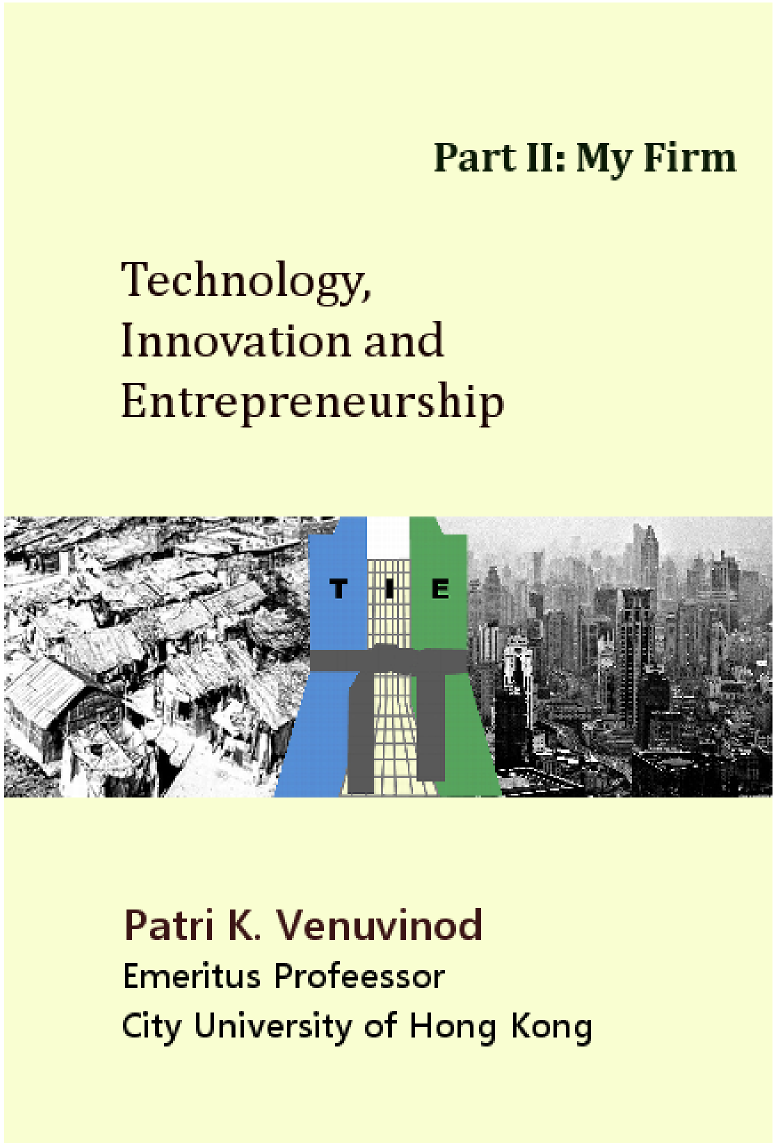

Technology, Innovation and Entrepreneurship

Part II: My Firm

Patri K. Venuvinod

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Dedication

To Mrudula, my wonderful wife.

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Technology, Innovation and Entrepreneurship, Part III: My Startup

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About this Book

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Thomas Jefferson said "[E]very generation needs a new revolution." The revolution for the generations in the first half of the 20th century was socialism/communism. For the generations of the second half of the same century, it was the return to capitalism. For the current generation, it seems to be entrepreneurialism.

Three insights concerning economic growth have become clear in recent times. First, the key to economic growth is technology (T). Secondly, innovation (I) is the driver of technology growth. Finally, entrepreneurship (E) is a highly powerful but extremely underappreciated contributor to innovation. Yet, there continues a paucity of academic books covering the large variety of issues impinging on TIE-exploitation from a contemporary viewpoint. This book is the third and final part of a textbook-trilogy that seeks to fill this gap.

Part I: My *World, My Nation* examined TIE interactions from a world-perspective but stressing nation building. *Part II* (this book) is titled *My Firm* as it discusses how an established firm could prosper in the contemporary world of globalized competition and technology. *Part III: My Startup* discusses issues of particular interest to the growing number of youth pursuing an entrepreneurial career.

The origins of this trilogy lie in the class notes compiled by the author while teaching 'Management of Technological Innovation' to undergraduate and graduate students from science, engineering and business departments. The final contents have been influenced strongly by the insights derived by him while living and working in India, the UK, Hong Kong (including extensive travels to mainland China), and the USA. Thus, rather than focusing just on the lessons to be learnt from the experiences of a developed country such as the USA (as most books on the themes examined do), this trilogy empathizes with the biases and concerns of the developing parts of the world as well.

Among the topics examined in this book (Part II) are diffusion of technology, industry dynamics, competition, competitive advantage, competitive forces, strategy development, research and development, R&D management, technology and market forecasting

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Preface

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My childhood was spent in a small Indian township housing the largest Asian sugar factory of the time. Yet the town didn’t even have a primary school. Consequently, I couldn’t receive formal education till I turned nine. Only then could I be trusted to lug my school bag across water-laden paddy fields to a small government school located in a larger neighboring town.

The difference between the two towns was palpable. In keeping with their rural setting, people in my school-town were mostly steeped in age-old traditions, and religious or caste rivalries. This was in sharp contrast with the people in the industrial township I lived who tended to temper blind belief with rationality, dogma with pluralism, and disorder with organization. This contrast provided me with my earliest practical lesson in the power of technology as a vehicle for bringing forth social transformation.

My technicism led to a dilemma, though, as I approached graduation from my high school and started thinking about what I could/should become. The choice was obvious for most of my classmates. A farmer's son would become a farmer, a grocer's a grocer, and a feudal landlord's a landlord. Being a technologist's son, none of these choices was immediately available to me. In any case, all were unexciting.

Meanwhile, independent India was struggling to find its road ahead. The "Father of the Nation", Mahatma Gandhi, passionately advocated a bottom-up, village-oriented approach underpinned by altruism. Technology was accorded only a peripheral role, if at all.

But, Gandhi's influence was already waning as that of Jawaharlal Nehru was rising. As India's prime Minister for seventeen years, Nehru pursued a national development strategy based on socialistic principles and central planning. (During his formative years, Marx's works were well-known while Schumpeter had not written his counter-thesis yet. Schumpeter gained some fame by the time Nehru became the prime minister. But, apparently, Nehru's mind had set by then.) Nehru also acknowledged the central role of technology in development and created a range of public sector industries which became vehicles for technology transfer mainly from the Soviet bloc. Taking cue from this trend, I joined an engineering college in the state capital in the hope of eventually becoming a public sector employee.

One of the few non-technical subjects we had to study was Economics. One would have thought that the syllabus of this subject reflected the prevailing Marxist bias. As it happened, the books prescribed dwelt essentially on classical capitalism. Further, my teacher was an eloquent laissez-faire enthusiast. All this exposed to me to the flipside of Nehru's strategy: it was ignoring the role of the individual through personal enterprise. In fact, individual entrepreneurship was being discouraged through elaborate licensing requirements. This didn't bother me since I, like most of my compatriots, believed that no public good can come out of greedy individuals.

Immediately upon obtaining my engineering degree, I proceeded to one of the premier institutes of technology in the country to specialize in design and production engineering. The particular institute I joined was set up with Soviet collaboration, so a good number of my professors were from the U.S.S.R. I learnt a lot about mechanical technologies from them but little about the new developments that were occurring in electronics and computers. There was also little curricular emphasis on the human and market sides of engineering.

My association with Russians and the like didn't end there as the UNESCO expert from the Soviet Union assessing my masters' thesis reacted favorably to it. He started persuading me to take up academic career at a newly established Regional Engineering College. The idea was that I would assist him on developing the curricula for eight post-graduate programs in technology across India. I agreed.

Over the next few years, I got associated with many more experts from the Soviet Union and Eastern Europe. From them I learnt more about technology and their countries where vertically integrated industries were producing the goods that the respective governments thought their citizens needed.

Next, I was selected to go to the U.K. as a UNESCO fellow to work on my Ph.D. The personal niche in technology (metal cutting) research I was to find there was to remain with me for the rest of my professional life. While in the U.K., I also spent some time at an ILO institute in Italy and secured a deeper appreciation of the role of technology in economic growth. These experiences helped me develop a more secular, and global outlook.

Upon receiving my research degree, I returned to my previous place of employment in India. The aura of my 'foreign' PhD helped intensify my research activity. It also made it easier for me to initiate several non-curricular learning activities amongst students. For instance, noting that the college's curricula had not included management science as a subject of formal study, I organized interested students into what we called the Management Studies Group. Not everyone was happy, though, with our enthusiasm for management science. For instance, during an address to the group, the main message of our Principal was that 'management' was no more than a euphemism for worker-exploitation. Many others were also offended as the campus was rapidly becoming a hotbed of communism. The resulting tensions made me think about finding a place more conducive to academic pursuits.

A few years later, I moved to Hong Kong—then still a British colony. I worked at two different polytechnic-universities. At the first, I obtained a broad understanding of how Hong Kong ticked. Hong Kong was very different from India or the U.K. While India was still struggling to find its path and the U.K. was past its prime at least in terms of world domination in technology, Hong Kong was fast becoming a prominent 'Asian Tiger' despite being just a city state without any natural resources and little industrial history. It had already acquired international reputation in finance and manufacturing. In terms of manufacturing, it had developed well past the era of Productivity (P) into the era of Quality (Q). It achieved all this by pursuing free market capitalism based on thousands of horizontally integrated small and medium-sized private enterprises. The government assiduously pursued a hands-off policy believing that other social problems would be mitigated automatically as economic prosperity is achieved. The reliance on personal enterprise (entrepreneurship) seemed to infuse many a young person with confidence in the future. These observations made me more sensitive to the power of individual entrepreneurship in economic growth. I also became convinced of the importance of creativity and broad-based education in the preparation of youth for entrepreneurial careers.

All this preparation proved to be particularly useful when I became the founding head of the Department of manufacturing Engineering at a newly formed polytechnic-university in Hong Kong. I promptly set in motion several curricular and pedagogic experiments. The results only confirmed my convictions.

