cost_Leader_Operational_Efficiency = 1
 INFLOWS:
 Cost_Leader_Increase_in_Operational_Efficiency_Rate =
 Cost_Leader_Operational_Efficiency*Cost_Leader_Operational_Improvements_Increase_Rate*Effect_of_
 technological_limits_in_the_improvement_of_Efficiency
 OUTFLOWS:
 Cost_Leader_Operational_Efficiency_Decrease_Rate =
 Cost_Leader_Operational_Efficiency*Cost_Leader_Technology_Change_Effect__on_Operational_Efficie
 ncy
 Cost_Leader_Product_Technology(t) = Cost_Leader_Product_Technology(t - dt) +
 (Cost_Leader_Change_in_Product_Technology_Rate) * dt
 INIT Cost_Leader_Product_Technology = 12.5
 INFLOWS:
 Cost_Leader_Change_in_Product_Technology_Rate =
 (Cost_Leader_Technology_Gap/Cost_Leader_Time_to_adjust_Technology_Gap)
 Cost_Leader_Financial_Resources_allocated_to_Op_Improvement =

$Cost_Leader_Investment_Allocation_in_Technology_Resources - Cost_Leader_Financial_Resources_allocated_to_Product_Technology$
 $Cost_Leader_Financial_Resources_allocated_to_Product_Technology = Cost_Leader_Investment_Allocation_in_Technology_Resources * Cost_Leader_Effect_of_Perceived_Technological_Gap_on_Investment$
 $Cost_Leader_Product_Technology_Relative_Change = Cost_Leader_Change_in_Product_Technology_Rate / Cost_Leader_Product_Technology$
 $Cost_Leader_Technology_Gap = Diff_Leader_Product_Technology - Cost_Leader_Product_Technology$
 $Maximum_Technological_Efficiency = 1.5$
 $Cost_Leader_Effect_of_Perceived_Technological_Gap_on_Investment = GRAPH((Diff_Leader_Product_Technology) / Cost_Leader_Product_Technology)$
(1.00, 0.05), (1.05, 0.0775), (1.10, 0.083), (1.15, 0.0885), (1.20, 0.0912), (1.25, 0.0995), (1.30, 0.122), (1.35, 0.165), (1.40, 0.223), (1.45, 0.33), (1.50, 0.6)
 $Cost_Leader_Operational_Improvements_Increase_Rate = GRAPH(Cost_Leader_Financial_Resources_allocated_to_Op_Improvement)$
(0.00, 0.0005), (100, 0.00325), (200, 0.0065), (300, 0.011), (400, 0.0148), (500, 0.0203), (600, 0.031), (700, 0.0403), (800, 0.0452), (900, 0.0495), (1000, 0.05)
 $Cost_Leader_Technology_Change_Effect_on_Operational_Efficiency = GRAPH(Cost_Leader_Product_Technology_Relative_Change)$
(0.00, 0.00), (0.1, 0.001), (0.2, 0.003), (0.3, 0.005), (0.4, 0.008), (0.5, 0.013), (0.6, 0.02), (0.7, 0.029), (0.8, 0.037), (0.9, 0.045), (1, 0.05)
 $Cost_Leader_Time_to_adjust_Technology_Gap = GRAPH(Cost_Leader_Financial_Resources_allocated_to_Product_Technology)$
(0.00, 40.0), (100, 37.0), (200, 33.0), (300, 28.0), (400, 22.0), (500, 17.0), (600, 13.0), (700, 10.0), (800, 8.00), (900, 6.00), (1000, 4.00)
 $Effect_of_technological_limits_in_the_improvement_of_Efficiency = GRAPH(Cost_Leader_Operational_Efficiency / Maximum_Technological_Efficiency)$
(0.00, 1.00), (0.1, 0.995), (0.2, 0.975), (0.3, 0.925), (0.4, 0.81), (0.5, 0.63), (0.6, 0.46), (0.7, 0.355), (0.8, 0.2), (0.9, 0.075), (1, 0.00)

MARKET DEVELOPMENT DRIVERS AND CONSUMER COMPETITION

Market Development Drivers at potential adopters level.



Differentiation Leader Market Development Drivers

Diff_Leader_Advertising_Expenditure =

(Diff_Leader_Effect_of_Management_Goal_Achievement_on_Advertising*Diff_Leader_Normal_Advertising_Expenditure)

Diff_Leader_Normal_Advertising_Expenditure = 1500

Diff_Leader_Price = Diff_Leader_Unit_Costs_of_Goods_Sold*(1+Diff_Leader_Gross_Margin)

Diff_Leader_Unit_Costs_of_Goods_Sold =

(Diff_Leader_Basic_Operational_Cost_per_Unit)/Diff_Leader_Actual_Productivity_per_Unit_of_Operational_Resource

Diff_Leader_Basic_Operational_Cost_per_Unit = GRAPH(Diff_Leader_Operational_Resources)

(0.00, 1.00), (500, 0.983), (1000, 0.969), (1500, 0.956), (2000, 0.94), (2500, 0.931), (3000, 0.924), (3500, 0.918), (4000, 0.917), (4500, 0.917), (5000, 0.917)

Diff_Leader_Effect_of_Management_Goal_Achievement_on_Advertising =

GRAPH(Diff_Leader_Customers/Diff_Leader_Expected_Market_Size)

