Industry Evolution: A dynamic behavioural model

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Abstract

This paper addresses the influence of managerial decision-making processes on the evolution of industries. Managers face very complex investment decisions due to uncertainties about customer acceptance, market size, technology, actions of competitors, and a dynamic complex feedback system. Managerial decision-making processes are almost the most influential variable to manipulate the evolution of an industry. However, managerial decision-making has been neglected in the literature of industry evolution.

This paper is the first step on analysing 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: firm's growth, market evolution, and technology development. This paper provides a framework termed Dynamic Behavioural Model of the Evolution of Industries to encompass all the issues that imply the analysis of industry's dynamic behaviour from a managerial point of view.

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. Uncertainties about customer acceptance, market size, technology, and actions of competitors in a dynamically complex environment affect these investment decisions. Simon (2001)) affirms “although the presence of uncertainty does not make intelligent choice impossible, it places a premium on robust adaptive procedures instead of optimising strategies that work well only when [are] finely tuned to precisely known environments.”

The literature offers vast evidence about the role of managers on some of the key processes that drive the evolution of industries: firm’s population dynamics, technology evolution, and market. For example, Carnerer and Lovallo (1999) found that managers are overconfident about their skills and excessively optimistic about their futures when they have to enter in a new market. Even though, they expect competition and negative profits, they think that their firms will succeed in a new market while other would fail. After studying the development of the rail network and telecommunications in US during 1900s, Lipartito (1997) found that network externalities are not an exogenous factor that comes into play independent of the strategic actions of the industry incumbents. Network externalities are generated through the sponsoring strategic actions of competing firms. Parker (1994) observed that many authors encouraged the use of historical analogies and managerial judgements to calibrate model parameters such as market potential, penetration ceiling, and speed of adoption for forecasting the diffusion of innovations. Then, managers use these models to make investment decisions; thereby they try to fulfil their own view of the market and industry.

However, the literature on industry evolution has not offered a comprehensive analysis of the effect of managerial decision-making on the dynamic behaviour of industries. Models

that suggest stochastic elements to explain performance and firm behaviour (Nelson and Winter (1982)); models using game theory are based on a conceptualisation of the decision-maker far from reality Camerer (1991) or models using empirical estimates for variables such as organisational age, size, and population density offer little theoretical explanations of real firm behaviour (Baum and Amburgey (2002)). Even, Barney (1991)recognized the role of managers in generating competitive advantage under the resource-based view paradigm when he affirmed that "managers are important in this model, for it is managers that are able to understand and describe the economic performance potential of a firm's endowments", and he added "without such managerial analyses, sustained competitive advantage is not likely" (pp.117)

This paper addresses the influence of decision-making processes on the evolution of industries given the restrictions on information and the effect of the dynamics generated by the industry feedback structure. Consequently, this paper offers a dynamic behavioural model of industry evolution rather than the traditional models based on technology development (Schumpeterian) or structure-conduct-performance (Porter's five forces) as a base to categorize industries.

This paper includes the conceptual development of the model, and a basic formalisation of the conceptual model using System Dynamics.

A Dynamic Behavioural Model of Industry Evolution. Conceptualisation

Industries as feedback systems

The concept of industry describes an environment where firms develop their business supplying similar products or services to a market. Basically, an industry is a feedback system comprised by firms and a market. On the one hand, firms provide services or products to satisfy potential customers' needs. On the other hand, potential customers have needs that

must be satisfied. Firms and markets dynamically interact over time through a process of adjustment between consumers' requirements and firms' products. Successful firms grow when an increasing number of potential customers accept and adopt their products; however, other firms abandon the industry when their products do not satisfy consumers' needs. However, even successful firms face uncertainties such as customers needs, potential market size and competitors reaction. Product Life Cycle or Industry Life Cycle[1] are concepts that represent the dynamic behaviour of this system (for a review of the concept of industry life cycle see Klepper (1996); for empirical evidence and theoretical models see Klepper (1997), Agarwal and Gort (1996), Jovanovic and MacDonald (1994), Klepper and Graddy (1990), and Gort and Klepper (1982); for a practitioner approach see Porter (1998)).

The dynamic interaction between firms and market can be represented as two feedback processes, which are the drivers of the evolution of industries, market evolution and firm evolution. Figure 1 shows the behaviour over time of two variables that describe these processes. Market evolution is usually represented by the variable total cumulative sales, which follow an S-shaped growth curve (Mahajan, Muller & Wind 2000; Bass 1969; Rogers 1983). The evolution of markets has three stages: *introduction, growth and maturity*. This dynamic process, which is also known as diffusion of innovations, has been extensively studied as a self-contained process (for a comprehensive review of product diffusion models see Mahajan et al. 2000). However, Kuester, Gatignon, and Robertson (2000) suggest firms can strategically influence the process. Finally, the study of diffusion of innovations is usually presented at industry level, but the same process is similar for firms with their own product.

[1] Klepper (1996) suggests that both terms can be used interchangeably.

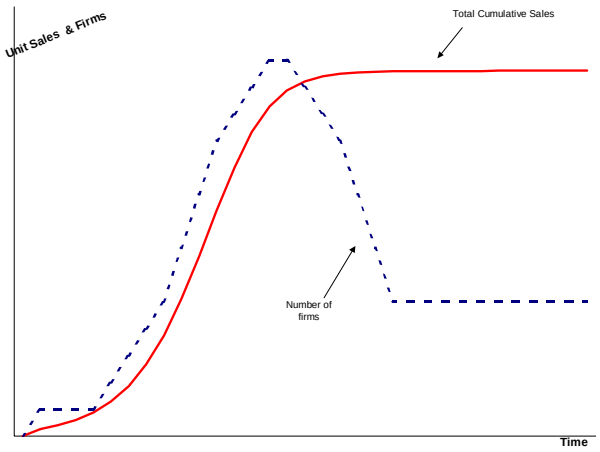

FIGURE 1. MARKET AND FIRMS EVOLUTION

From a feedback system point of view, market evolution is a balancing feedback loop, which can be represented in a causal loop diagram like in figure 2. As firms grow, they reduce the pool of potential customers until they reach the market saturation level. This pool of potential customers is a natural limit to growth for industries unless firms diversify into new markets, engage in product innovation to attract more consumers or expand geographically. Market size is directly related to the number of potential customers attracted by their products.