My 25-year stay in Hong Kong also provided me with ample opportunities not only to learn about but also to interact with mainland China. When I first arrived in Hong Kong, China had just embarked on a journey that was to lift some half a billion people out of poverty within the next 30 years. I had the good fortune of being chosen as a member of the first international delegation organized by some Hong Kong elders to visit China after Deng Xiaoping had declared China's "Open Doors Policy". This was only the first of many similar trips to come.

When I first went to South China, I found the place in a shambles following the self-inflicted injuries during the Cultural Revolution. Yet, today, the region is a thriving industrial complex actively contributing to China's well-earned reputation as the "factory of the world".

As I noticed during my subsequent trips to different parts of China, this was mainly the consequence of technological advancement resulting from technology transfer underpinned by unprecedented openness. Equally importantly, it was because the government managed to release the entrepreneurial energies of individuals without putting overall political stability in serious jeopardy. China was also wise in adopting the unprecedented “one country, two systems” policy with regard to post-1997 Hong Kong. The policy has already yielded rich dividends—Hong Kong’s industrialists have been providing between 50 and 70% of FDI in China.

The above political developments suggested to us that our department’s programs and curricula would have to recognize not only the local aspirations of Hong Kong but also how the territory could contribute to the rest of China. In particular, we had to take into account the fact that Hong Kong needed to move on to the era of Innovation (I). Keeping this in mind, we sought to broaden our program portfolio beyond manufacturing engineering in a manner that would enable students to equip themselves for the coming era of innovation and entrepreneurship. We also introduced, for the first time in Asia, a bachelor’s program in Mechatronic Engineering and a master’s program in Engineering Management. The former emphasized the design of products and processes involving the integration of mechanical, electronic and computer elements. The latter sought to convert engineers into managers capable of conceiving and operating technology-intensive firms and startups. For over ten years, I personally taught the subject of Management of Technological Innovation (MTI) to both engineering and non-engineering students drawn from sub-degree to doctoral levels.

A major problem I encountered while teaching MTI was that there was no suitable textbook to support my teaching. Whereas I was seeking to examine technology, innovation and entrepreneurship (TIE) in fair detail and in an integrated manner, the existing text books focused on the management of the first while treating the latter two only in a cursory manner. Clearly, there was a need for a new book. It was then that I set upon writing this trilogy.

It took me several years of personal research and learning to come to grips with the book’s contents. I embarked upon such an exercise immediately upon retiring from active service in Hong Kong and setting up residence in the U.S. My work was significantly helped by the fact that my immediate circle in the U.S. included several young, budding entrepreneurs. I learnt a lot by keenly observing their entrepreneurial trials and tribulations.

Upon retirement from formal teaching, I tried to disseminate in India the TIE lessons I had learnt abroad. I managed to bring together over twenty engineering colleges in and around Hyderabad to collaborate under the umbrella of International Organization of Developing Universities (IODevUni). One of the projects initiated by the Chapter was the application of the emerging e-learning technologies to facilitate the teaching of subjects for which member-colleges did not have enough experts.

E-learning enables students to learn anywhere at the pace, time and location of their choosing. The contents of an e-book itself can be updated frequently. One can also use the power of the Internet to build and sustain a learning community around the particular professor/subject. The learning community itself can contribute material such as case studies, adaptation to local and current conditions, and so forth. This is why this trilogy is being offered first in the form of e-books and a website called tecinnovent.com has been set up in its support.

This trilogy is based on five premises that seem to hold in any economy irrespective of the ‘ism’ being followed:

~ The key to economic growth is productivity improvement through improved technology.

~ Innovation drives technology growth.

~ Competition spurs innovation.

~ Entrepreneurship consummates innovation.

~ The above four premises are equally applicable at the levels of nation-building, managing an existing firm, as well as launching a new venture or a startup.

The first four premises resonate with the recent arguments made by Edmund Phelps, 2006 winner of Nobel Prize for Economics, that general knowledge—encompassing business, technology, and the economic environment at large—is an important enabler of the virtuous circle of creativity, innovation, and growth.

Following the last premise, this work is organized into three parts, each devoted to one of these three levels. The picture on the cover page seeks to capture the way each part is addressed. The shape of the central structure in the picture is inspired by Wilson Hall of Fermilab situated close to the author's residence in the suburbs of Chicago (see figure below). Till very recently, Fermilab had been housing the largest particle accelerator in the world. Thus it captures the central role of systematic science. Systematic science of course is the springboard for a great deal of modern technology.

Adapted from Fermilab website.

The central structure is made up of three parts labeled Technology (T), Innovation (I), and Entrepreneurship (E). This, of course, is in agreement with this trilogy's title. However, the intention is not just to examine T, I and E as themes worth studying in their own right, but also to 'tie' them together in a purposeful manner. Nations, firms and professionals who understand how the three elements can be synergistically united will enjoy a clear competitive advantage in the modern, globalized world. This emphasis on pulling T, I, and E together so as to beat the competition is reflected by the black belt around the central structure's 'waist'.

Part I consisting of Chapters 1 to 8 is titled 'My World, My Nation' as it explores the theme of TIE from a world-perspective but stressing nation-building. As citizens of the world and of a specific nation we all engage in animated discussions about some aspect or other of current trends and events in the world. This part aims to make such discussions more informed and purposeful. The issues discussed should be of particular interest to public officials/workers and those at executive levels.

Part II (Chapters 9 to 17) is titled 'My Firm' as it discusses the TIE theme from the perspective of how an existing firm or organization could prosper in the contemporary world of globalized competition. The issues discussed should be of particular interest to professionals and managers at all levels.

Part III (Chapters 18 to 26), titled 'My Startup', focuses on issues of particular importance to the growing number of youth across the world seeking an entrepreneurial career. It should also be of interest to serial entrepreneurs and intrapreneurs (mentors of entrepreneurial employees).

Although much of the material covered in the present trilogy is available in other books, few have put all of them together. The trilogy also includes several segments drawing on the author's research.

An examination of literature on the subject of TIE reveals a variety of discursive approaches. Some rely on a selection of case studies to find commonalities to arrive at a list of do's and don'ts. Some choose a particular sociopolitical belief system, e.g., capitalism or socialism, and use it to theorize. The method adopted in this trilogy is neither. The term 'evidence-based reasoning' captures the preferred mode of discussion.

Although the trilogy adopts an academic writing style, it should be useful to working professionals as well as general readers in addition to university students and researchers. It is not necessary that all the chapters are covered in a single semester. Depending on the course objectives, one can pick and choose chapters. There is enough material in the trilogy to engage students for 2 to 3 semesters.

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Chapter 9

The Diffusion and Dynamics of Innovation

"Knowledge is not simply another commodity. On the contrary, knowledge is never used up. It increases by diffusion and grows by dispersion."

—Daniel J. Boorstin

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Schumpeter's characterization of innovation as "creative destruction" carries the message that innovation and its effects are essentially dynamic in nature. It highlights the tensions between stability and change, optimism and pessimism, gain and pain, and so forth. It also raises many questions. What is being created and what is being destroyed? Do they balance, or is there a net gain/loss? How are creation and tension related temporally? Answers to these questions are
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mostly contained in literature carrying the label “The Dynamics of Innovation.” Another closely related body of literature concerns the diffusion of innovations which attempts to answer questions such as the following. Why do some innovations fail while others succeed? Amongst the successful, why are some adopted faster? Of these two fields, the latter is more classical, so we will start this chapter with a review of the theory of diffusion of innovations.

Theoretical Origins

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The theory of diffusion of innovations attempts to explain the process by which a new idea or new product is accepted by the market. The development of the field can be traced back to the beginning of the twentieth century in certain German, Austrian and British schools of Anthropology and to a French sociologist and social psychologist by name Gabriel Tarde.

Towards the end of the nineteenth century Tarde was witness to many innovations, some of which were quickly adopted while others were ignored. He then set out to explain why it was so. His explanation hinged on his broader thesis that sociology is based on small psychological interactions among individuals with the fundamental forces being imitation and innovation (Tarde, 1890). He suggested that individuals learn about an innovation by copying it. The more similar the new idea to ideas that have already been accepted, the more likely is its adoption. Tarde also observed that the rate of adoption of a new idea usually followed an S-shaped curve over time and that the takeoff in this curve occurs when the opinion leaders in the society adopt the new idea.

Tarde’s insights could not be followed up immediately as social scientists of the day lacked the methodological tools needed to conduct quantitative diffusion studies. It was only after forty years that his ideas were resurrected by Ryan and Gross in their seminal study of the diffusion of hybrid seed among two corn-farming communities in Iowa (Ryan & Gross, 1943; Ryan, 1948). A summary of this study is provided in Box 9.1. A major finding of the study was that the rate of adoption of the new type of seed did follow the S-shaped diffusion curve graphed earlier by Tarde (see Figure 9.1).

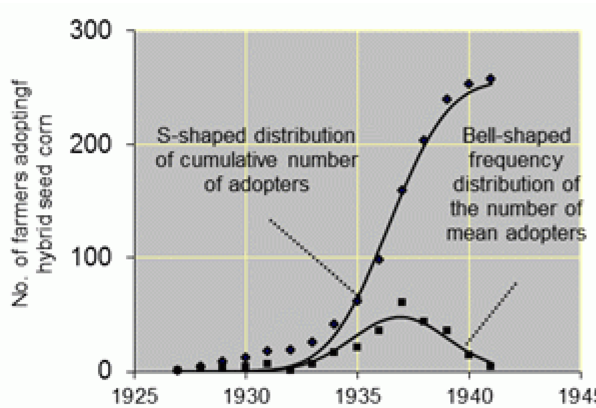

Figure 9.1 The technology-adoption S-curve observed by Ryan & Gross (1943).

Another finding was that “the adoption of innovation depends on some combination of well-established interpersonal ties and habitual exposure to mass communication." This suggested that diffusion was a "social process through which subjective evaluations of an innovation spread from earlier to later adopters rather than one of rational, economic decision making." Further, the adoption process could be divided into five major stages: awareness, interest, evaluation, trial, and adoption.