(0.8, 1.60), (0.84, 1.59), (0.88, 1.59), (0.92, 1.57), (0.96, 1.55), (1.00, 1.51), (1.04, 1.45), (1.08, 1.39), (1.12, 1.32), (1.16, 1.20), (1.20, 1.00)

Diff_Leader_Expected_Market_Size = GRAPH(TIME)

(0.00, 1.00), (8.00, 500), (16.0, 1625), (24.0, 2350), (32.0, 3025), (40.0, 4025), (48.0, 4550), (56.0, 4825), (64.0, 5000), (72.0, 5000), (80.0, 5000)

Diff_Leader_Gross_Margin =

GRAPH(SMTH1((Diff_Leader_Customers/Diff_Leader_Expected_Market_Size),Diff_Leader_Planning_Horizon))

(0.8, 1.00), (0.84, 1.11), (0.88, 1.38), (0.92, 1.54), (0.96, 1.68), (1.00, 1.76), (1.04, 1.78), (1.08, 1.79), (1.12,

1.79), (1.16, 1.80), (1.20, 1.80)

Cost Leader Market Development Drivers

Cost_Leader_Actual_Advertising_Expenditure = 1000

Cost_Leader_Actual_Market_Share =

$$(Cost_Leader_Customers)/(Diff_Leader_Customers+Focus_Customers+Cost_Leader_Customers)$$

Cost_Leader_Advertising_Expenditure_Level =

$$Cost_Leader_Effect_of_Management_Goal_Achievement_on_Advertising * Cost_Leader_Actual_Advertising_Expenditure$$

Cost_Leader_Expected_Market_Share = 0.5

Cost_Leader_Price = Cost_Leader_Unit_Costs_of_Goods_Sold*(1+Cost_Leader_Gross_Margin)

Cost_Leader_Unit_Costs_of_Goods_Sold =

$$((Cost_Leader_Basic_Operational_Cost_per_Unit)/Cost_Leader_Actual_Productivity_per_Unit_of_Operational_Resource)$$

Diff_Leader_Actual_Market_Share =

$$(Diff_Leader_Customers)/(Cost_Leader_Customers+Diff_Leader_Customers+Focus_Customers)$$

Focus_Actual_Market_Share = 1-Cost_Leader_Actual_Market_Share-Diff_Leader_Actual_Market_Share

Total_Consumers = Focus_Customers+Cost_Leader_Customers+Diff_Leader_Customers

Cost_Leader_Basic_Operational_Cost_per_Unit = GRAPH(Cost_Leader_Operational_Resources)

(0.00, 1.00), (500, 0.983), (1000, 0.969), (1500, 0.956), (2000, 0.94), (2500, 0.931), (3000, 0.924), (3500, 0.918), (4000, 0.917), (4500, 0.917), (5000, 0.917)

Cost_Leader_Effect_of_Management_Goal_Achievement_on_Advertising =

$$GRAPH(Cost_Leader_Actual_Market_Share/Cost_Leader_Expected_Market_Share)$$

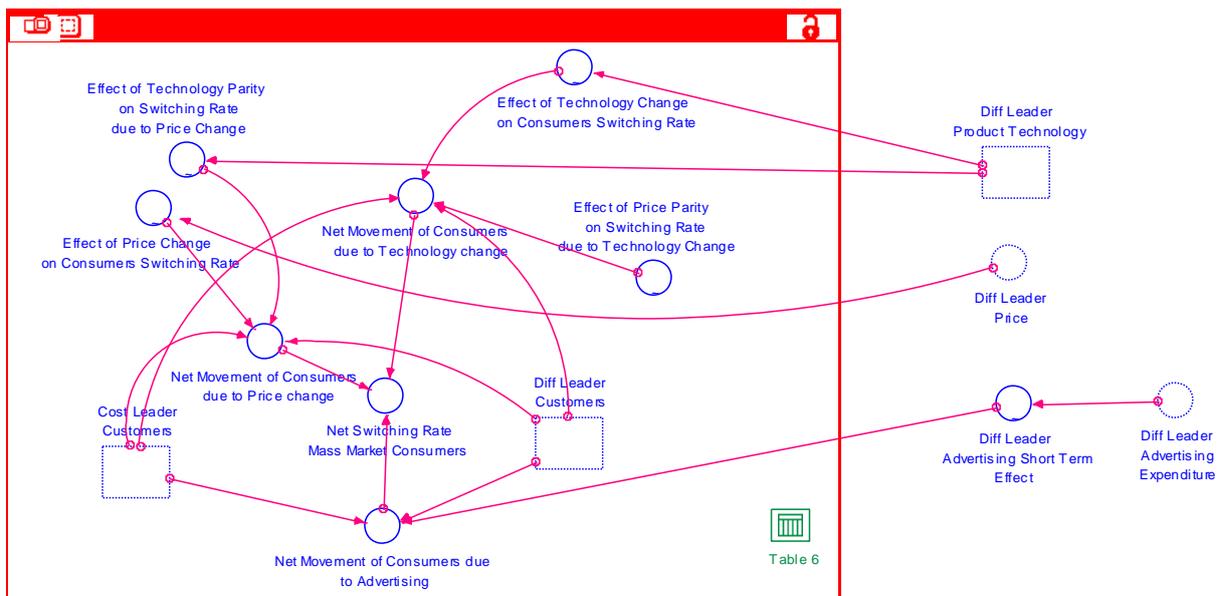
(0.8, 1.20), (0.84, 1.18), (0.88, 1.15), (0.92, 1.10), (0.96, 1.05), (1.00, 0.979), (1.04, 0.853), (1.08, 0.714), (1.12, 0.626), (1.16, 0.535), (1.20, 0.5)