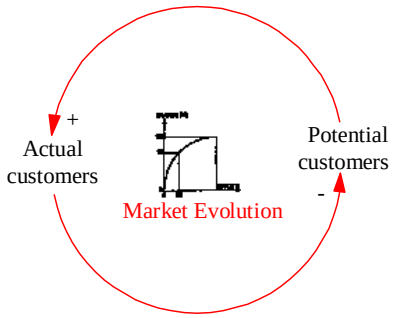

FIGURE 2. MARKET EVOLUTION - CAUSAL LOOP DIAGRAM

The second dynamic process is evolution of firms. The process that governs firms during the industry evolution can be summarized in one concept reflected in this phrase: “the growth of demand for a firm’s existing products...is a powerful influence on the direction of productive activity and on the expansion of firms” Penrose (1959). Thus, successful firms grow to satisfy

an increasing demand for their products, and displace their competitors out of market. Growth, which is sketched in figure 3, is a reinforcing process that drives successful firms. Successful firms attract customers and generate revenues that are invested in resources to capture more customers. As a non desired consequence, successful firms attract competitors –not shown in figure 3- because their competitors perceive that profit opportunities are related to successful experience of other firms in the market, a concept known as "demonstration effect"[2] (Gort and Konakayama 1982). However, not all firms succeed in the industry. Failed firms are governed by identical reinforcing process, but it operates on the opposite direction. As firms lose unsatisfied customers, revenues collapse, then investment in operational resources falls, and operational resources available diminish (not shown in figure 3); consequently, these firms may not be able not only to attract lost customers but also to retain the existing customers.

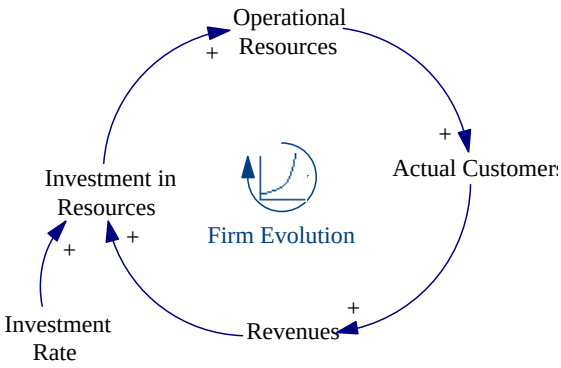

FIGURE 3. FIRM EVOLUTION - CAUSAL LOOP DIAGRAM

The aggregate pattern at industry level of the firm evolution is captured by the concept of "Industry Life Cycle." (Gort and Klepper 1982).

[2] Firms may also enter for other reasons, for example an attractive market growth rate, legitimisation process, similar technology, that are not the aim of this study since entry process has been thoroughly studied by industrial organisation economists (Tirole 1990, Geroski 1991) and organizational ecology researchers (Hannan and Freeman 1977, Carroll 1984).

These two feedback processes constitute the structure of industries from a system feedback point of view. The model presented in figure 4 not only reflects the process at firm level, but also represents the process at an industry level. Industries grow over time reaching a limit defined by the market size.

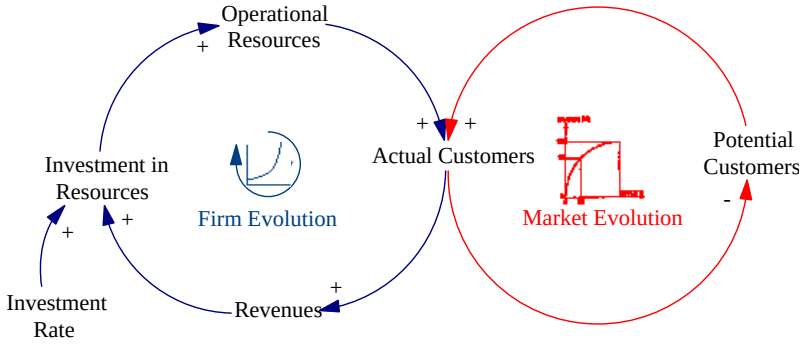

FIGURE 4. INDUSTRY EVOLUTION MODEL

However, the relevant issue is neither the structure of the industry nor its behaviour, but the perceptions that decision makers have about them. These perceptions, which can be influenced by distorted information, cognitive limitations and ability to estimate environment's effect on firm's performance, affect organisational decision making process reducing firm survival rate and influencing the evolution of industries. Perceptions affect managerial decision-making because it is only through managerial perceptions that the environment becomes "known" to the organization (Bourgeois 1980). For example, Sterman (1989a, 1989b), and Paich and Sterman (1993) found that subjects did not account that the effects of their decision feeds back through the market to influence not only his future outcomes but also the reactions of the other participants. This problem is known as “misperceptions of feedback.” (Sterman 1989b). Consequently, the effect of decision-making processes, which determine the behaviour of firms, may account more of the evolution of industries than it has been considered in

previous studies such as Geroski & Mazzucato (2001), Utterback (1994), Carroll & Hannan (1992), Nelson & Winter 1982, and Gort & Klepper 1982).

Models of firm behaviour

Managerial decision-making processes determine the behaviour of firms, and influence the evolution of industries. From a feedback view of management approach, management is viewed as a process of transforming information into action called decision-making (Forrester 1994). Management success depends on the information selected and its transformation into action. The environment becomes "known" to management using the information selected, which are influenced by their mental models (Senge 1999). Management perception of the feedback system where they are embedded clearly defines the outcomes of the decision-making process.

The transformation of selected information into action involves three components: a *desired state,* an *apparent state* and *actions.* The concept of *desired* state defines the goals or objectives of the organisation at a particular decision point. The *apparent* state of *actual* conditions represents the distortion between real conditions and what is perceived as the actual condition at the decision point. The last component is the generation of decisions or *actions* to reduce any discrepancy between the apparent and the desired conditions.

In summary, the feedback view of management can be summarised as a process of setting goal-seeking feedback policies that work as control structures regulating prices, product development, sales force, production capacity, and financial resources (Morecroft 2000, Morecroft 1985a, Lant 1992, Weick 1979). An example of this concept is exhibited in figure 5. Firms have resources like sales force that change over time according to a desired level determined by their management. Management modifies goals based on information flows about internal/external requirements and expectations such as actual customer growth rate,

number of salesman per customer, and expected customer growth rate. The difference between the desired level and the actual level of the sales force determines the direction of the corrective action, i.e. the number of salesman to hire or fire, which is accomplished over a certain time.