The credit for creating a comprehensive framework for diffusion studies however goes to Everett Rogers whose1962 book, *Diffusion of Innovations*, has been recognized as the most definitive work on the subject. Interestingly, Rogers was also an Iowan and his childhood was linked with the hybrid seed story of Ryan and Gross. As it transpired, Everett's father was one of the Iowan farmers who had resisted hybrid seed corn planting. Unfortunately, there was a drought in that year and the Rogers' farm withered. Apparently, this episode played a role in Rogers' subsequent decision to undertake Ph.D. studies on the diffusion of innovations at Iowa State University.

Rogers defined an artifact of innovation as "an idea, practice, or object perceived as new by an individual or other unit of adoption…Newness in an innovation need not just involve new knowledge. Someone may have known about the innovation for some time but not yet developed a favorable or unfavorable attitude towards it, nor have adopted or rejected it. [Newness] of an innovation may be expressed in terms of knowledge, persuasion, or a decision to adopt."

Rogers then reviewed the diffusion patterns reported in over 3,000 previous studies covering a variety of innovations including: water boiling in a Peruvian village, scurvy-control measures by the British navy, hybrid seed corn in Iowa, hard tomatoes in California, miracle rice in Bali, modern mathematics in Pittsburgh, drugs such as Tetracycline, the QWERTY keyboard, bottle-feeding in the third world, mid-water trawling by U.S. fishermen in the Pacific, etc. The studies reaffirmed the general applicability of the S-type technology-adoption curve and the bell-shaped frequency distribution curve shown in Figure 9.1. From these reviews, Rogers developed a generalized framework for the study of diffusion of innovations. We will use this framework as the basis of our discussion in this chapter.

The Technology-Adoption S-curve

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One of the major findings by Rogers was the ubiquity of the S-shaped curve shown in Figure 9.1. More importantly, the bell-shaped frequency distribution curve could be approximated by the cumulative curve of a Gaussian normal distribution. In other words, the technology-adoption S-curve can be assumed to be a cumulative normal distribution. Note that we have already come across the term 'Technology S-curve' in Chapter 6. There, our intent was to study progress in the performance of a given technology over time. By contrast, our intent here is to study the rise in the number of adopters over time. To distinguish between the two, we will use the term *Technology-adoption S-curve* while referring to a graph depicting growth in the number of people adopting an innovation.

Rogers suggested that a theoretical explanation for the normal approximation lies in the fact that the cumulative influences upon an individual to adopt or reject have a tendency to increase over time. If the first adopter discusses it with two other members of the system, and each of the adopters passes it two other peers, and so forth, the resulting distribution follows a binomial expansion. Now it is a well-known consequence of the Central Limit Theorem of statistics that, as the number of trials (adoptions) increases, the binomial distribution increasingly approximates a normal distribution.

Rogers however warns against putting undue faith in the normal approximation for the reason that the members of the system might not have completely free access to interact with one another owing to status differences, geographical barriers, social taboos, and so forth. In such a situation, members of the system would find it increasingly difficult to tell about the innovation to a new adopter, since such "nonknowers" become increasingly scarce. This would result in a technology-adoption curve that starts leveling off after about half the individuals in the system have adopted the innovation.

Another caveat is that the S-shaped technology adoption curve only describes cases of successful innovation. Many innovations however are not successful because the innovation is rejected after only a few adopters. In such a situation the S-curve may level off well before the take-off point or, even, nosedive if the innovation is discontinued. Such effects may also be triggered by the appearance of a more powerful innovation thus wooing away potential adopters of the current innovation. It is possible that the current innovation itself gets progressively modified through the efforts of its users (adopters). Yet another reason for the deviation from the normal S-shaped curve is the lock-in caused by path dependence, as in the case of the QWERTY typewriter keyboard (recall Box 6.1). The diffusion process is particularly sensitive to all these effects until the number of adopters has reached 10% to 20% of all potential adopters. However, once the takeoff point has been reached, it is usually impossible in the short run to stop the spread of the innovation.

Adopter Categorization

According to Rogers, the process of adoption of an innovation can be broken down into five stages. The first is the awareness stage during which the individual is exposed to the innovation but has incomplete information about it. Mass media can play a major role in enhancing adopter awareness.

Once the individual has become interested in the new idea, he/she starts seeking additional information about it. This is called the *information stage*. The knowledge sought in this period is essentially of the 'how to' type although some adopters may also look for an understanding of the functional principles underlying the innovation.

After sufficient information has been acquired, the individual starts to mentally apply the innovation to his/her present and anticipated future situations with a view to deciding whether or not to adopt the innovation (*evaluation stage*). If the decision to adopt is positive, he/she would fully apply it (*trial stage*). Finally, if the results are up to expectation, the individual continues to adopt the innovation (*adoption stage*).

Not all individuals, though, go through all the five stages. At any given stage, the individual can reject or discontinue the innovation either because he/she is disenchanted (*disenchantment discontinuance*) or because a new and better idea has arrived on the scene (*replacement discontinuance*). Even when an individual goes through all the five stages, there can be significant variation in the times spent at each stage.

These insights lead us to the notion of *innovativeness* defined as "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than the other members of the system." Combining this notion with the normal approximation of the adopter frequency distribution, Rogers advocated the classification of adopters into the five categories illustrated in Figure 9.2. The categories are delineated on the basis of the mean time of adoption, *t*m, and the standard deviation, *s*, of the normal approximation of the frequency distribution curve. Let us examine now the natures of these five categories.

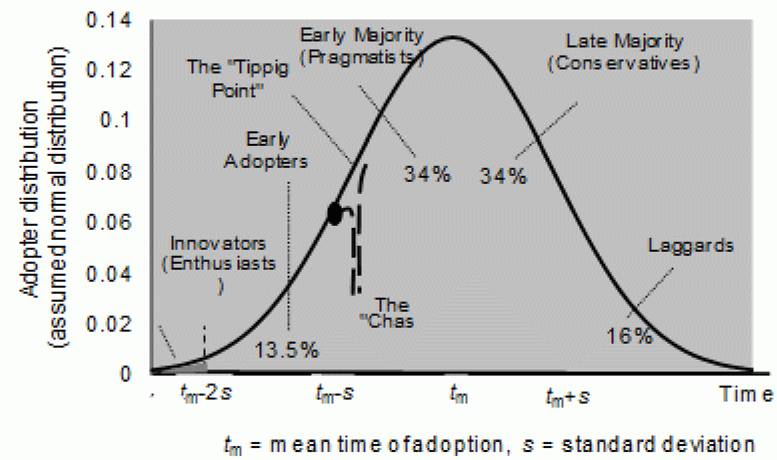

Figure 9.2 Rogers' adopter categorization.

Innovators: These are the adopters before time t_m -2*s*, so they make up just 2.5% of the total number of adopters. They are labeled "innovators" because they are the first to be attracted to the innovation. They usually have substantial financial resources. This enables them to undertake rash, daring, or risky ventures. Thus, venturesomeness is their main characteristic. Owing to their obsessive interest in new ideas, they seek cosmopolite social relationships extending beyond the local peer networks. They communicate regularly with other innovators thus forming cliques that may extend over long distances. Owing to these characteristics this group of adopters has been labeled "enthusiasts" in other literature (Moore, 1991).

Early adopters: These are the adopters in the time-period t_m-2s to t_m-*s*, thus constituting about 13.5% of the total number of adopters. By contrast with innovators, early adopters tend to be more integrated into the local social system. They are judicious in making adoption decisions, so their peers respect them highly and seek their opinions and advice. Thus they constitute the opinion leaders and serve as role models for many other members in the social system. Consequently this group is generally sought by change agents and other missionaries trying to speed up the diffusion process. Owing to these characteristics this group is also known as 'visionaries' (Moore, 1991).

Early Majority: These are the adopters in the time-period t_m-*s* to t_m, thus accounting from about a third of all adopters. These individuals tend to adopt the new idea just before the average member of the social system. They prefer not to be the first trying out the new. At the same time, they do not want to be the last to lay the old aside. They frequently interact with their peers but not to the degree that the early adopters do. Their main role in the diffusion process is to act as a link between the opinion leaders and the late majority. The innovation-decision period of this group is longer than that of the two earlier groups. Owing to these characteristics this group of adopters is also called 'pragmatists' (Moore, 1991)

Late Majority: These are the adopters in the time-period t_m to t_m +*s*, so about a third of all adopters would belong to this category. Their resources are usually limited, so they tend to be a skeptical and cautious lot. Consequently they do not adopt new ideas until most others in the system have done. They need peer-pressure before they are able to take the plunge. Owing to these characteristics this group of adopters is also referred to as ‘conservatives’ (Moore, 1991).

Laggards: These are the adopters in the time-period beyond t_m+s, hence accounting for about 16% of all adopters. Their resources are usually limited severely, so they tend to be the most localite in the system. Many are near isolates. The point of reference for them is the past, so they interact mainly with those having traditional values. As a result, their innovation-decision process is lengthy, as in the case of Everett’s father. They tend to adopt a new idea only if it is an economic necessity. However, prior conditions other than innovativeness can affect the innovation-decision process, e.g., previous practice, felt needs and problems, and the norms of the social system.

Rate of Diffusion

Although most innovations have an S-shaped curve of adoptions, how upright the “S” is varies from innovation to innovation. This raises the question why some innovations have a rapid rate of adoption while others exhibit a lazy S-curve. The rate of adoption of an innovation may be measured by the length of time required for a certain percentage of the members of a social system to adopt it. This means that we need to consider the nature of the innovation itself as well as how it is communicated within the social system in question.

Recall that, from the viewpoint of diffusion, it is not necessary for an innovation to be new in an objective sense. It just needs to be perceived as being new by the members of some social system. Such perceptions may be rooted in the innovation or in the halo created around it through clever advertising. Whatever be the case, the perceptions can relate to five features. The first is the perceived relative advantage of the innovation over the one it is replacing. The *relative advantage* may be with respect to cost, ease of use, ease of storage.

The second is the *compatibility* between the innovation and the social system within which it is expected to diffuse. For instance, birth control pills are not compatible with the religious beliefs of some communities. Likewise, what works in a developed society may not work in a severely underdeveloped society. Such considerations have prompted many a developing country (e.g., India) to initiate projects aimed at “appropriate” technologies. More recently, following the 2008 recession, India’s IT industry refined the notion and packaged it into a new management buzzword, *Jugaad*. In Hindi, this word means inexpensive innovation on the fly, i.e., innovation driven by scarce resources while focusing on customer’s immediate needs. Ford Model T and the recently unveiled Tata Nano have been cited as examples of *Jugaad*.