Cost_Leader_Gross_Margin =

$$GRAPH(SMTH1(Cost_Leader_Actual_Market_Share/Cost_Leader_Expected_Market_Share, Cost_Leader_Planning_Horizon))$$

(0.8, 0.8), (0.84, 0.853), (0.88, 0.892), (0.92, 0.94), (0.96, 0.969), (1.00, 0.992), (1.04, 0.998), (1.08, 1.00), (1.12, 1.00), (1.16, 1.00), (1.20, 1.00)

Competitive Actions at consumer competition level.



Cost Leader Competitive Drivers

Cost_Leader_Advertising_Short_Term_Effect = GRAPH(Cost_Leader_Advertising_Expenditure_Level)

(0.00, -0.1), (30.0, -0.08), (60.0, -0.05), (90.0, 0.00), (120, 0.03), (150, 0.06), (180, 0.07), (210, 0.08), (240, 0.08),

(270, 0.08), (300, 0.08)

Differentiation Leader Competitive Drivers

Diff_Leader_Advertising_Short_Term_Effect = GRAPH(Diff_Leader_Advertising_Expenditure)

(0.00, -0.1), (30.0, -0.08), (60.0, -0.05), (90.0, 0.00), (120, 0.03), (150, 0.06), (180, 0.07), (210, 0.08), (240, 0.08), (270, 0.08), (300, 0.08)

Focus Competitor Competitive Drivers

Focus_Product_Technology(t) = Focus_Product_Technology(t - dt) +
(Focus_Change_in_Product_Technology_Rate) * dt

INIT Focus_Product_Technology = 14

INFLOWS:

Focus_Change_in_Product_Technology_Rate =

(Focus_Technology_Gap*Focus_Expected_Rate_of_Change_in_Product_Technology)

Focus__Gross_Margin(t) = Focus__Gross_Margin(t - dt) + (Focus_Gross_Margin_Change_Rate) * dt

INIT Focus__Gross_Margin = 1.1

INFLOWS:

Focus_Gross_Margin_Change_Rate = Focus_Gross_Margin_Adjustment

Focus_Expected_Consumers_Technological_Requirements =

Diff_Leader_Product_Technology/Focus_Segment_Consumers__Requirements_respect_to_best_technology

Focus_Gross_Margin_Adjustment = Focus_Short_term_Gross_Margin-Focus__Gross_Margin

Focus_Price = Focus__Unit_Cost_of_Goods_Sold*(1+Focus__Gross_Margin)

Focus_Segment_Consumers__Requirements_respect_to_best_technology = 1.07

Focus_Technology_Gap = Focus_Expected_Consumers_Technological_Requirements-
Focus_Product_Technology

Focus__Unit_Cost_of_Goods_Sold = GRAPH(Focus_Customers)

(0.00, 1.00), (500, 0.983), (1000, 0.969), (1500, 0.956), (2000, 0.94), (2500, 0.931), (3000, 0.924), (3500, 0.918), (4000, 0.917), (4500, 0.917), (5000, 0.917)

Consumer Competition between Differentiation Leader and Focus

Net_Segment_Consumers_Movement_Focus_vs_Diff =

IF(Net_effect_of_Technology_Change_on_Segment_Consumers_Switching>=0)THEN(Diff_Leader_Customers*Net_effect_of_Technology_Change_on_Segment_Consumers_Switching*Effect_of_Price_Parity_on_Segment_Consumers_Switching_Rate)ELSE(Focus_Customers*Net_effect_of_Technology_Change_on_Segment_Consumers_Switching*(1/Effect_of_Price_Parity_on_Segment_Consumers_Switching_Rate))

Effect_of_Price_Parity_on_Segment_Consumers_Switching_Rate = GRAPH(Focus_Price/Diff_Leader_Price)
(0.57, 0.695), (0.62, 0.756), (0.67, 0.817), (0.72, 0.878), (0.77, 0.939), (0.82, 1.00), (0.87, 1.06), (0.92, 1.12), (0.97, 1.18), (1.02, 1.24), (1.07, 1.30)

Net_effect_of_Technology_Change_on_Segment_Consumers_Switching =

GRAPH(Focus_Product_Technology/Diff_Leader_Product_Technology)

(0.625, -0.028), (0.675, -0.022), (0.725, -0.016), (0.775, -0.01), (0.825, -0.005), (0.875, 0.00), (0.925, 0.005), (0.975, 0.01), (1.03, 0.014), (1.08, 0.018), (1.13, 0.023)

Consumer Competition between Focus and Cost Leader

Net_Segment_Consumers_Movement_Focus_vs_Cost =

(IF(Net_effect_of_Price_Change_on_Segment_Consumers_Switching_Rate>=0)THEN(Cost_Leader_Customers*Net_effect_of_Price_Change_on_Segment_Consumers_Switching_Rate*Effect_of_Technology_Parity_on_Segment_Consumers_Switch_price)ELSE(Focus_Customers*Net_effect_of_Price_Change_on_Segment_Consumers_Switching_Rate*(1/Effect_of_Technology_Parity_on_Segment_Consumers_Switch_price)))