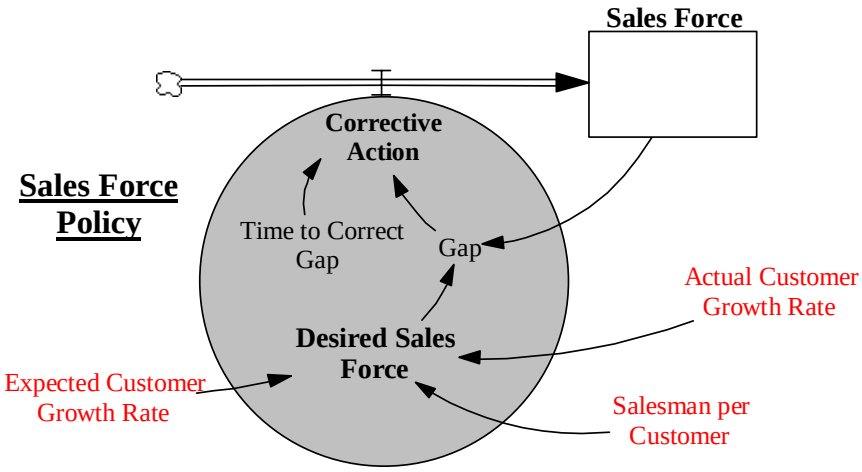

FIGURE 5. FEEDBACK VIEW OF MANAGEMENT AND POLICY (adapted from Morecroft 2000)

In this approach, the level of analysis of decision processes, which are viewed as a continuous stream of decisions rather than a discrete choice selection process, is the management level. Since it is in this level of analysis that perceptions about the environment are most influential on the behaviour of the firm, and in consequence, on the evolution of industries, the feedback view of management is the base to develop this dynamic behavioural model of industry evolution.

Industry Evolution: A dynamic behavioural model

Since management is viewed as a process of transforming information into action, the dynamic behaviour of the firm depends on what information is captured and how it is transformed into strategic actions. Managerial thinking is the natural process that transforms information into action. However, managers rarely think in ways viewed as “perfectly rational”

because of their cognitive limitations, so they use mental models to formulate their decisions (Senge 1999, Huff 1990; Fiol & Huff 1992, Simon 1991). Mental models, which are filters that interpret the information and associate it with an adequate action, affect the dynamic behaviour of firms during the evolution of the industry. This dynamic behaviour can be categorised as reactive or proactive based on its intervention during the evolution of the industry.

Reactive behavioural type may be observed as following the evolution of the industry. This behavioural type tends to use mainly information provided by the market, and "reacting" to the events as the market evolves. Reactive management seems to be more conservative as the information arrives with delays, and it only reacts after some time has passed from the events. External events determine the course of actions more than rigorous analysis of proactive and long-range plans. In terms of chief executive personality, this behavioural type can be associated to a flexible personality Miller and Toulouse (1986). Flexible personalities tend to follow a reactive, intuitive and short time horizon decision-making process. Reactive behavioural-type can also be associated to an external type of person that perceives the events out of his control and attributable to chance or fate Miller and Toulouse 1986. This type of personality has positive implications for performance in stable environments because it tends to maintain the status quo. Using Miles and Snow (1978) classification of organisations, organisations categorised in this behavioural type are a combination of defenders and reactors. Defenders have narrow-product-markets, where they grow cautiously and incrementally, because their little capacity for exploiting new areas of opportunity; and they appraise performance comparing their present with their past. Reactors rarely make adjustment to any sort until they are forced to do it by environmental pressures making the organization inconsistent and unstable, and reluctant to act aggressively in the future. Consequently, this behavioural type heavily discounts present and future information, so its *desired* state of the organisation is only an update of the actual conditions to past events. The goal setting process

is based on past events or backward looking. Experiential wisdom that accumulates as a result of positive and negative reinforcement of prior choices is associated to backward-looking tendencies (Gavetti & Levinthal 2000).

Proactive behavioural type may be observed as pushing the evolution of the industry. This behavioural type "creates" its own information based on expectations that "forecast" the evolution of the market. Proactive management tries proactively to manage the evolution of the market through its decisions controlling the rate at which the balancing feedback loop works. This approach is close to the concept that organisations create their own environments through a series of choices regarding markets, and desired scale of operations (Weick 1979). In terms of chief executive personality, this behavioural type can be associated to a need for achievement personality Miller and Toulouse 1986. Need for achievement personalities tend to follow an analytical, long-term planning, and proactive decision-making process. Proactive behavioural-type can also be associated to an internal type of person that believes that the results achieved are a consequence of his actions Miller and Toulouse 1986. This type of personality tries to grow his firm more rapidly than a personality having low achievement needs. Using Miles and Snow 1978 classification of organisations, organisations categorised in this behavioural type are a combination of analysers and prospectors. Analysers maximise their profit opportunities, combining market penetration with market development so they have a mix domain with some product in stable markets and others in changing markets. Prospectors' capabilities allow them to find or exploit new product and market opportunities changing their industries, and growing in spurts. This behavioural type uses the *actual* state of the organisation to verify the discrepancy with respect to its *desired* state, so the greater the discrepancy the greater the resulting action even though the actual state clearly represents the optimal situation given the existing constraints. The goal is based on forecasts and expectations, a concept similar to forward-looking. Forward-looking is premised on an actor's

beliefs, which derive from the actor's mental model of the world, about the linkage between the choice of actions and the subsequent impact of those actions on outcomes. This type of cognition assesses alternatives "off-line", that is, actors need not engage in an activity in order to evaluate it favouring forecasting processes. (Gavetti & Levinthal 2000).

Concluding, 'reactive' firms grow as the balancing feedback process that controls market evolution unfolds or metaphorically they 'chase' the market, and 'proactive' firms grow through controlling this balancing feedback process or metaphorically they 'make' the market based on their expectations. Simon 2001 affirms that the formation of expectations has disestabilising effects in a system because expectations can push a system to overreact to its predictions and go into unstable oscillations. He also added that feed forward in markets could become especially disestabilising when each actor tried to anticipate the actions of others, and their expectations. However, if one type of firm or the other has better performance, it will depend on the interaction effect between all firms and the market given the uncertainties that managers face during the evolution of the industry.

Management of key uncertainties under different behavioural types of firms

Management faces amongst other problems, two that are fundamental during the evolution of an industry: uncertainties and speed. There are three questions that management continuously makes to himself that represent its key uncertainties: What is the market's size? What are the requirements of potential customers? How will competitors react? The first question determines the perceived limits to growth for incumbent firms and to market attractiveness for potential entrants, so market size is one of the key uncertainties that each behavioural type provides with a different answer. The second question is fundamental to establish the market where firms will compete as well as the technology trajectory that firms will build over time. In this situation, each behavioural type will put firms into different

strategies to develop technologies and levels of influence to the development of industry technology. The last question is closely related to firms' growth rate or expansion speed. Industries reach a limit determined by their market size, so management expects to find a strong competition to obtain most of the potential customer. This strong competition for being first implies an emphasis on fast decision-making and resource allocation processes. In the following sub-sections, these three uncertainties are expanded, and how each behavioural type manage them is explained with some considerations on their effects on relevant industry variables.