The third important feature of an innovation is its complexity. The greater is the perceived complexity, the slower will be the rate of diffusion. For instance, many people are intimidated by the idea of using the internet. Much technophobia is of this nature.

The next is *trialability* which refers to the ability of the consumer to give the innovation a test run before deciding to adopt it. The easier it is to try out a product before purchase, the higher is its rate of adoption.

The final feature of importance is *observability* which is the degree to which the results of the innovation are visible to others. For instance, movements promoting safe sex as a preventive measure countering the spread of HIV/AIDS face an uphill battle because it involves unobservable and ambiguous practices such as sexual abstinence and monogamy.

We now turn to the social features affecting the rate of diffusion. According to Rogers, a *social system* is "a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal. The members or units of a social system may be individuals, informal groups, organizations, and/or subsystems." For instance, the corn farmers of Iowa were jointly deciding how to react to the idea of substituting their open-pollinated seeds with the new hybrid seed corn. Every social system has its norms, communication channels, opinion leaders and change agents. All these affect the rate of adoption.

Norms are the established behavior patterns for the members of a social system. *Traditional norms* are characterized by a preference for less complex technologies, low levels of literacy and education, little communication between the social system and outsiders, apparent lack of economic rationality, and a one-dimensional way of adapting and viewing others. By contrast, *modern norms* are characterized by developed technology with complex jobs, a tendency for placing strong importance placed on education, acceptance of free thought and new ideas, great importance being placed on economic considerations, and a desire to see and understand other people's situations. Empirical data show that societies with modern norms accept and adapt to innovation faster and easier than those with traditional norms.

In the context of diffusion of innovations, communication is the process by which participants create and share information with one another in order to reach mutual understanding. A *communication channel* is the means by which messages get exchanged between units of the social system. Two common types of such channels are mass media such radio, television and newspapers, and *interpersonal channels* which involve face-to-face information exchange between two or more individuals. Mass media are quite effective in spreading knowledge of innovations to a large audience rapidly. They may also be able to change weakly held attitudes.

However research shows that firm attitudes are developed only through interpersonal communication which are more trusted and have greater effectiveness in dealing with resistance or apathy on the part of the communicatee. The effectiveness of interpersonal communications is determined by the degree to which they are similar in beliefs, education, social status, and so forth. Societies exhibiting a high degree of similarity are said to be *homophilous*. However, one of the most distinctive problems in the diffusion of innovations is that the participants usually are quite *heterophilous*. A common approach to overcoming this problem is to persuade opinion leaders (early adopters) to foment positive attitudes toward the innovation. Positive attitudes can also be fomented by professionals from an external agency such as a governmental unit promoting a particular technology or the marketing division of the company that has produced the technology. Rogers calls these professionals change agents. A *change agent* usually seeks to obtain the adoption of the innovation being promoted and discourage the adoption of undesirable competing innovations. In this he/she uses local opinion leaders as his/her lieutenants.

In view of the importance of the mass media in the diffusion of contemporary innovations, it is useful to know about two classical models of mass communication flows. The first is the *hypodermic needle model* which emerged from the Marxist Frankfurt School of intellectuals in the 1930s mainly to explain the rise of Nazism in Germany before World War II. The model postulated that the mass media had direct, immediate, and powerful effects on mass audience. The media were pictured as being omnipotent and hence capable of conveying messages to atomized masses of individuals (Katz & Lazarsfeld, 1955), as in the case of Goebbels' propaganda campaign to promote Nazism in Europe during World War II. It was suggested that a very large group of people can be influenced directly and uniformly by "injecting" them with appropriate messages designed to trigger a desired response—hence the hypodermic needle analogy. A problem with this model, however, is that it does not recognize any escape. People are seen as sitting ducks. This of course is not true at least in many modern, democratic societies (Lazarsfeld et al., 1944). For instance, empirical data concerning political decisions in the U.S. showed that ideas often first flow to opinion leaders through mass media and from these to the less active sections of the society (Lazarsfeld & Menzel, 1963). This *two-step flow model* was subsequently found to be quite accurate for a variety of communication behaviors, including the diffusion of innovations. This model implied that mass media were neither so powerful nor direct as suggested by the hypodermic needle model. The communication model suggested by Rogers however is far more fine-grained owing to the introduction of notions such as homophily and change agents.

Finally in this section we draw attention to the case study on the diffusion of Broadband internet in South Korea presented in Box 9.2. We leave it to the reader(s) to examine how far this case is in agreement with the diffusion theories presented above.

One thing is clear however: The time periods for technology diffusion have been falling owing to the development of more effective communication channels (e.g., Facebook, Twitter). For instance, a 2002 study by MIT's Entrepreneurship Center noted that the length of time needed to reach 25% of U.S. households from the time of invention has been falling significantly: automobile (1886) 56 years; electricity (1873) 45 years; telephone (1876) 36 years; microwave (1953) 31 years; television (1926) 26 years; internet (1975) 23 years; the cell phone (1983) 14 years (Kaplan & Morse, 2002).

Adoption of High-Tech Products

Rogers' model is particularly applicable when, as in the case of continuous innovations, the innovation does not force a significant change of behavior on the part of the customers. This stipulation is however not satisfied in the case of discontinuous innovations such as is the case with some high-tech innovations. A model more closely suited to the latter case is that proposed by Geoffery Moore (1991).

Moore pointed out that "Our [high-tech] marketing ventures, despite normally promising starts, drift off-course in puzzling ways, eventually causing unexpected and unnerving gaps in sales revenues, and sooner or later leading management to undertake some desperate remedy... The point of greatest peril in the development of a high-tech market lies in making the transition from an early market dominated by a few visionary customers to a mainstream market dominated by a large block of customers who are predominantly pragmatists in orientation." Moore called the gap between these two markets a "chasm" (see Figure 9.2) and suggested that *crossing this chasm* must be the primary focus of any long-term high-tech marketing plan. It is only after passing the chasm that one reaches the *tipping point* (Gladwell, 2000) signaling the establishment of a self-reinforcing feedback loop toward the new idea.

According to Moore, the chasm arises mainly because of the nature of the "pragmatist" group of adopters. Statistics, research and even facts don't sway pragmatists. Their purchase decisions are generally based on references within the given vertical market. More importantly, for them, references should come from other pragmatists, not early adopters (visionaries). Visionaries alienate pragmatists because of their lack of respect for experience, their greater interest in technology than industry, and their failure to value the existing infrastructure, and their tendency to take all the credit while not sticking around to make things work in the long run. For all these reasons, one can't sell high-tech products to pragmatists the same way as to enthusiasts and visionaries. In other words, the use of visionaries as references (as Everett suggested) is likely to lead to a plunge into the "chasm." Moore then studied successful campaigns conducted by companies such as Apple, Tandem, Oracle and Sun and came up with the several guidelines for high-tech companies preparing to cross the chasm (for the guidelines, see Moore, 1991).

Industry Dynamics

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When we say something is dynamic we mean it changes with time. Faster the change, the more dynamic is the phenomenon. In other words, what is constant is change—a notion that is being repeated ad nauseam in recent management literature. Another way of interpreting this notion is that everything has a life cycle. Nothing stays the same indefinitely. Everything has a finite lifecycle. Everything is born at some time and is gone after some time. What matters is what happens in between.

The life cycle of any entity can be divided into the following stages: birth, embryonic stage, growth, maturity, decline, death. The entity of interest for us here is an industry or, more specifically, an industry sector. At any time, a given industry sector can be seen as an aggregate of firms serving a loosely defined market through the provision of the associated products and services. *Industry lifecycle theory* links the intensity of competition in a particular market with the time since the breakthrough (radical) innovation(s) that made that market possible.

Incumbents versus New Entrants

The birth of an industry segment is commonly correlated with the cycles of some product or process innovation. Other factors that may launch it include government intervention or deregulation, the liberalization of external trade and lower transportation costs. However, the most common cause is the emergence of a breakthrough or radical innovation.

By definition, a *radical innovation* is one that fundamentally changes the structure of an industry by creating new market segments. If the innovation is from an already established firm (an incumbent), that firm will of course gain substantial competitive advantage over the rest of the incumbent firms. The only thing the other incumbents can do is to start imitating and improving upon the original radical innovation. But an industry is not a closed system. Others, including established firms from other industries as well as totally new upstarts are watching the industry. Any one of these can jump on to the bandwagon. Things get more interesting when this happens, which is usually the case. Now the competition is extended to include the new entrants. Things get even more interesting when the original radical innovation is from a small, entrepreneurial firm from outside the industry. The battle then resembles more like that between David and Goliath since the new entrants and the incumbents have very heterogeneous resources and capabilities (Chandler & Hikino, 1990; Freeman & Soete, 1997).

A key to the understanding the dynamics of a given industry during its lifecycle is to examine how the number and size of firms constituting the industry changes over time. The first formal model in this regard was that by a French economist by name Robert Gibrat (1931). Gibrat examined a broad range of data of the size and distribution of French agricultural, commercial, and industrial establishments in the period 1896 to 1921 and came to the conclusion that *the expected value of the increment of firm size in each period is proportional to the firm size*. This principle is now commonly referred to as Gibrat's rule of proportionate growth or, simply, *Gibrat's Law*.

An implication of Gibrat's law is that the growth rate of a firm is independent of its size. If a company with sales of $10m doubles in size over a period of time, it is likely the same will happen for a company beginning with sales of only $1m. Subsequently, the "law" prompted several alternative models. The overall conclusion is that, although it has several flaws, Gibrat's Law can be used as a first approximation in many situations (Sutton, 1997).

However, the contemporary view of industry dynamics following a pioneering innovation owes much to the works of Abernathy and Utterback whose findings are neatly summarized in *Mastering the Dynamics of Innovation* published by Utterback in 1994. This book contains several graphs illustrating how the numbers of firms entering and exiting a range of U.S. industries varied over their lifecycles. Although there are some variations in the patterns for different industries, we may base our general discussion on the stylized patterns shown in Figure 9.3a.