Effect_of_Technology_Parity_on_Segment_Consumers_Switch_price =

GRAPH(Focus_Product_Technology/Cost_Leader_Product_Technology)

(0.87, 0.972), (0.92, 0.978), (0.97, 0.984), (1.02, 0.99), (1.07, 0.995), (1.12, 1.00), (1.17, 1.00), (1.22, 1.01), (1.27, 1.01), (1.32, 1.02), (1.37, 1.02)

Net_effect_of_Price_Change_on_Segment_Consumers_Switching_Rate =

GRAPH(Focus_Price/Cost_Leader_Price)

(0.8, 0.029), (0.85, 0.023), (0.9, 0.016), (0.95, 0.011), (1.00, 0.005), (1.05, 0.00), (1.10, -0.005), (1.15, -0.009), (1.20, -0.014), (1.25, -0.018), (1.30, -0.022)

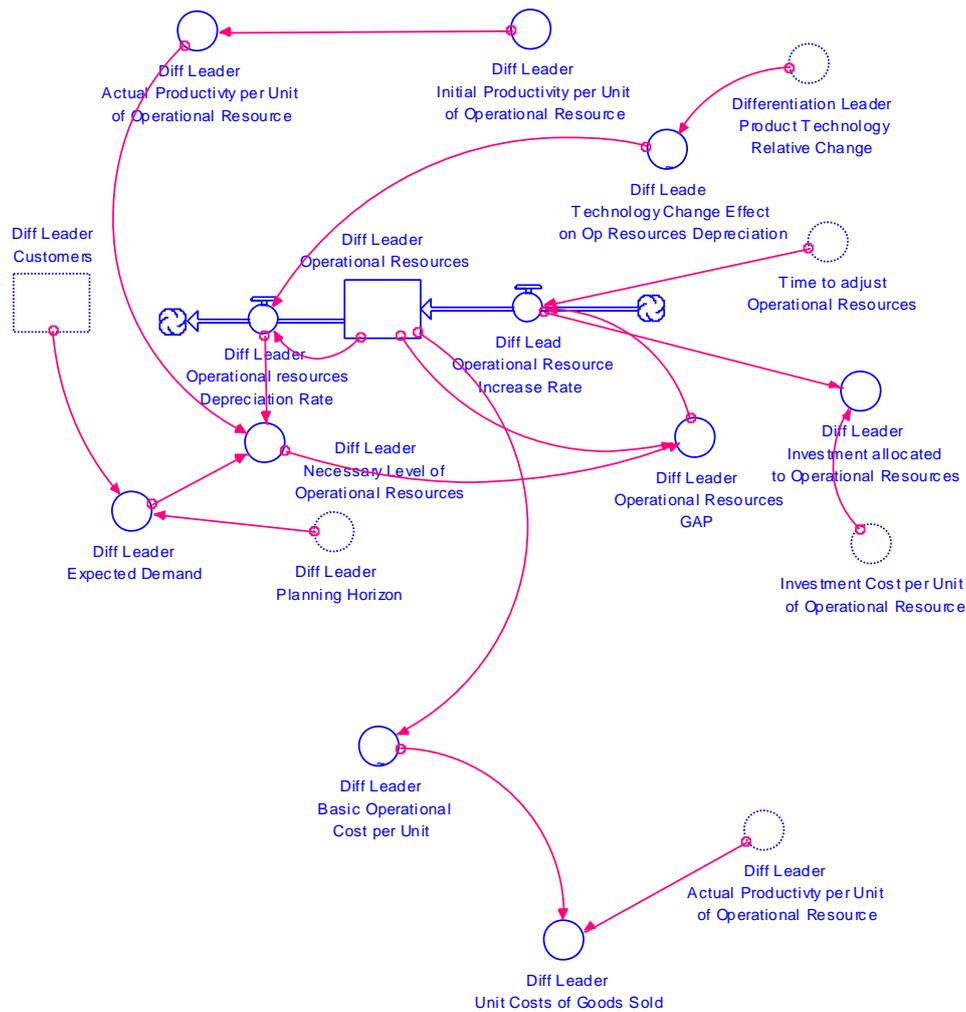
Consumer Competition Level Between Cost Leader and Diff Leader