Market size. In new markets, management does not know the exact number of potential customers. Management may forecast the market size based on similar products (Mahajan et al. 2000). However, the exact market size is only revealed over time as the market develops, so forecasting is difficult because data is scarce especially at the beginning of the market (Meade and Islam (2001). Forecasted market size becomes the base for decisions on initial and future investment. Optimistic forecasts may generate an overshoot in industry capacity with respect to total market demand generating periods of excess capacity, which results in low prices and negative profits. On the other hand, an underestimated market size implies smaller investments in capacity depressing future market size because potential consumers perceive that the product is very difficult to find, so firms may generate a self-fulfilling prophecy with respect to the market size because they do not invest enough to expand and exploit it.

Management can regulate firm growth rate as industry life cycle unfolds controlling the investment rate to avoid or reduce the problems mentioned. Higher (lower) investment rate generates a faster (slower) firm growth rate and a rapid (moderate) market development and potential customers depletion. There are two possible sources of information to set firm expansion rate. The first source is to use the information provided by the market growth rate and react as the balancing feedback loop unfolds. The second source is a forecast of the market

size to establish the pace for capacity expansion. In this case, management adopts a 'proactive' approach trying to manage the balancing feedback loop. Consequently, the behavioural type defines the weight given to one or another source of information and investment rate.

Firms' size reflects the emphasis on growth that management assigns to the organisations goals. Reactive firms may damp initial diffusion process because there is not enough incentive to expand their level of operational resources, which reduce product availability. If the market finally grows, firms delay, which are caused by their trend to use past information, to develop their operational resources will reduce their market share. Proactive behavioural types strongly emphasise firm growth up to a desired level set by management expectations. However, if management receives exceptional positive feedback that confirms and exceeds their initial expectations, they will adjust the desired level to reflect this change on expectations. Otherwise, proactive management will reduce growth rate when it reaches the expected size, and it will be sooner than firms following reactive strategy. In consequence, reactive firms will have smaller size than proactive firms.

Industries have mixed populations in terms of behavioural types: some firms are proactive, and others reactive. As a result of the combination of reactive and proactive firms the distribution of firms' size in an industry will be skewed. Skewed distributions have been observed in numerous studies; for example, Klepper & Graddy (1990) and Ijiri & Simon (1964), but there has not been any reference to the effect of decision making process in the distribution of firms size, so firm size has not been considered to be a result of conscious managerial decision. In this model, firm size is a consequence of the behavioural type that influence managerial decisions, so the proportion of firms with a proactive (reactive) behavioural type will determine the firms' size distribution skewness in the industry to be right (left)

A second issue referred to market size is the time to saturate the market. This time, which will vary with each industry behavioural type, represents the longest period to deplete a pool of potential customers. Proactive firms manage expectations as their basic input to decision making; however, these expectations may be unreal to consider not only individually but also collectively. It is not surprising to find that in some industries the collective expectations of potential customers are higher than the total population of the country. In an industry where most of firms are proactive, the pool of potential customers may be reduced quickly hitting the saturation level soon. Proactive industries will have a short life cycle, and the population of firms will go through dramatic processes of exponential growth and abrupt collapse. On the contrary, reactive industries will have a longer life cycle, and the population will grow slowly as the market unfolds. However, it is possible that a market, which grows explosively due to word of mouth, will create a similar situation to a proactive industry because reactive firms will chase the market evolution growing fast and large. Summarising, industries where most of firms are proactive reach saturation levels sooner than reactive industries in similar circumstances.

Potential customers requirements. Initial customers' needs and their evolution over time influence managerial decisions on technology trajectory that firms will pursue. Since customer requirements are uncertain, the number of actual customers gives a close indication of the success on satisfying them. Thus, changing product characteristics along with a technology may attract more customers as they find that new product characteristics satisfy requirements not fulfilled previously. Consequently, the number of potential and actual customers changes over time as firms change their products as a consequence of innovation, a process known as supply-based view of technology competition. Norton & Bass (1987) found evidence of these 'waves' in the semiconductor industry, and Mahajan & Muller (1996) on successive generations of IBM mainframe computers. On the other hand, customer preferences also

change over time because they learn from other technologies and products as well as different uses for the actual product. Hence, consumers requirements not only are heterogeneous initially but also change over time influenced by learning process or the irruption of new products demanding new products characteristics and the movement along a technology trajectory, a process known as demand-based view of technology competition (Adner 2002, Adner & Levinthal 2001).

Management has two issues in respect of customer requirements: initial technological level to attract the first customers, and the pace of technology development to keep revenues stable before revenues fall to replacement sales. Technology change is defined not as a stochastic process but a process controlled by management in this model. During the first stages of an industry, management goal is to capture most of the new customers before competitors; however, management has two problems to solve: one is to find the right product and second is to grow as fast as it can. The first issue is usually represented as a period of ferment or variation in products and technologies because no product is massively accepted. Firms try products until they obtain satisfactory results in terms of profits and market growth rate. Once the first issue is solved within a standard product or an accepted technology, building capacity is a 'rational choice', and not engaging in product innovation. Consequently, product innovation falls, and operational innovation increases as Utterback (1994) suggests. But soon, after growth stages pass, firms' operational capacity may overshoot the final level of sales as the initial purchases fall and replacement sales take off, which are much lower than initial purchases. Capacity in excess generates negative profits because structure costs are higher than revenues. Management has two options: downsize operational resources or search for new products investing in new technology. Reactive firms that ground their decision on market feedback will behave different than proactive firms regarding these technological challenges.

If an initial technological level provides a satisfactory level of revenues, reactive behavioural type of firms will lock in to this initial technological level. In case that market feedback is not satisfactory, reactive firms will set their technology goal based on the average or most accepted market technology, so again lock in to the most accepted market technology. Arthur (1989) in a classical paper affirms that technological lock in occurs under increasing returns in a context where increasing returns arise naturally as agents choose between competing technologies. Reactive firms will definitely contribute to this situation as they are focused on market feedback to make their decisions. He also suggested that when two or more increasing-return technologies compete for a market of potential adopters, insignificant events might, by chance, give one of them an initial advantage in adoptions. Under this behavioural type only homogenous customers requirements will give one technology its final advantage, otherwise the market will be segmented with reactive firms in different technological levels to satisfy heterogeneous customer requirements if these segments are profitable enough for them.