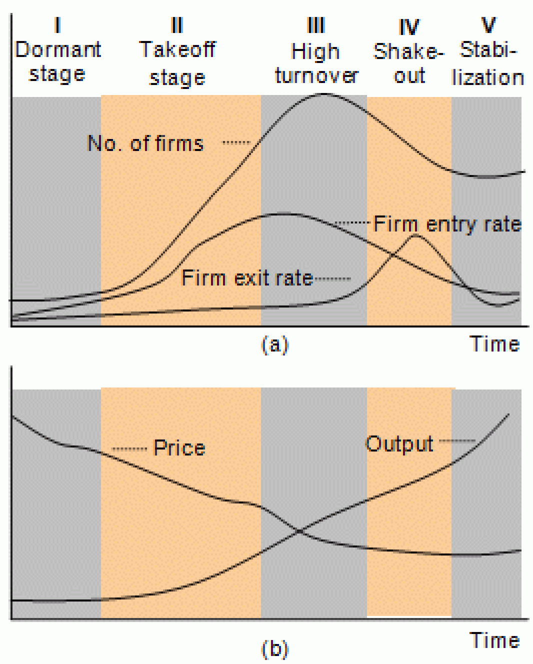


Figure 9.3 Some stylized facts related to industry lifecycle (Abernathy & Utterback, 1994).

The number of firms active in an industry at any given time is the cumulative number of firms entering the industry from the time of its birth less the cumulative number of firms exiting. As shown in the figure, the industry lifecycle can be divided into five stages:

~ *The dormant stage* during which a small number of competitors enjoy high monopoly profits.
~ The *takeoff stage* during which there is soaring entry and virtually non-existent exit from the market.
~ The *high turnover stage* during which a large number of firms enter and leave the market.
~ The *shakeout stage* with mass exit via mergers, bankruptcies, etc.
~ The *stabilization stage* during which a stable oligopoly emerges.

Stages I to III constitute what is known as *the entrepreneurial regim*e in which new entrants are favored because the stock of industry-specific knowledge is low and the knowledge that is critical to innovation lies outside the incumbent firms.

In stages IV and V, the industry has matured into a *routinized regime* during which innovation is determined by non-transferable, internalized, market-based knowledge. As a result, the knowledge-based advantage of new entrants over incumbents reverses when the industry moves into the routinized regime (Sarkar et al., 2006).

Some Stylized Facts

Another highly cited contribution to the understanding of industry lifecycle is the list of stylized facts prepared by Gort and his associates after studying the historical development of a large number of products in terms of their sales, price, output, and the counts of producers over their respective lifecycles (Gort & Klepper, 1982; Agarwal & Gort, 1996). Here are the main stylized facts identified by them (see Figure 9.3b):

~ Sales and output of a product grow at a rate that declines rapidly with that product's age, and the rate tends to converge to zero.
~ Product price declines fairly steadily and at a decreasing rate as the product ages.
~ After the product is born, first there is a rapid entry of firms, then a mass exit, a shakeout, and finally stabilization in the number of firms at a level of about 40% below the peak number.
~ Innovation activity as evidenced by patenting does not fall off as the industry matures. Neither does it decline with the age of the product. However, innovations occurring while the product is young matter more than those occurring later.
~ A firm's exit hazard declines with the age of the firm.
~ A firm's exit hazard rises with the age of the industry.

Stylized facts (i) and (iii) are particularly heartening. Output from an industry continues to increase over its lifecycle as prices decrease. The reason lies in fact (iv) which suggests that innovation activity persists over the entire industry lifecycle. New entrants play a significant role in innovation across the industry. There is compelling evidence showing that the market share of new entrants over a period of time is strongly related to the TFP (Total Factor Productivity—see Chapter 4) of the industry (Bessen, 1998). All this implies that creation wins over destruction despite the painful churning that industries experience.

Insights from Abernathy & Utterback

Let us now turn to the insights provided by Abernathy and Utterback concerning the nature of industry dynamics following a pioneering innovation. Although their initial work had focused on the automobile industry (Abernathy, 1978; Abernathy & Utterback, 1994), similar patterns were observed when they examined other *assembled product industries* such as typewriter, electric lamp, personal computer, television and television tube, transistor, electronic calculator, integrated circuit, and disk drive. On the other hand, some major differences were found in non-assembled product industries such as plate glass-making (Box 9.3), petroleum cracking and rayon. So they chose to discuss patterns of technological growth in terms of these two extremes while recognizing that there is a broad middle ground of products exhibiting some characteristics of both (e.g., color photographic film). An excellent review of their findings interspersed with numerous case studies is available in (Utterback, 1994).

Changes in Assembled Product Industries

Figure 9.4a shows some common patterns of change in assembled products industries following the introduction of a new technological paradigm. When a pioneering firm introduces a radical product, it triggers a growing market around it. New competitors enter the market with alternative product versions hoping to capture as big a chunk of the market as possible. However, at this stage, none of the versions is perfect and none of the competitors has yet mastered the related production and distribution processes. At the same time, the customers are not sure of what they are looking for. Both producers and consumers are learning as they move along. One may therefore say that the industry is in a *fluid stage*. An implication of the fluidity is that the capital and technical barriers to new entrants are not too daunting, so many aspiring entrants start experimenting with the new idea.

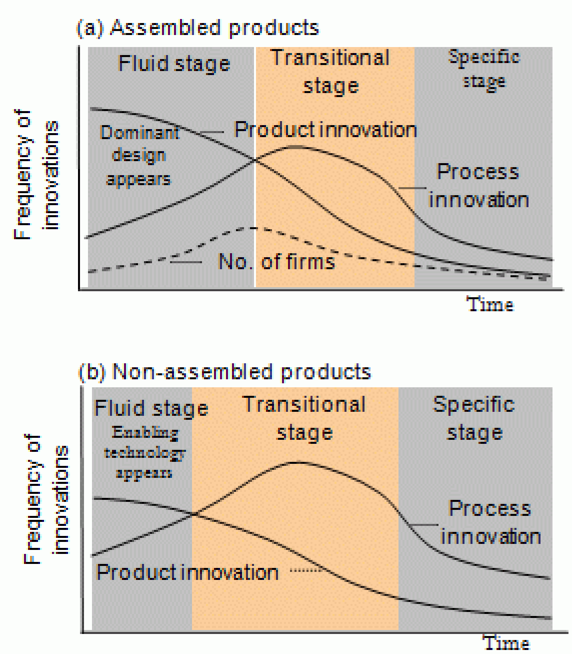


Figure 9.4 Patterns of industrial change following a major change in technology.

It is common to think that, in the fluid stage, new entrants to an industry are smaller firms. This might or might not be the case since there are numerous examples of large firms entering young industries, e.g., Remington's entry into the typewriter industry in 1873 and IBM's entry into the PC industry in 1981. Whatever be the case, initially, technical progress is slow as there are only a few firms participating. As larger firms enter the scene, technical progress and productivity pick up. On the other hand, since industry standards are not yet firmed up, new entrants start coming up with bold new designs. Meanwhile established firms continue to perfect their original designs and keep coming up with improved new models. The response of the customers to various new products acts as feedback stimulating producers to take corrective actions in the next product introduction (Klein, 1977). However, no single design captures customer allegiance. Thus the fluid stage is one of experimentation and competition.

During the fluid phase of an assembled product industry, firms compete mainly on the basis of product innovation rather than on lower cost or higher quality. So process innovation lags behind product innovation (Figure 9.4a). The processes specific to each new product remains a mixture of skilled labor and general purpose machinery. Since there is no single design to market on a large scale, it does not make economic sense to develop specialized tools and machines.

At some point, one of the designs wins a level of consumer allegiance that forces competitors and other innovators to start mimicking it. Such a design is called the *dominant design*. The dominant design is usually a synthesis of individual technological features sought by specific groups of customers, so it seeks a compromise through the interplay of a range of technical possibilities and market choices.

The notion of dominant design can be applied to products as well as processes. When its dominant design arrives, the industry starts undergoing significant structural transformations. If the market leader had originated the dominant design, that firm's position is considerably strengthened. If it was from an industry outsider, the incumbent's market leadership is severely compromised. Table 9.1 lists the major dominant design sequences identified by Utterback (1994, 2003) in a selection of industries.

Table 9.1 Examples of dominant designs (Utterback, 1994, 2003).

Industry	Dominant design sequence
Ice and Refrigeration	Harvested natural ice → Mechanically made ice → Refrigeration → Aseptic packaging
Imaging	Daguerrotype → Tintype → Wet plate photography → Dry plate → Roll film → Electronic imaging → Digital electronic imaging
Lighting	Oil lamps → Gas lamps → Incandescent lamps → Fluorescent lamps → Light emitting diodes
Plate glass making	Crown glass → Cast glass through many changes of process architecture → Float process glass
Typewriters	Manual → Electric → Dedicated word processors → Personal computers

A dominant design may persist for a considerable period of time, even though it might not represent the best technical solution (e.g. VHS versus Betamax). Typically, it significantly reduces the number of explicitly stated performance requirements by making them implicit in the design itself. Thus, for instance, everybody now assumes that the car they are purchasing would include indicator lights and windshield wipers, though not necessarily seat warmers. At the same time, the performance criteria that had remained ill-defined during the fluid stage become well-articulated. Many of the preferred features are already set by the marketplace, so the product innovation focus moves to product variation rather than to radical innovation. The result of all this is the flurry of radical product innovation that had characterized the fluid stage ends after the emergence of a dominant design. Hence the period of industry development around the introduction of a dominant design is called the *transition stage* leading up to the specific phase to be described later. Table 9.2 summarizes the typical changes occurring in industry following the emergence of a new dominant design.

Table 9.2 Changes brought in by a dominant design (Utterback, 1994).		
	Before dominant design	After dominant design
Products	Change is rapid and radical. Fluid specifications. High variety leading to a dominant design. Reviews and demonstrations are the basis of differentiation. Performance sensitive.	Change is slow and incremental. Stable specifications. Small improvements to dominant design based on a standard. Features and flexibility are the basis of differentiation. Price sensitive.
Processes	Ad hoc and experimental.	Highly standardized based on low skill.
Innovation	Mainly in products.	Mainly in processes.
Markets	Fragmented. Uncertain size. User-maintenance and modification.	Commodity. Predictable size. Service and reputation.
Competition	Many small firms. Low cost of entry.	Oligopoly with similar products. High cost of entry.
Organization	Entrepreneurial.	Mechanistic with well-defined tasks.