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Net_Movement_of_Consumers_due_to_Advertising =
  (IF(Cost_Leader_Advertising_Short_Term_Effect>=0)THEN(-
  Diff_Leader_Customers*Cost_Leader_Advertising_Short_Term_Effect)ELSE(-
  Cost_Leader_Customers*Cost_Leader_Advertising_Short_Term_Effect))+
  (IF(Diff_Leader_Advertising_Short_Term_Effect>=0)THEN(Cost_Leader_Customers*Diff_Leader_Advertising_
  Short_Term_Effect)ELSE(Diff_Leader_Customers*Diff_Leader_Advertising_Short_Term_Effect))
Net_Movement_of_Consumers_due_to_Price_change =
  (IF(Effect_of_Price_Change_on_Consumers_Switching_Rate>=0)THEN(Cost_Leader_Customers*Effect_of_
  Price_Change_on_Consumers_Switching_Rate*Effect_of_Technology_Parity_on_Switching_Rate_due_to_Pr
  ice_Change)ELSE(Diff_Leader_Customers*Effect_of_Price_Change_on_Consumers_Switching_Rate*(1/Effe
  ct_of_Technology_Parity_on_Switching_Rate_due_to_Price_Change)) )
Net_Movement_of_Consumers_due_to_Technology_change =
  IF(Effect_of_Technology_Change_on_Consumers_Switching_Rate>=0)THEN(Cost_Leader_Customers*Effe
  ct_of_Technology_Change_on_Consumers_Switching_Rate*Effect_of_Price_Parity_on_Switching_Rate_due
  _to_Technology_Change)ELSE(Diff_Leader_Customers*Effect_of_Technology_Change_on_Consumers_Swi
  tching_Rate*(1/Effect_of_Price_Parity_on_Switching_Rate_due_to_Technology_Change))
Net_Switching_Rate_Mass_Market_Consumers = Net_Movement_of_Consumers_due_to_Price_change+
Net_Movement_of_Consumers_due_to_Technology_change+
Net_Movement_of_Consumers_due_to_Advertising
Effect_of_Price_Change_on_Consumers_Switching_Rate = GRAPH(Diff_Leader_Price/Cost_Leader_Price)
(1.03, 0.155), (1.08, 0.118), (1.13, 0.085), (1.18, 0.054), (1.23, 0.026), (1.28, 0.00), (1.33, -0.024), (1.38, -0.047),
(1.43, -0.067), (1.48, -0.087), (1.53, -0.106)
Effect_of_Price_Parity_on_Switching_Rate_due_to_Technology_Change =
  GRAPH(Diff_Leader_Price/Cost_Leader_Price)
(1.03, 0.805), (1.08, 0.844), (1.13, 0.883), (1.18, 0.922), (1.23, 0.961), (1.28, 1.00), (1.33, 1.04), (1.38, 1.08),
(1.43, 1.12), (1.48, 1.16), (1.53, 1.20)
Effect_of_Technology_Change_on_Consumers_Switching_Rate =
  GRAPH(Diff_Leader_Product_Technology/Cost_Leader_Product_Technology)
(1.03, -0.134), (1.08, -0.106), (1.13, -0.078), (1.18, -0.051), (1.23, -0.025), (1.28, 0.00), (1.33, 0.025), (1.38,
0.049), (1.43, 0.072), (1.48, 0.095), (1.53, 0.118)
Effect_of_Technology_Parity_on_Switching_Rate_due_to_Price_Change =
  GRAPH(Diff_Leader_Product_Technology/Cost_Leader_Product_Technology)
(1.03, 0.805), (1.08, 0.844), (1.13, 0.883), (1.18, 0.922), (1.23, 0.961), (1.28, 1.00), (1.33, 1.04), (1.38, 1.08),
(1.43, 1.12), (1.48, 1.16), (1.53, 1.20)

```

OPERATIONAL RESOURCES



$Diff_Leader_Operational_Resources(t) = Diff_Leader_Operational_Resources(t - dt) + (Diff_Lead_Operational_Resource_Increase_Rate - Diff_Leader_Operational_resources_Depreciation_Rate) * dt$
 INIT Diff_Leader_Operational_Resources = 200
 INFLOWS:
 Diff_Lead_Operational_Resource_Increase_Rate =