On the other hand, proactive firms will continuously engage in new technologies development because these firms reach their perceived saturation level sooner than reactive firms, and they need to sustain their expected revenues. However, there must be some demand conditions that enable this kind of disruptive dynamics because if demand requirements are homogenous, changing technology will only deteriorate performance. So, proactive firms may be successful in conditions with segmented demand or continuously consumer evaluation of the technology that change as performance improves.

Consequently, the proportion of behavioural types in an industry may indicate a tendency towards technological change – more proactive firms means more technological change, but they are also the customer requirements that facilitate technological change.

Competitors' actions. The lack of information about competitors' actions creates a dilemma to management with firm growth rate. On one hand, being the first that depletes the pool of

potential customers or takes most of it may generate higher income from replacement sales than competitors. Still, a competitor may bring a better product to market and attracts its actual customer base, but a firm with a large customer base has time and resources before losing all customers, and imposes an important investment in operational resources to its competitors, which may help to deter them. On the other hand, an aggressive growth strategy may generate bold reactions from other firms, which results in a Hypercompetitive industry as firms escalate their reactions. Bogner and Barr (2000)) found that these processes could become institutionalised as shared recipes within industries. In these types of industries, decision-making process will emphasise speed rather than market feedback. Perlow, Okhuysen & Repenning (2002) found that organisations that make fast decisions might fall in a potential pathology defined "speed trap." This emphasis on decision speed is, at the expense of decision content, increasing the chances of making mistakes that reduce firm survival.

Reactive firms, which consider past market feedback as their primary information source, assign low priority to competitors' actions. Reactive behavioural type is more focused on market evolution rather than on firm evolution since it does not have a clear expected size or market share to achieve. As a result of this bias, this kind of firms will not easily engage on an escalation of actions. Proactive firms see competitors' actions as threats to achieve their expectations, so they consider them as an input for decisions. Hence, their decisions include past actions or indicators of competitors' actions such as competitors growth rate or new technology level.

Model Summary

Given previously mentioned uncertainties –competitors' actions, market size and consumer needs– that managers faces decisions that specify the right direction of the organisation are difficult to achieve when they are compared to a situation with perfect

information and not dynamically complex. Managerial decisions such as the rate at which operational resources grow, and the direction of technological development may influence dramatically the evolution of industries. To capture this behavioural view of industries, the model presented in figure 4 has been expanded to include dynamic behavioural processes. Figure 4 presents the complete but highly simplified dynamic behavioural model of the evolution of industries. Variables "Technology requirements," "Potential customers" and "Competitors' actual customers" reflect the questions that managers have: What are the potential customers' technology requirements? How attractive is my technology for the potential customers and compared with my competitors? What is the number of potential customers interested in my technology? How fast are competitors gaining customers? And how many customers left? Variable "Investment decision" represents the outcomes of the decision making process that control the level of operational resources and firm technology. The behavioural types preferences on possible sources of information flows for the decision making process are represented as 'R' for reactive behavioural type, which departs directly from "Actual customers", and 'P' for proactive behavioural type, which departs from 'Perceived saturation'.

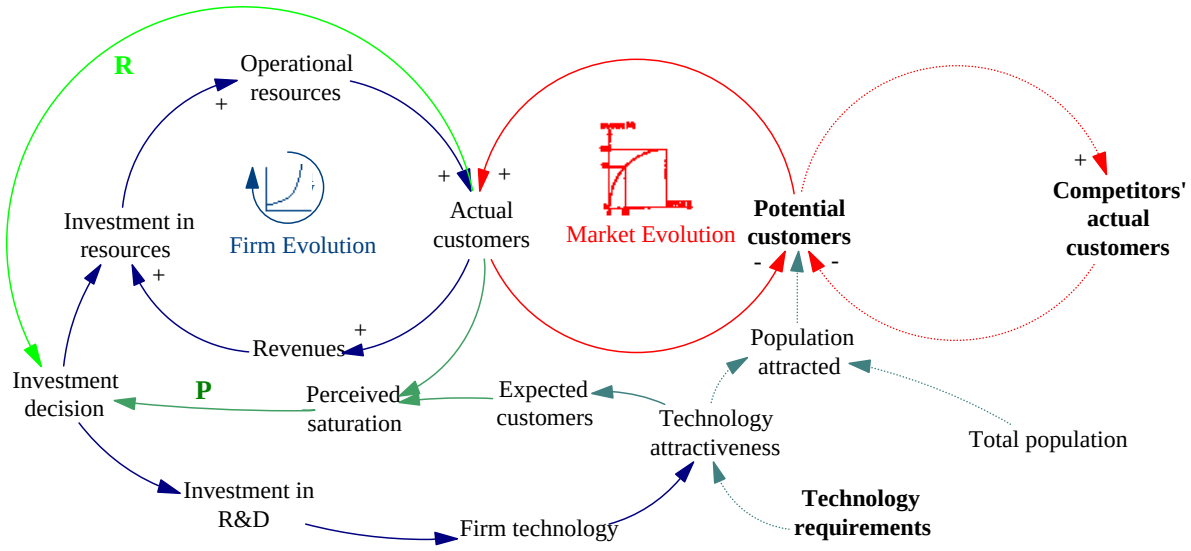

FIGURE 6. INDUSTRY EVOLUTION: A DYNAMIC BEHAVIOURAL MODEL

The basic structure that determines industry dynamic is a reinforcing feedback loop “Firm Evolution” and a balancing feedback loop “Market Evolution.” Once a firm enters an industry, it invests in operational resources to capture potential customers. More actual customers generate more revenues, which may be invested in more operational resources, research and development or both. Investment decisions are made using any of two information sources according to the management behavioural type: the evolution of the number of actual customers or the perceived saturation achieved. Investment decisions are represented very simple, but the process, a representation of which can be observed in figure 6, is more complex. In a competitive industry, there is not only one firm that captures customers reducing the pool of potential customers but other firms also capture customers from the same pool, which are represented by the dashed loop at the right in figure 6. Firms engage in a race for capturing most of potential customers increasing the gain of the reinforcing feedback loop ‘Firm Evolution’ similar to all of them through their investment decisions. The number of potential customers at any time is a function of how attractive is the technology of the firm with respect to the requirements that the total population has, which is represented by dashed links at the bottom of the causal loop diagram. Hence, firms may be able to increase the pool of potential customers if they change their technology to satisfy more or new requirements, which are unknown. Firms in this model compete in two dimensions: operational resources and technology, which are the basis of the Schumpeterian Competition (Winter 1984, Dosi 1982, Kamien & Schwartz 1982), but their behaviour as well as the evolution of industries, are determined by the behavioural type used to perceive the structure of the industry. Consequently, industry evolution patterns have to be inferred from the interaction of firms’ behavioural types existing in an industry.