The emergence of a dominant design is not simply a matter of technological progress since it can be influenced by many other factors. For instance, governments can influence the process by favoring specific technologies for political and social reasons. Likewise, firms in possession of greater collateral assets such as brand image and strong communication channels with customers can make the market swing either way (Teece, 1986).

If they are in command of the dominant design, they can use their market clout in favor of their product. If they are in possession of the dominant design, they can use their communication channels to persuade customers not to move over to the new design. Firms can also influence the emergence of the dominant design through strategic maneuvering as illustrated by the story of the rivalry between JVC and Sony in Box 9.4 (Christensen et al., 1992).

Two characteristics of transition phase are worthy of note. Firstly, while product innovation takes the backstage, firms start investing more and more into process innovation (Figure 9.4a). With the clear articulation of desirable product features as embodied in the dominant design, the remaining firms can look forward to a mass- market. As a result, specialized sections and some automated islands start appearing in the plants. The source of innovation moves from industry pioneers and product users to manufacturers and users. Organizational control which was informal and entrepreneurial during the fluid phase starts relying more and more on structured project and task groups.

Secondly, the number of competing firms starts decreasing significantly as the market swings more and more in favor of firms possessing the dominant design. At some point the number of firms reduces to just a few, so the market resembles classic oligopoly with relatively stable market shares. Because there are relatively few participants in this type of market, each oligopolist is aware of the actions of the others. The decisions of one firm influence, and are influenced by, those of other firms. Each firm is producing a very specific range of products that are essentially undifferentiated and standard. So this final phase is called the *specific stage*. The only way firms can now compete is on the basis of price, so the scope for innovation has reduced to cumulative improvements in productivity and quality. Through learning, production processes become efficient. Since scale is the main source of price reduction, plants become more capital intensive with high reliance on special-purpose and automated equipment while the role of labor is reduced mainly tending and monitoring the plant. Owing to the resulting rigidity, cost of change becomes even higher, thus inhibiting further product or process innovation. Table 9.3 summarizes the changing character of innovation in the fluid, transition, and specific stages of an industry.

Table 9.3 Typical patterns of innovation during fluid, transition, and specific stages (Abernathy & Utterback, 1978).

	Fluid stage	Transition stage	Specific stage
Competitive emphasis	Functional product performance	Product variation	Cost reduction
Innovation stimulated by	Information on users and user needs, technical inputs	Opportunities created by expanding internal technical capability	Pressure to reduce cost and improve quality
Type of innovation	Frequent major changes in products	Major process changes required by rising volume	Incremental for product and process, with cumulative improvement in productivity and quality
Product line	Diverse, including custom designs	Includes at least one product design stable enough to have significant production volume	Mostly undifferentiated standard products
Production processes	Flexible to accommodate major changes easily, inefficient	Becoming more rigid, with changes occurring in	Efficient and capital intensive but rigid owing to high cost of

	because of frequent changes	major steps	changes
Equipment	General-purpose, requiring highly skilled labor	Some sub-processes automated, creating 'islands of automation'	Special-purpose, mostly automatic with labor mainly engaging in monitoring and control
Input materials	Limited to generally available materials	Specialized materials may be demanded from suppliers	Specialized materials will be demanded. If they are not available, extensive vertical integration is pursued
Plant	Small-scale, located near user or source of technology	General purpose with specialized sections	Large-scale, highly specific to particular products
Organizational control	Informal and entrepreneurial	Through liaison relationships, projects and task groups	Through emphasis on structure, goals, and rules

Changes in Non-assembled Product Industries

Many of the patterns discussed in the previous section carry over to industries producing non-assembled products. However there are also several major differences (see Table 9.4) as illustrated by the story of plate glass presented in Box 9.3.

Table 9.4 Transitional phases of assembled and non-assembled product industries (Utterback, 1994).		
	Assembled product industries	Non-assembled product industries
Nature of innovation	Incremental product improvement and product variation	Process changes inspired by rising demand
Source of innovation	Manufacturers or users	Manufacturers and equipment makers
Competitors	Initially many but declining after the emergence of dominant design	Initially many but declining after the emergence of enabling technology
Industry leaders	Vulnerable to improved products and more efficient producers of current products	Vulnerable to more efficient and higher quality producers
Products	Differentiation through new features unique to individual producers	Increasingly undifferentiated
Production processes	Islands of automation	Becoming more automated, continuous and capital intensive
Plant	General purpose with specialized sections	Single purpose, small
Cost of process change	Moderate	High

The main difference is that there is greater and earlier focus on process innovation. In other words, although product innovation precedes process innovation, it does not last too long and attention soon shifts to the latter (Figure 9.4b).

Process innovation dominates the industry as it moves first into the transitional and specific stages. In the case of the plate glass industry, this happened with respect to each of the four waves of innovation: Siemens tank furnace, the annealing tunnel, continuous casting, and the Pilkington Float Process. A similar pattern has been observed when numerous other cases related to oil refining, chemicals, rayon, wood-pulping, aluminum, steel, ice-making, and textiles were examined. In each case, the waves of innovation resulted in large productivity gains.

Innovations that Disrupt Incumbents

Intuition suggests that, with respect to radical innovation, established large firms must have an advantage over small new firms since such firms have the capacity to invest in the required R&D and take up the associated risks. Does this mean that large firms always succeed while small firms have no hope of dislodging incumbent firms from their current commanding positions? Clearly, this question is of enormous interest to the thousands of small but brilliant entrepreneurs who hope to carve a niche for themselves in the face of the immense muscle of the incumbents.

Fortunately for the small entrepreneurs the biblical story of David versus Goliath is repeated quite regularly in almost every industry. How is this possible? We will now look at a very counter-intuitive but convincing answer provided by Clayton Christensen, a Harvard University professor (Christensen, 1993, 1997, 2001, 2003; Christensen & Bower, 1996).

In his book, *The Innovator's Dilemma* (1997), Christensen summarized the histories of a range of industries and the associated incumbents and new entrants. In almost all cases, he found that many of the incumbents had acquired a reputation for being highly efficient, aggressive, innovative, and customer-sensitive. Yet there were many occasions when these firms became easy prey to small industry outsiders coming up with unexpected, radical innovations. For instance, although IBM had created mainframe computers thus achieving a predominant position in the computer industry, it missed by many years the emergence of minicomputers. The minicomputer, in turn, was developed and marketed by companies such as Digital equipment Corporation (DEC) and Data General who missed the desktop computer wave initiated by new entrants such as Apple, Commodore and Tandy. It is only several years later that IBM could enter the desktop market. Christensen called innovations that displace incumbents as *disruptive innovations*, with the opposite being *sustaining innovations*. Box 9.5 summarizes a case-study on computer disc-drives prepared by Christensen to illustrate the differences between the two types of innovation. Most technological innovations, irrespective of whether they are incremental or radical, are sustaining in character, i.e., they strengthen the position of incumbents. Such innovations usually aim to improve the performance of established products along dimensions that mainstream customers have historically valued. In fact, quite often in mature industries, they are ahead of customer expectations, i.e., they provide performance levels superior to what customers are able to absorb at the particular time. Examples of sustaining innovations drawn from the computer disk-drive industry include removable disk packs, Winchester drives, thin-film heads, and magneto-resistive heads (see Box 9.5). The first two were innovations of the architectural type whereas the last two were materials-based improvements resulting from process innovations.

By contrast, disruptive innovations usually aim at new applications rather than the mainstream market. They are usually innovations that are simpler and cheaper in providing attractive features that a few fringe (often new) customers value. However from the viewpoint of mainstream consumers, they usually exhibit worse performance than the prevailing solutions in the near term. Hence, in a very conventional ROI sense, they appear to be irrational investments for established firms. On the other hand, although the initial profit margin is low, they establish a foothold within this niche and grow from there. As the performance is improved through incremental innovations, at some point, they become capable of entering the mainstream market. Meanwhile, as they do not have the needed knowledge of the new, simpler and cheaper technology to compete, incumbent firms watch helplessly. Having not foreseen or appreciated the new technologies in time, the incumbents lose a substantial part of their market share. Sometimes, they lose everything. Examples of disruptive innovations taken from the computer disk-drive industry include the 8-, 5.25-, 3.5-, 2.5-, and 1.5-inch disks (Box 9.5). Note that all these innovations were of the *architectural type*.

Why is that, so often, many firms regarded as astutely managed at one point lose their positions when faced with technological changes brought in by upstarts from outside the industry? It appears that the answer lies with managerial myopia, organizational lethargy, bureaucracy, tired managerial blood, arrogance, and short-term investment horizons.

But a more fundamental reason lies at the heart of the paradox. Leading companies succumb to one of the most popular, and valuable, management dogmas of staying close to their customers. All this happens because of the general tendency of companies with a long and successful history to gradually move towards a hierarchical and bureaucratic managerial structure (visit Chapter 17 to note Handy's views on this subject). It is not that such firms are not technologically competent or poor at innovation. In fact, many of them are very sensitive to the needs of their customers and continually satisfy their changing needs and wants through innovation.

But who are these customers? They are *their* current customers. The problem is that, owing to their highly structured innovation management practices, they tend to undervalue new ideas that are out of the current organizational and strategic context of the firm. In other words, firms develop mindsets and processes that revolve around doing what they already know. Once that happens, it becomes difficult for managers to justify to others or even themselves the need to turn their processes upside down to respond to a barely emergent market change.

It is not necessary that the incumbents are aware of the moves the new entrants are about to make. In fact, many a time, the idea might have been mentioned by someone in the incumbent firm itself. But it was rejected by the managers because they perceived it to be an unnecessary threat than an opportunity. "There's a lot of work in cognitive psychology that suggests that if you take a phenomenon to somebody and pose it to him as a threat, it elicits a far deeper response than if you take the very same phenomenon and pose it as an opportunity. So there are deep reasons why people frame change as a threat" (Christensen, 2001).