 $(Diff_Leader_Operational_Resources_GAP / Time_to_adjust_Operational_Resources)$
 OUTFLOWS:
 Diff_Leader_Operational_resources_Depreciation_Rate =
 $Diff_Leader_Operational_Resources * Diff_Leade_Technology_Change_Effect_on_Op_Resources_Depreciation$
 Diff_Leader_Actual_Productivity_per_Unit_of_Operational_Resource =
 $Diff_Leader_Operational_Efficiency * Diff_Leader_Initial_Productivity_per_Unit_of_Operational_Resource$
 Diff_Leader_Expected_Demand =
 $Diff_Leader_Customers * (1 + TREND(Diff_Leader_Customers, Diff_Leader_Planning_Horizon)) * Diff_Leader_Planning_Horizon$
 Diff_Leader_Initial_Productivity_per_Unit_of_Operational_Resource = 1
 Diff_Leader_Investment_Rate_in_Operational_Resources =
 $Diff_Lead_Operational_Resource_Increase_Rate * Investment_Cost_per_Unit_of_Operational_Resource$
 Diff_Leader_Necessary_Level_of_Operational_Resources =
 $(Diff_Leader_Expected_Demand / Diff_Leader_Actual_Productivity_per_Unit_of_Operational_Resource) + Diff_Leader_Operational_resources_Depreciation_Rate$
 Diff_Leader_Operational_Resources_GAP =
 $Diff_Leader_Necessary_Level_of_Operational_Resources - Diff_Leader_Operational_Resources$
 Diff_Leade_Technology_Change_Effect_on_Op_Resources_Depreciation =

GRAPH(Differentiation_Leader_Product_Technology_Relative_Change)
 (0.00, 0.05), (0.1, 0.053), (0.2, 0.0563), (0.3, 0.0593), (0.4, 0.0633), (0.5, 0.0675), (0.6, 0.074), (0.7, 0.0795),
 (0.8, 0.0865), (0.9, 0.092), (1, 0.1)

Cost_Leader_Operational_Resources(t) = Cost_Leader_Operational_Resources(t - dt) +
 (Cost_Leader_Increase_Rate_Operational_Resources -

Cost_Leader_Depreciation_Rate_Operational_Resource) * dt

INIT Cost_Leader_Operational_Resources = 200

INFLOWS:

Cost_Leader_Increase_Rate_Operational_Resources =

(Cost_Leader_Operational_Resources_GAP/Time_to_adjust_Operational_Resources)

OUTFLOWS:

Cost_Leader_Depreciation_Rate_Operational_Resource =

Cost_Leader_Operational_Resources*Cost_Lead_Technology_Change_Effect__on_Op_Resources_Depre-
 ciation

Cost_Leader_Actual_Productivity_per_Unit_of_Operational_Resource =

Cost_Leader_Initial_Productivity_per_Unit_of_Operational_Resource*Cost_Leader_Operational_Efficiency

Cost_Leader_Expected_Market_Size =

Cost_Leader_Customers*(1+TREND(Cost_Leader_Customers, Cost_Leader_Planning_Horizon))*Cost_Leader
 _Planning_Horizon)

Cost_Leader_Initial_Productivity_per_Unit_of_Operational_Resource = 1

Cost_Leader_Investment_Rate_in_Operational_Resources =

Cost_Leader_Increase_Rate_Operational_Resources*Investment_Cost_per_Unit_of_Operational_Resource

Cost_Leader_Necessary_Level_of_Operational_Resources =

Cost_Leader_Depreciation_Rate_Operational_Resource+Cost_Leader_Expected_Market_Size/Cost_Leader_
 Actual_Productivity_per_Unit_of_Operational_Resource

Cost_Leader_Operational_Resources_GAP = Cost_Leader_Necessary_Level_of_Operational_Resources-

Cost_Leader_Operational_Resources

Cost_Leader_Planning_Horizon = 8

Investment_Cost_per_Unit_of_Operational_Resource = 1

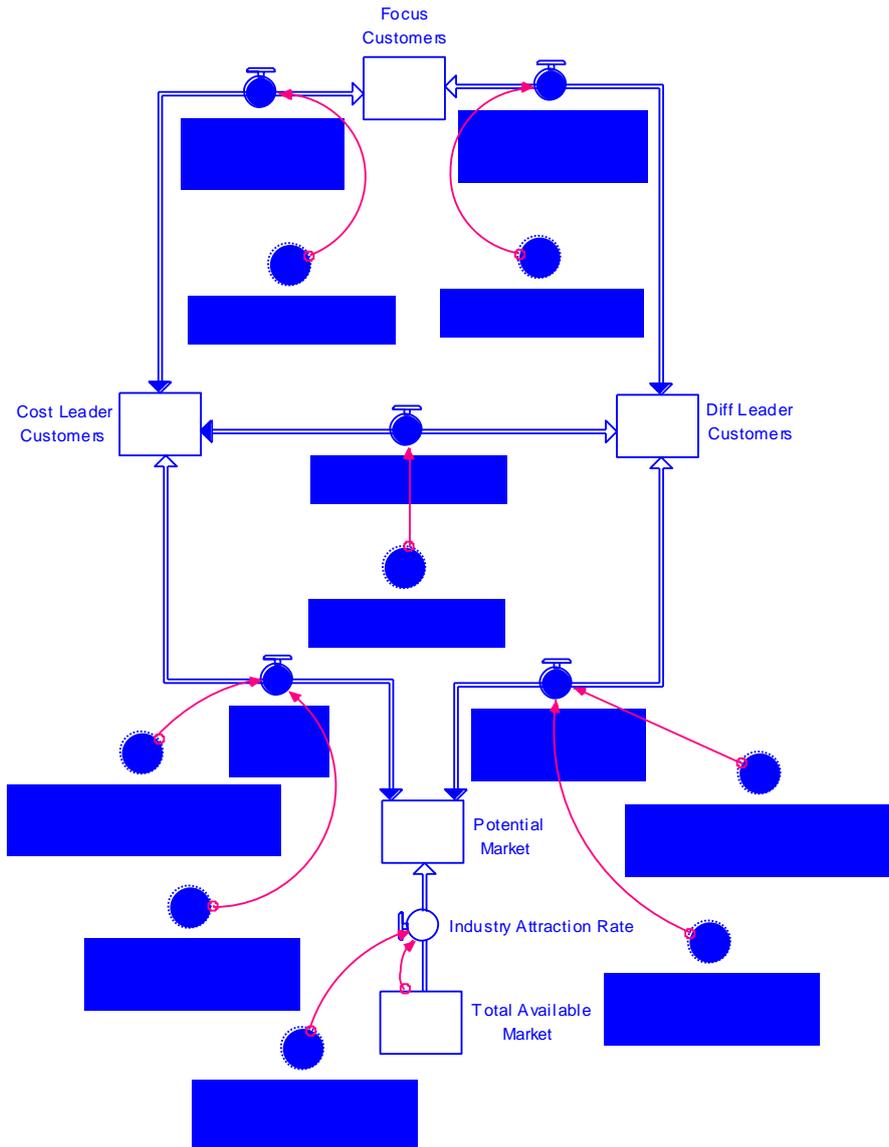
Time_to_adjust_Operational_Resources = 4