A Dynamic Behavioural Model of Industry Evolution. Formalisation

The model represents the components of an industry: firms, market and interactions between firms and market. The model is grounded on the tradition of behavioural simulation models (Sterman 1987, Morecroft 1985b, Morecroft 1983, Levinthal & March 1981). These models portray bounded rationality where the decision functions use simple rules of thumb to mimics the simplification of complexity that managers make using their mental models. Firms have two main components: decision making processes that are modelled using the feedback view of management and policy (Morecroft 2000, Forrester 1994); and resources that are based on the approach depicted in the dynamic resource-based view of strategy (Morecroft 2000, Warren (2000), Warren (1999), Morecroft (1999)). Market sector is based on literature related to the diffusion and adoption models in homogeneous and heterogeneous populations (Adner & Levinthal 2001**,** Mahajan et al. 2000, Chatterjee & Eliashberg 1990, Granovetter 1978, Bass 1969). There are two possible interactions: one type of interaction is between firms and market that is modelled considering one of the possible dimensions of this type of interaction: technology evolution; and the second type of interaction is between firms that is modelled through processes of information selection like imitation or through market selection like competition.

Firm Sector

Firms in this model are assumed to be embedded in a reinforcing feedback process regulated by managerial decision making processes that control a set of resources using information flows.

Figure 15 represents the structure of a firm in the dynamic behavioural model of industry evolution, and how it will be represented in this model. Management reduces

organisational decision-making complexity by focusing its attention on specific measures of performance such as profits. Profits are the only inflow rate to slack resources, which are necessary for firm survival and growth. Management does not maximise profits, it sets an aspiration level for profits since it is enough to keep profits slightly above slack outflows to have a financially healthy firm. Cyert and March (1992)) defined slack resources as the "difference between total resources and total necessary payments", and they added: "when the environment becomes less favourable, organizational slack represents a cushion ... [which] permits firms to survive in the face of adversity." Moreover, profit goal helps management to coordinate among different organisational decision-making processes as an input to establish resources goals or control the actions that drive resources level. In this model, firms have two more key resources: technology and operational resources. Technology is critical for firms because it is the link to market, which serves to attract customers over time. Management changes technology desired state –technology level– based on profit goal achievement: a failure to achieve the level of profits means a change on the technology level to increase product attractiveness, and then pull more customers from the pool of potential customers and improve actual profits. This decision making process is influenced like any other decision making process in this model by the behavioural type of firm. Not less critical than technology are Operational Resources since they determine the capacity of firms to provide the products required by their customers. This goal is not directly influenced by profit level, but it strongly affects the level of profits because operational resources have a two-edge sword nature: provide products that generate revenues, and increase fixed costs that reduce profits if sales decline. The main input for this goal is customer growth rate or forecasted market size according to the behavioural type of the management.

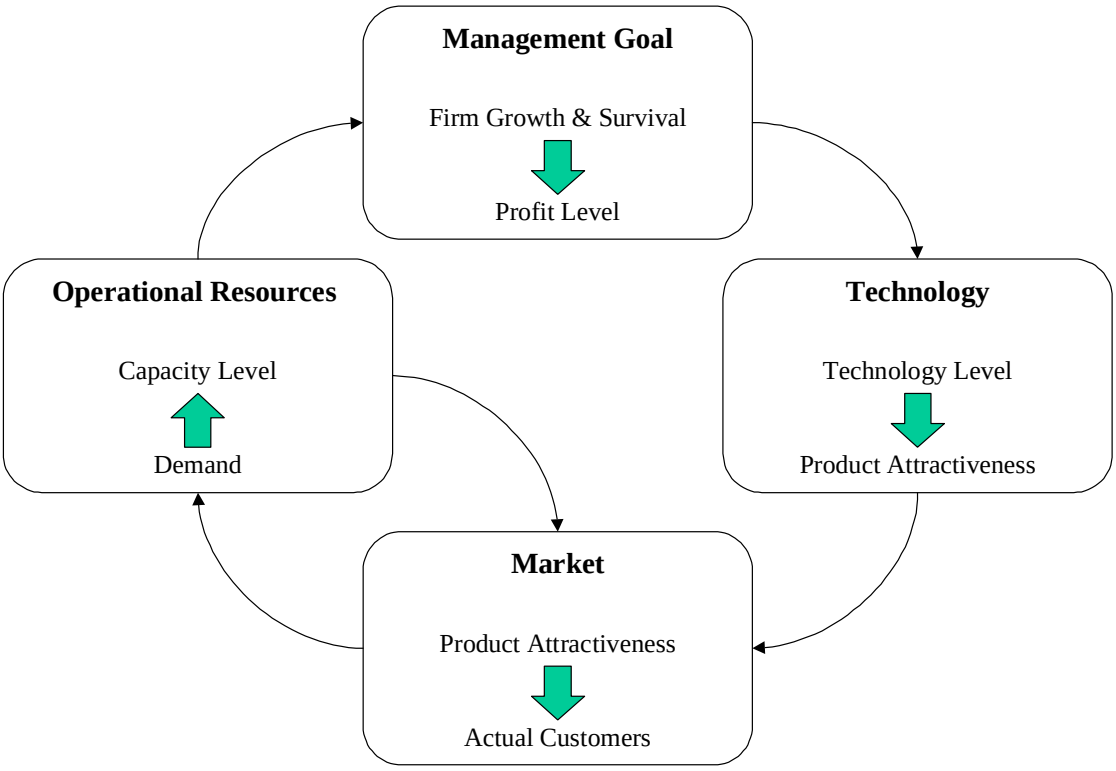

FIGURE 15. FIRM STRUCTURE

General Decision Making Processes

Decisions under the feedback view of management involve three components: a *desired state*, an *apparent state* and *actions.*

The *desired state* indicates the direction that management wants for a resource, and aggregating the set of resources for the whole organisation. There are many formulations that capture the goal formation process (for a review see Sterman 2000); however, I will refer to two processes that reflect the reactive and proactive behavioural type. Proactive behavioural type creates expectations about the trend that the market growth rate will have in the future favouring long-term planning. Reactive behavioural type continually updates its goal based on market past behaviour.