So, what can managers do to recognize potentially disruptive innovations? Christensen provides two litmus tests (Christensen, 2001). Firstly, "in almost every case, a disruptive technology enables a larger population of less skilled people to do things that historically only an expert could do. Secondly, "the disruptive technology almost always takes root in a very undemanding application, and the established market leaders almost always try to cram the disruption into the established application. In so doing, they spend enormous amounts of money and fail."

Finally, how should a firm faced with an imminent disruptive technology react? Here are some ideas thrown in by Christensen (1997):

~ Embed projects within organizations that serve a focused customer base.
~ Make the project teams small enough (skunk works) to get "excited about small wins."
~ Isolate the teams from the stifling demands of the mainstream organization. Plan to fail early and inexpensively in the search for an appropriate market for disruptive technology.
~ Focus on new markets rather than existing ones.

Box 9.1 Ryan and cross's study of the diffusion of hybrid seed corn in Iowa.

In 1928, the Iowa Agriculture Extension Service and salesmen from a few seed companies started promoting a new type of hybrid seed corn among corn farmers of Iowa. The seed, which was developed by Iowa State University, offered many advantages over the prevailing open-pollinated corn seeds. It was drought-resistant and yielded 20% more corn per acre. The corn was also more suited for mechanized harvesting. On the flip side, the seed lost its vigor after the first generation, so the farmers had to purchase new seed every year rather than select them from the best-looking plants raised the previous year.

In the period 1939-41, two researchers from Iowa State University, Bryce Ryan and Neal Gross, started a quantitative study on the diffusion of the new corn seed. They interviewed hundreds of farmers and finally settled on data collected from 259 respondents. In 1943 they published their findings.

The most important finding was that the cumulative number of adopters of the hybrid seed approached an S-shaped curve over time, while the frequency distribution of the number of mean adopters approached a normal, bell shaped curve (see Figure 9.1). The curve showed that the adoption rate was slow initially. However, at the end of five years, when the cumulative adoption reached 10% of the final value, it "took off" and shot up by 40% in the next three years. Then the rate leveled off as fewer and fewer farmers remained to adopt the new idea.

Next the investigators classified farmers as "innovators" and "later adopters" on the basis of when they had adopted the new seed variety. Interestingly, the characteristics of the farmers in the two categories were quite distinct. Compared to later adopters, the innovators had larger farms and higher incomes. They also had more years of formal education and were more cosmopolite.

Another finding was that the communication channels played different roles at different stages during the innovation-decision process exhibited by the farmers. The typical farmer first heard about the new seed variety from a neighbor or a salesman. Next he tried out the seed on a small trial part. Some three to five years after that he decided to cover 100% of his acreage with the new variety. Diffusion during this period was essentially driven by exchanges of personal experiences among the experimenting farmers. Diffusion took off only after enough exchanges were accumulated, thus pointing to the importance of interpersonal networks in the diffusion of innovations.

—Condensed form Rogers (1962), 4th edition, pages 31-35

Box 9.2 Diffusion of Broadband in South Korea.

In 2001, South Korea was the best in the world in terms of high-speed internet adoption (OECD 2001). The enviable status was a result of growing government intervention in IT innovation and internet diffusion coupled with fierce domestic competition. The following table presents some interesting statistics related to the broadband movement in the country.

Year	1997	1998	1999	2000	2001	2002
No. of broadband subscribers (millions)			0.074	2.074	4.453	6.386
ADSL		0.013	0.156	1.386	2.723	3.717
Cable Television			0.006	0.557	0.630	0.936
Others						
Types of connections (% value in December)					27.3	24.9
LAN					4.8	1.5
Modem					2.7	0.3
ISDN					49.9	62.0
DSL					11.8	9.3
Cable network						0.7
Wireless equipment					3.5	1.3
EC/DK						
No. of internet subscribers, millions	1.634	3.103	10.86	19.04	24.38	26.27
On-line advertising revenue as % of total advertising revenue	0.7	1.5	1.8	2.3	2.4	2.9

In 1995 the government announced a comprehensive plan to build an advanced nation-wide information infrastructure consisting of communications networks, internet services, application software, computers, and information products and services. All information and communications services in voice, data and video were to be provided easily, reliably, and cost-effectively in a timely manner. The initiatives included technology development, human resources development, deregulation, and the introduction of fair competition in the IT market. Anyone was allowed to start high speed internet businesses. Small startup companies were even offered subsidies and guidance. PC companies were successfully persuaded to develop an inexpensive "internet PC" with moderate functions.

Following the 1997 Asian financial crisis, the government decided to further strengthen the IT industry with a view to hastening the overall recovery of the economy. In 1999 it launched the "Cyber Korea" program. It started providing internet education to the people (including housewives) through the "Internet Education for 10 Million Citizens" program. In 2002 the government announced the "e-Korea Vision 2006".

Traditionally, Korean Telecom (KT) had monopoly over the domestic telephone market. Things changed dramatically when Hanaro Telecom Co. was granted a license as a local carrier in 1997. However, Hanaro found it very difficult to compete with KT in view of the latter's high quality of service and low price. On the other hand, Hanaro discovered that many KT customers were complaining about KT's low access-speed and usage-based pricing schemes. Therefore the new entrant decided to focus on broadband as a niche and started marketing itself as a "multimedia company" rather than a plain "telephone company". As a part of this policy, Hanaro launched a commercial service using the ADSL (Asymmetrical Digital Subscriber Line) technology. Initially, the service was offered at 40% discount to preempt the market before KT started providing a matching service. By 2000, Hanaro had bagged 1.1 million subscribers. In retaliation, KT started its DSL service and soon regained its leadership of the market. In the process, the traditional cable modem companies lost out in a big way. With the diffusion of broadband, people interested in online services started migrating from the prevailing closed serviced system to the more open and resourceful WWW. Advertisers began to place targeted interactive multimedia campaigns on big portal sites.

—Adapted from (Ryu et al., 2003)

Box 9.3 The story of plate glass making.

Plate glass consists of a homogeneous mass of glass of uniform thicknesses with flat and polished surfaces in sufficiently large sizes to be useful as window panes and mirrors.

Plate glass was first manufactured in Europe in the late 1600s. The process at that time started with the mixing of sand, lime, soda, and bits of broken glass in a clay pot. The pot was then placed in wood-fired furnace and heated to 1200-1500oC so as to liquefy the ingredients. The impurities and air bubbles accumulated on the surface were then skimmed off and the remaining liquid poured onto a large table mold with raised edges. The surface was then smoothed with heavy copper rollers such that the resulting plate thickness was as uniform as possible. The plate was then placed in an annealing furnace where it was slowly cooled. This step aimed to relieve internal stresses and strains so the plate wouldn't shatter during subsequent processing steps. The final processing steps consisted of grinding and polishing. Each processing step was performed manually using a simple, separate piece of equipment. The resulting process chain was flexible but inefficient, with wages accounting for over 40 percent of total cost. There were some incremental process innovations such as replacement of wood-fired furnaces by coal-fired furnaces over the next two centuries.

In 1861, Siemens of Germany obtained a breakthrough by using a preheated gas and air for melting the glass. The method improved thermal efficiency and avoided contamination of molten glass with smoke and ash. Siemens also introduced the "tank furnace" to enable continuous melting. The tank consisted of a baffle placed in the middle. When ingredients were poured on one side of the baffle, the impurities and debris floated only on that side while pure molten glass at the bottom flowed to the other side, from where it could be drawn off. Thus the two process steps of mixing and melting could be combined into a single one. Further, molten glass could be fed to subsequent steps in a continuous manner rather than in batches as was done previously. The new process however was more capital intensive and less flexible, so it became more expensive to handle changes in color or composition. The number of tank furnaces in use in the U.S. increased to 598 by 1919 while the traditional pot furnaces, which had peaked at 370 in 1909, dropped to 289.

In the 1880s, another breakthrough was achieved, this time with respect to the annealing step. Casting tables were hooked together to form a train that could be rolled through a long annealing "tunnel" with a gradually reducing temperature. This innovation helped collapse several previous operational steps into a single, automated process. Productivity was thus increased, although quality remained essentially unchanged.

Casting was the next step to be automated. The first attempt, the Bicheroux process, consisted of casting molten glass between two rollers. The advantages were that casting had become continuous and while homogeneity of thickness and flatness of the plates increased.

In 1922, Ford motor company collaborated with Pilkington Brothers from the U.K. to link the casting and annealing processes into a single, automated step by placing the continuous, rollercast ribbon on to a conveyor that passed through the annealing tunnel. Thus everything from mixing to annealing became continuous and automated. But the problems associated with manual grinding and polishing remained. It is said that the best way of performing a task is to eliminate the need for it. This is what happened next in the saga of plate glass making.

In 1952, Alistair Pilkington initiated a massive R&D project aimed at eliminating the grinding and polishing steps. After spending millions of pounds over the seven years, his team arrived at a very simple but elegant solution. In the new process a continuous ribbon of molten glass was carefully drawn on to a long pool of melted tin enclosed in a chemically neutral atmosphere. The ribbon just floated over the molten tin pool. Further, the temperature of the moving ribbon was gradually dropped to meet the annealing requirements. The result, the need for grinding and polishing was eliminated and all the previous process steps had collapsed into one continuous, fully automated process. Compared to the original totally manual process, the new process provided 80 percent reduction in labor costs and some 50 percent reduction in energy and capital costs—all this while providing substantially improved product quality.

—adapted from (Utterback, 1994, pp. 106-116)

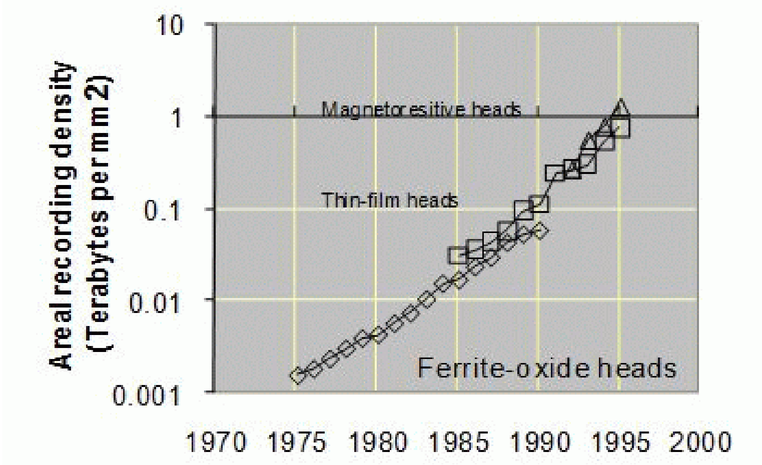
Box 9.4 The case of JVC versus Sony (Utterback, 1994).