Cost_Lead_Technology_Change_Effect__on_Op_Resources_Depreciation =

GRAPH(Cost_Leader_Product_Technology_Relative_Change)

(0.00, 0.05), (0.1, 0.053), (0.2, 0.0563), (0.3, 0.0593), (0.4, 0.0633), (0.5, 0.0675), (0.6, 0.074), (0.7, 0.0795),
 (0.8, 0.0865), (0.9, 0.092), (1, 0.1)

MARKET



Market Customers Segments

$$\text{Cost_Leader_Customers}(t) = \text{Cost_Leader_Customers}(t - dt) + (\text{Cost_Leader_Adoption_Rate} - \text{Segment_Customers_Driven_by_Price_Switching_Rate} - \text{Mass_Market_Consumers_Switching_Rate}) * dt$$

$$\text{INIT Cost_Leader_Customers} = 1$$

INFLOWS:

$$\text{Cost_Leader_Adoption_Rate} =$$

$$\text{Cost_Leader_Adoption_Rate_of_Consumers_driven_by_functionality} + \text{Cost_Leader_Adoption_Rate_of_Consumers_driven_by_price}$$

OUTFLOWS:

$$\text{Segment_Customers_Driven_by_Price_Switching_Rate} =$$

$$\text{Net_Segment_Consumers_Movement_Focus_vs_Cost} * I$$

$$\text{Mass_Market_Consumers_Switching_Rate} = \text{Net_Switching_Rate_Mass_Market_Consumers}$$

$$\text{Diff_Leader_Customers}(t) = \text{Diff_Leader_Customers}(t - dt) + (\text{Differentiation_Leader_Adoption_Rate} + \text{Mass_Market_Consumers_Switching_Rate} - \text{Segment_Customers_Driven_by_Functionality_Switching_Rate}) * dt$$

$$\text{INIT Diff_Leader_Customers} = 1$$

INFLOWS:

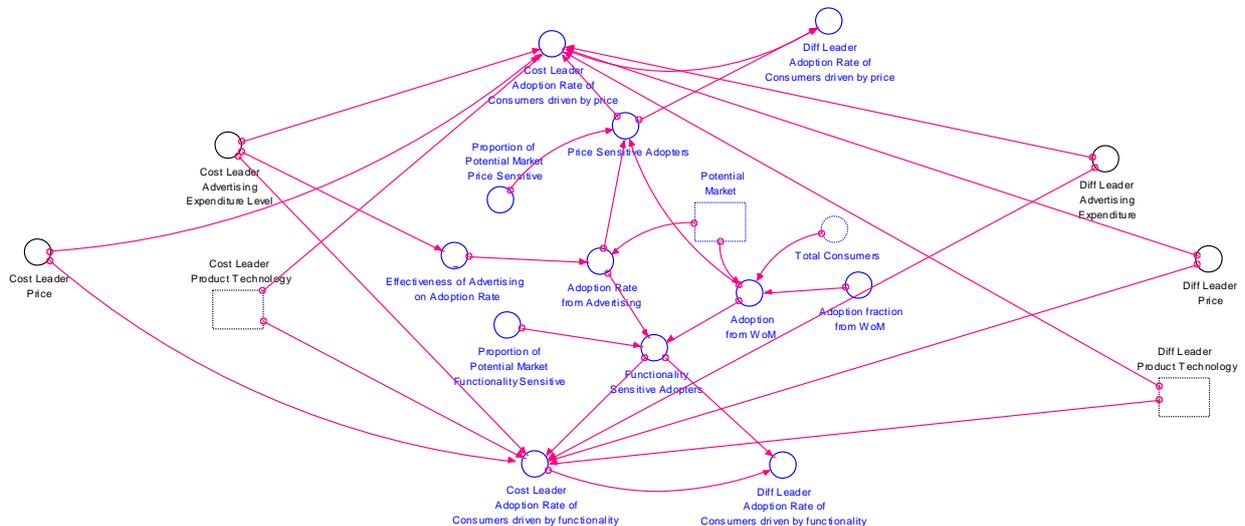
$$\text{Differentiation_Leader_Adoption_Rate} =$$

$$\text{Diff_Leader_Adoption_Rate_of_Consumers_driven_by_price} + \text{Diff_Leader_Adoption_Rate_of_Consumers_driven_by_functionality}$$

$$\text{Mass_Market_Consumers_Switching_Rate} = \text{Net_Switching_Rate_Mass_Market_Consumers}$$

OUTFLOWS:

$Segment_Customers_Driven_by_Functionality_Switching_Rate =$
 $Net_Segment_Consumers_Movement_Focus_vs_Diff*1$
 $Focus_Customers(t) = Focus_Customers(t - dt) + (Segment_Customers_Driven_by_Price_Switching_Rate +$
 $Segment_Customers_Driven_by_Functionality_Switching_Rate) * dt$
 $INIT Focus_Customers = 0$
INFLOWS:
 $Segment_Customers_Driven_by_Price_Switching_Rate =$
 $Net_Segment_Consumers_Movement_Focus_vs_Cost*1$
 $Segment_Customers_Driven_by_Functionality_Switching_Rate =$
 $Net_Segment_Consumers_Movement_Focus_vs_Diff*1$
 $Potential_Market(t) = Potential_Market(t - dt) + (Industry_Attraction_Rate - Cost_Leader_Adoption_Rate -$
 $Differentiation_Leader_Adoption_Rate) * dt$
 $INIT Potential_Market = 0$
INFLOWS:
 $Industry_Attraction_Rate =$
 $Total_Available_Market*Industry_Technology_Fractional_Rate_of_Attraction_of_Total_Market$
OUTFLOWS:
 $Cost_Leader_Adoption_Rate =$
 $Cost_Leader_Adoption_Rate_of_Consumers_driven_by_functionality+Cost_Leader_Adoption_Rate_of_C$
 $onsumers_driven_by_price$
 $Differentiation_Leader_Adoption_Rate =$
 $Diff_Leader_Adoption_Rate_of_Consumers_driven_by_price+Diff_Leader_Adoption_Rate_of_Consumer$
 $s_driven_by_functionality$
 $Total_Available_Market(t) = Total_Available_Market(t - dt) + (- Industry_Attraction_Rate) * dt$
 $INIT Total_Available_Market = 10000$
OUTFLOWS:
 $Industry_Attraction_Rate =$