The *apparent* state of *actual* conditions represents the distortion between real conditions and what is perceived as the actual condition by the decision-maker. In this model of firm, there are two basic information flows: one from the set of resources that comprise the

firm, and the other from external sources such as market growth rate, market technology or competitors actions. External sources of information may be received with delays from their original sources, and sometimes affected by biases; for example, market information may be received after three or six months which is the time to process statistics from different agencies or information from competitors may be reduced or increased by a certain percentage showing the apprehension that management has with respect to a competitor information. On the other hand, there is also an influence from the behavioural type on the source of information to identify the apparent state; for example, reactive types will give more importance to external sources because they are more focused on following the evolution of market, while proactive types will follow internal sources to contrast against their desired or expected state as well as to 'forecast' future states.

The last component is the *action* that will be taken to reduce any discrepancy between apparent and desired conditions. Actions are also assumed to be performed as a continuous stream rather than in discrete choices selection process, so there is no set of choices to select, try and adopt, to optimally select from a set given certain constraints, to generate stochastically or to strategically rationalised. In this model of firm, actions take time to be performed. Thus, a resource adjustment to its desired level takes time, which represents the natural process and physical limits to perform an action. For example, to change the technology level takes time because the R&D staff has to develop, experiment, and prepare for commercial use a new technology; however, in some circumstances more resources may reduce this time but at a diminishing rate due to the diseconomies of scale.

Technology

Considering that managers set a desired state for its technology implies a departure from established literature on technology innovation, which defines new technology driven by

stochastic processes such as it is suggested in Nelson & Winter (1982) and Anderson & Tushman (1990). In this model, technology evolution is a result of a managerial decision making process based on a simple decision rule of adjustment to performance feedback known as attainment discrepancy model (Lant 1992). Thus, successful technologies in terms of market performance will not change, while unsuccessful technologies will be selected out. The profitability of a technology depends on customers' requirements and competitors' technology developments both of them uncertain and variable over time. Then, technology in the simulated firm will be stable over time depending on the behavioural types of the other firms.

The technology goal is formed considering the state of actual technology, the achievement of the profit level, and the behavioural type that determines the information source to guide the development of the new technology. Reactive behavioural type firms will focus on external sources such as average or leader market technology. Proactive behavioural types will have an internal orientation towards new technology. Finally, if actual technology is profitable there is less incentive to change it, so technology change is driven by the achievement of profit goals also know as the satisfacing principle Winter (2000).

Firm technology is an intangible resource that describe the technological level of the product portfolio. For simplicity, I assume that firm technology is an index that can be directly associated to the level of customers' requirements; for example, if technology level is 100 and customers' requirements are in the same level, the firm may be able to attract a huge number of potential customers. The higher the discrepancy, the lower the attractiveness for potential customers.

Management corrects the discrepancy between the direction established for the technology and the actual level of technology through investment decisions. This investment is a simplification of the investment in researchers, projects, trials, patents, licenses and other activities necessary to have and develop a new technology. Investment in Research &

Development is usually measured as a percentage of total revenues (Klepper & Cohen 1992), and it is assigned to two actions: new technology generation and discrepancy reduction between the desired and the actual state.

New internal technology generation is a cumulative function of the actual level of technology and the additional increment on the technology due to R&D investment at decreasing marginal returns. More resources due to a better performance mean a higher level of internal technology development, so “success breeds success.”

R&D investment to reduce the discrepancy is the amount of money necessary to develop projects that update firm technology to the desired level by the management. Discrepancies will not be reduced unless the firm makes a minimum investment, but huge investment in discrepancy reduction will not reduce the delay to zero because physical and knowledge limits.

Operational Resources

To simplify the model, only one resource will be used to capture physical, capital and human assets necessary to provide the products demanded by customers. This resource is denominated Operational Resources. Similarly to technology, the decision making process that controls operational resources involves three components: a desired state, an apparent actual state and an action to correct the differences between both states.

The desired state or goal for operational resources is quite complex because the number of possibilities that management has to define the desired state of this resource. It is important to realise that firm starts with an initial endowment of operational resources that reflects the initial expectations of management at the beginning of an industry. So, a firm starts with a certain level of operational resource initially that it has to change over time to reflect their success in the market.

According to each behavioural type, there are many information sources to set the expected level of operational resources: customer or market growth rate for reactive types, and forecasted market size or expected market share for proactive types. Hence, the basic sources of information that management uses are either industry demand (external orientation) or specific demand for firm products (internal orientation). Additionally, goal setting process is focused on past or expected rates or states of demand at market or firm level. For example, a reactive firm will define its operational resources goal using smoothed market growth rate for the last four quarters if it has an external orientation. And a proactive firm will define its operational resources goal using expected customer growth rate for the next four quarters if it has an internal orientation. Consequently, reactive firms will follow the market as it unfolds and proactive firms will unfold the market. In both cases, the process is influenced by operational resources utilisation ratio that they may expand or reduce the requirements defined by the previous processes.

The actual state of operational resources is not subject to delays or distortions. However, its actual state is very important for firms since it determines revenues as well as the number of adopters that becomes customers or user of the product, which gives to the firm a strong influence in the average industry technology –average industry technology is each firm technology weighted with the number of actual users of its products. In this model, the level of operational resources determines firm revenues because it is assumed that there is no backlog or infinite supply to any level of demand. Operational resources are also a key indicator of firm size; for example, ships in the experimental study were the operational resources for fishing fleets. Finally, operational resources level are determined by goal adjustment to correct any discrepancy between the actual level and a replacement rate, which represents the usual depreciation normal rate increased by technology obsolescence when firm changes its technology.

Management action to control the level of operational resources is explicit through the adjustment rate of the operational resources, and non-explicitly through the technology adjustment and its effect on operational resources replacement rate. Desired adjustment rate, which indicates management intended level for operational resources, groups the desired level defined in management goal and the replacement of depreciated resources. The capacity acquisition processes are usually subjects to delays, but for simplicity purposes only the desired level defined by management goal is subject to adjustment time.

Profits Goal and Slack Resources

In the firm, Profit goal represents the dominant logic of the firm (Prahalad & Bettis 1986). Profit goal is the source that management has to coordinate the network of decision making points which constitutes a firm; while some resources will need to grow if profit goal achievement fails, other resources must be reduced to achieve the profit goal. Profit goal represents the desired state of the whole set of resources, so it is a key information to control the firm behaviour. Consequently, it is also through the profit goal that behavioural types influence firm behaviour: a reactive firm may have its profits updated with the results obtained as market unfolds, and a proactive firm may have a established level of profits fixed or expected to achieve over time. Behavioural types also affect the sources of information used to update the profit goal: internal such as actual profits or past goals, and external such as industry average profits or one specific competitor profits; however, the preferences for the initial sources of information may change over time as management observes a continuous failure in firm performance, which is captured by variable Bias adaptation.