 $Total_Available_Market*Industry_Technology_Fractional_Rate_of_Attraction_of_Total_Market$



Consumer Adoption Process

Adoption_fraction_from_WoM = 0.12

Adoption_from_WoM =

$$Adoption_fraction_from_WoM * Potential_Market * (Total_Consumers / (Potential_Market + Total_Consumers))$$

Adoption_Rate_from_Advertising = Potential_Market * Effectiveness_of_Advertising_on_Adoption_Rate

$$Cost_Leader_Adoption_Rate_of_Consumers_driven_by_functionality = Functionality_Sensitive_Adopters * ((0.65 * (Cost_Leader_Product_Technology / (Diff_Leader_Product_Technology + Cost_Leader_Product_Technology))) +$$

$$(0.20 * (Cost_Leader_Advertising_Expenditure_Level / (Diff_Leader_Advertising_Expenditure + Cost_Leader_Advertising_Expenditure_Level)))) +$$

$(0.15 * (\text{Diff_Leader_Price} / (\text{Cost_Leader_Price} + \text{Diff_Leader_Price})))$
 $\text{Cost_Leader_Adoption_Rate_of_Consumers_driven_by_price} = \text{Price_Sensitive_Adopters} * ((0.15 * (\text{Cost_Leader_Product_Technology} / (\text{Diff_Leader_Product_Technology} + \text{Cost_Leader_Product_Technology}))) + (0.20 * (\text{Cost_Leader_Advertising_Expenditure_Level} / (\text{Diff_Leader_Advertising_Expenditure} + \text{Cost_Leader_Advertising_Expenditure_Level}))) + (0.65 * (\text{Diff_Leader_Price} / (\text{Cost_Leader_Price} + \text{Diff_Leader_Price}))))$
 $\text{Diff_Leader_Adoption_Rate_of_Consumers_driven_by_functionality} = \text{Functionality_Sensitive_Adopters} - \text{Cost_Leader_Adoption_Rate_of_Consumers_driven_by_functionality}$
 $\text{Diff_Leader_Adoption_Rate_of_Consumers_driven_by_price} = \text{Price_Sensitive_Adopters} - \text{Cost_Leader_Adoption_Rate_of_Consumers_driven_by_price}$
 $\text{Functionality_Sensitive_Adopters} = (\text{Adoption_Rate_from_Advertising} + \text{Adoption_from_WoM}) * \text{Proportion_of_Potential_Market_Functionality_Sensitive}$
 $\text{Perceived_Average_Product_Technology_at_Industry_Level} = (\text{Cost_Leader_Product_Technology} + \text{Diff_Leader_Product_Technology}) / 2$
 $\text{Price_Sensitive_Adopters} = (\text{Adoption_Rate_from_Advertising} + \text{Adoption_from_WoM}) * \text{Proportion_of_Potential_Market_Price_Sensitive}$
 $\text{Proportion_of_Potential_Market_Functionality_Sensitive} = 1 - \text{Proportion_of_Potential_Market_Price_Sensitive}$
 $\text{Proportion_of_Potential_Market_Price_Sensitive} = 0.5$
 $\text{Effectiveness_of_Advertising_on_Adoption_Rate} = \text{GRAPH}(\text{Cost_Leader_Advertising_Expenditure_Level} + \text{Diff_Leader_Advertising_Expenditure})$
 $(0.00, 0.00), (100, 0.012), (200, 0.029), (300, 0.0495), (400, 0.0665), (500, 0.079), (600, 0.09), (700, 0.0955), (800, 0.098), (900, 0.099), (1000, 0.1)$
 $\text{Industry_Technology_Fractional_Rate_of_Attraction_of_Total_Market} = \text{GRAPH}(\text{Perceived_Average_Product_Technology_at_Industry_Level})$
 $(10.0, 0.0481), (19.0, 0.0485), (28.0, 0.0489), (37.0, 0.0495), (46.0, 0.0504), (55.0, 0.0515), (64.0, 0.0542), (73.0, 0.0569), (82.0, 0.059), (91.0, 0.0599), (100, 0.06)$