Organisational Slack is a concept that represents the difference between total resources available and total necessary payments. Organisational slack is defined as a cushion of

resources, which allows a firm to adapt to internal pressures for adjustment as well as to initiate change in strategy with respect to the external environment. The resources in excess are not subject to instantaneous distribution because, when environment becomes less favourable, organisational slack absorbs the variability in firm performance without drastically reducing existing resources. Slack is a resource that accumulates over time through firm profits, so success breeds slack providing a source of funds for innovations, and diminishes through payments for organisational survival processes such as operational resources expansion to capture more customers or R&D investment to develop products. Various authors have studied and found different measures for the concept of slack, and all of them coincide that it represents an important source for firm survival. (Bourgeois 1981; Singh 1986; Cheng & Kesner 1997; Greenley & Oktemgil 1998). Bourgeois (1981) suggests that slack must be measured as changes in amount of slack rather than the amount of existing slack because its effect on strategic behaviour and the existing information restrictions to obtain a clear picture of it; for example, indicators of increases in organisational slack are retained earnings (which is similar to the concept used in this model), general and administrative expenses, and working capital as a percentage of sales. Greenley & Oktemgil (1998) also suggest among other measures the use of a ratio between current assets/current liabilities, considering that this model is not as detailed as to track liabilities the concept of slack as accumulated profits less investments is quite close to their suggestion. Although some of the previous authors have related level of slack to strategic behaviour, in this model slack is only consider a resource to sustain firm evolution processes such as R&D and Operational Resources expansion. The strategic behaviour in this model is determined by the behavioural type of the firm, which determines the connection between firm and environment to determine desired states, and the profit goal achievement that is a good indicator of future problems with slack levels since profits are the only inflows to slack.

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 (Sterman 2000; Armstrong 2001) to describe the diffusion of innovations, which is a process similar to the behaviour generated by the "Market Evolution" feedback loop – the market describes an S-shape growth curve. However, there is a difference between the "Market Evolution" feedback loop and Bass Diffusion Model, in their basic version Bass Diffusion Model considers the diffusion process independently from the effects of firms' strategies or customer preferences distribution. Even though this model has these limitations, it is a solid starting point for modelling the market.

The Bass Model is a two-feedback process whose behaviour over time is an s-shaped growth. Similarly to the "market evolution" feedback loop, the model have two main stocks: potential adopters[3] and adopters. Even though the reinforcing "Word of Mouth" feedback loop dominates after an early growth phase, it is the balancing "Market Saturation" feedback loop that drives the first adopters through advertisement and other channels of awareness like media reports and direct sales efforts since there is no customer growth and zero is equilibrium. The "conversion" from potential adopter into adopter is generated through the number of contacts between adopters and potential adopters and the probability that a contact is successful in attracting a new adopter. The number of adopters compared to the Total Population, where the innovation takes place, dilutes this effect. As the number of adopter increases, the number of potential adopter decreases and the balancing feedback loop "Market Saturation" takes control. "Market Saturation" feedback loop reduces gradually the growth rate until there are no more potential adopters.

Bass Diffusion Model is an interesting starting point but it is limited in the behavioural assumptions that drive diffusion. Consequently, the market sector is enhanced with consumers'

[3] The terms adopters and consumers represent the same concept in this study.

aspects such as heterogeneity to represent more closely the life cycle of an industry rather than a specific product; and it has to include the effect of firms on its evolution

Bass Diffusion Model captures a very simple consumer behaviour process like the contagion process due to word of mouth. However, customers consider other factors before buying a product such as product functionality, availability and price. While price is an important factor that determines consumer behaviour and easy to implement, as it was used to test the misperception of feedback at market level (Paich & Sterman 1993), does not capture the most essential process that is the match between customer needs in terms of product functionality and firms ability to provide the product required. This parallel adjustment process between firms and customers to match functionality to preferences may originate a general pattern over time for the rate of product innovation at industry level described by Utterback (1994).

There are a number of models that portray this parallel behavioural adjustment between firms and customers. Granovetter (1978) suggests in his threshold model of collective behaviour that processes of mutual adjustment can be highly non-linear. Threshold models are based on the concept that the threshold is simply a point where the perceived benefits to an individual of doing the thing in question, i.e. buying a certain product, exceed the perceived costs. He also affirms that in the context of threshold models, the idea of "contagion" seems inappropriate, since there is more than an imitation of the last person observed. Chatterjee & Eliashberg (1990) use a micro modelling approach to consider the determinants of adoption at individual level in a decision analytic framework. Their model incorporates heterogeneity in the population with respect to initial perceptions, preference characteristics, and responsiveness to information; and provides a behavioural basis for explaining adoption at the disaggregate level and the consequent pattern of diffusion at the aggregate level. Adner and Levinthal 2001) characterise consumer behaviour as driven by a functionality threshold that defines a minimum

performance level at which a consumer will not accept a product independently the price of the product, and each consumer has different thresholds.

Considering the different approaches to capture demand heterogeneity and dynamic behaviour, I propose two modifications to actual market model:

- First, it is necessary to incorporate behavioural variables to represent a basic consumer decision making process such as compare between its requirements or needs with the functionality offered by existing products.
- Second, 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 attracted yet.

Final Considerations

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. Speed is a key issue during the first stages of an industry, not particularly for establishing a first-mover advantage or exploiting the network externalities, but for grasping the necessary customers to sustain a growth path. Managerial decision-making processes are almost the most influential variable to manipulate the evolution of an industry. However, managerial decision-making have been neglected in the literature of industry evolution.

This paper is the first step on analysing 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: firm's growth, market evolution, and technology development. This paper provides a framework termed Dynamic Behavioural Model of the Evolution of Industries to encompass all the issues that imply the analysis of industry's dynamic behaviour

from a managerial point of view. As an initial step, decision-making has been categorised as reactive or proactive based on the influence that exerts on the dynamic behaviour of the industry. Seeing the aggregate dynamic of an industry from a bottom-up approach implies the necessity to pay attention to the distribution of behavioural types of firms in order to comprehend their effects at an aggregate level.

To empirically test and refine the framework proposed, a whole model based on a case study is the next step.

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