During the mid-1970s JVC had beaten Sony in dominating the emerging video cassette recorder market during the middle 1970's. As it turned out, JVC had based its products on the VHS tape standard it had developed in house. By contrast, Sony's products were based on its Betamax standard. It soon became clear to either firm that its prospects of dominating the video cassette market depended critically on its ability to persuade the rest of the industry to favor their particular standard. So there was much strategic maneuvering by both firms (Cusanamo et al., 1992). JVC adopted the humble approach of making alliances initially in Japan and later in Europe and United States whereas Sony opted to go it alone so as to take advantage of its vertically integrated infrastructure. In the event, Sony lost out to JVC despite the fact that Betamax, owing to its higher bandwidth, resulted in sharper pictures and smaller tapes than possible with VHS.

Box 9.5 The story of computer disk-drives.

In 1956, IBM unveiled the first commercially viable computer disk-drive, called 305 RAMAC. Although its storage capacity was under 5MB, the drive was the size of a refrigerator since it was made up of 50 disks of 24-inch diameter each.

Over the next two decades, IBM maintained its hold on the industry through a series of sustaining innovations. Some of these were architectural. Until the mid-1970's, 14-inch removable disk packs accounted for all disk drives. Then 14-inch Winchester drive emerged to sustain performance. Most were used for mainframes. Some were innovations with regard to the material used on read-write heads: ferrite-oxide (1975), thin-film (1985), and magneto-resistive (1992). Each of these radical innovations was followed up through incremental innovations aimed at improving areal density (see figure above). For instance, in the case of ferrite-oxide heads, areal density was improved by grinding the heads to finer and more precise dimensions and by more finely dispersing oxide particles. However, when thin-film technology arrived, IBM and its rivals such as Control Data, Digital Equipment, Storage Technology, and Ampex invested tens of millions dollars in R&D efforts directed at improving that technology. As a result, new entrants such as Maxtor and Connor Peripherals who tried to perpetuate ferrite-oxide technology by refining it, perished. Thin-film heads in turn gave way to the new magneto-resistive heads that appeared in 1992. The race in the new technology was however led by IBM, Seagate, and Quantum with the new entrants being quickly thrown out.



Between 1978 and 1980, Shugart Associates, Micropolis, Priam, and Quantum developed 8-inch drives with 10, 20, 30, and 40 MB capacity. These were of no interest to mainframes which, at that time, asked for around 40MB. The entrants therefore shifted focus to the smaller market (at that time) of minicomputers. In the event, minis gained over mainframes—partly because of the availability of suitable disk drives. Meanwhile 8-inch disk saw process innovations that resulted in capacity growth at the rate of 40%. Again, capacity outstripped demand. Cost per MB of 8-inch became lower than that of 14-inch. Other advantages became apparent, e.g., lower vibration sensitivity. Hence, established 14-inch manufacturers began to fail one by one.

A similar story was repeated in 1980 when Seagate Technology introduced 5.25-inch disks. The capacities of these drives did not exceed 10MB, so minicomputer manufacturers who needed drives in the range 40 to 60MB were not interested. The new, smaller disks were also inferior to the ruling 8-inch in many other respects, e.g., the access time was over five times larger and the cost per MB was four times larger. However, although of little value for minicomputer manufacturers, 5.25-inch had its own advantages, e.g., nearly four times smaller volume, and over three times smaller weight. So, over the next three years, Seagate and other firms such as Miniscribe, Computer Memories, and International Memories started looking for new applications for their 5.25-inch disks. Fortunately for them, they soon found a bonanza in the emerging personal computer industry. Apple I and II and Commodore Pet computers had appeared in 1976/77, and the IBM PC had been introduced in 1981. However, it was not clear how big the PC market was going to be. On the other hand, the expansion of the market was significantly enabled by the incorporation of the 5.25-inch drives. From then on till 1990, the capacity of 5.25-inch drives increased by 50% every year, which was twice the capacity demanded by PC users. In the process, of the four leading 8-inch drive makers, only Micropolis survived to become the largest 5.25-inch drive manufacturer. IBM had long turned from being a manufacturer to user of disk drives.

Industry disruption stories similar to the above were repeated when 5.25-inch drives subsequently gave way to 3.5-inch, 2.5-inch, and 1.5-inch drives as desktop PCs were progressively supplemented first by portable and Palm Computers. In each case, the newer versions were not superior in the established market whereas they were attractive to fringe customers interested in an emerging technology.

—adapted from Christensen (1993, 1997).

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Chapter 10

Industry Development

"It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest."

—Adam Smith

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So far we have focused on the various aspects of technology, the first theme of this book. Now we start moving towards the second theme, innovation. Innovation is the source of all technology development which, as we have already seen, is the key to economic development. But who engages in innovation? The answer is not in nations per se but in the people working in the myriad firms making up the diverse industries in the nation. In recent times many firms have spilled over national boundaries in the form of multi-national or globalized corporations. But, invariably, any given corporation competes and operates within some industry sector which suggests that it is fruitful to examine what makes up an industry, why firms exist within industries, and how industries, in general, develop. This chapter seeks to answer such questions.
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What is an Industry?

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Competition is the distinguishing characteristic of a market economy. Hence, while segmenting industrial activity into specific industries, it makes sense to look for common patterns of competition and, hence, of innovation. In other words each industry is viewed as a distinct competitive playing field. But the notion of competition implies that the players are offering products or services with overlapping functionalities using fundamentally similar or different technologies. The similarity between two technologies is essentially determined by the science-bases used by them. If the science-bases are essentially the same then the technologies can be said to be similar, otherwise, not. Thus one can follow two contrasting approaches. The first aligns technologies with the corresponding science-bases (e.g., electrical technology, and biotechnology), whereas the second does the same with specific industry sectors. Between the two the latter is more common.

An industry sector may be defined as a group of firms that markets products and services which are close substitutes for each other (e.g., the car industry and the travel industry). Substitutes are products or services that perform the same generic function(s). A truck/bus differs greatly from a train, but they both perform the same generic function for the buyer—point-to-point freight or passenger transportation (Porter, 1985).

Industry Sectors

Product function has a substantial influence on the technologies adopted while designing and manufacturing the products in question. Hence the technologies used across different industries can be quite different. Some industries are classic, some are of recent origin. Those based on very recent technologies are said to be hi-tec. Being relatively new, high tech industries require more R&D support than older industries. Of course, today's high tech is tomorrow's low-tec.

Industries also differ substantially in terms of marketing requirements. In general the more end user oriented an industry's products are the greater is the requirement for advertisement. The relative requirements for R&D support and advertisement support can have substantial influence on the industry structure and ownership. Figure 10.1 illustrates this point with reference to the contemporary Chinese industry. The x-axis in the figure denotes advertisement intensity (the ratio between advertisement expenditure and sales) while the y-axis denotes the R&D intensity (the ratio between R&D expenditure and sales) of the industry in question. Note that the industries depicted are spread all across the map.

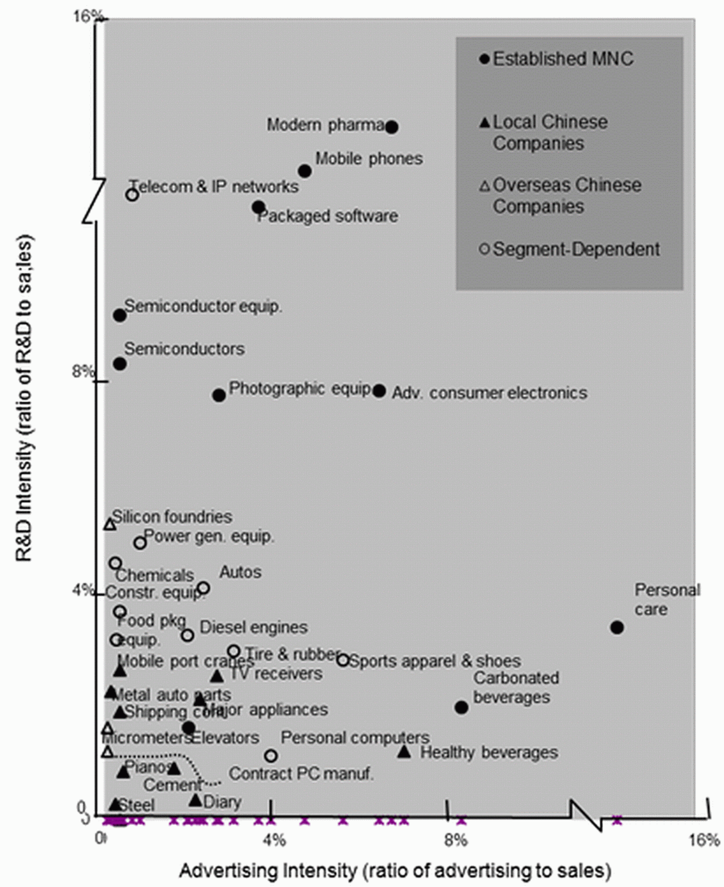

Figure 10.1 China's industry landscape (Ghemawat & Hout, 2008).

Industries requiring high levels of R&D or advertising are usually owned by established multi-national corporations (MNC) whereas those with lower intensities are owned by local or overseas Chinese. Of course, in time, one can expect Chinese firms to expand their activities into industries requiring higher levels of R&D or advertising.

The Value-Adding Chain of an Industry

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When we compare the balance sheets of a random selection of firms across disparate industries at any one time, we are likely to find that their long-term profitabilities vary widely. For instance, for the selection of U.S. industries listed in Figure 10.2, the ratio of operating profit to assets in the period 1988-1995 ranged from about 2% to 25%. Obviously this cannot be because industries exhibiting lower profitability are all being mismanaged. Rather, at any given time, not all industries offer equal opportunities for sustained profitability. In short, the *intrinsic attractiveness* (for investment) of different industries can differ to a remarkable degree.

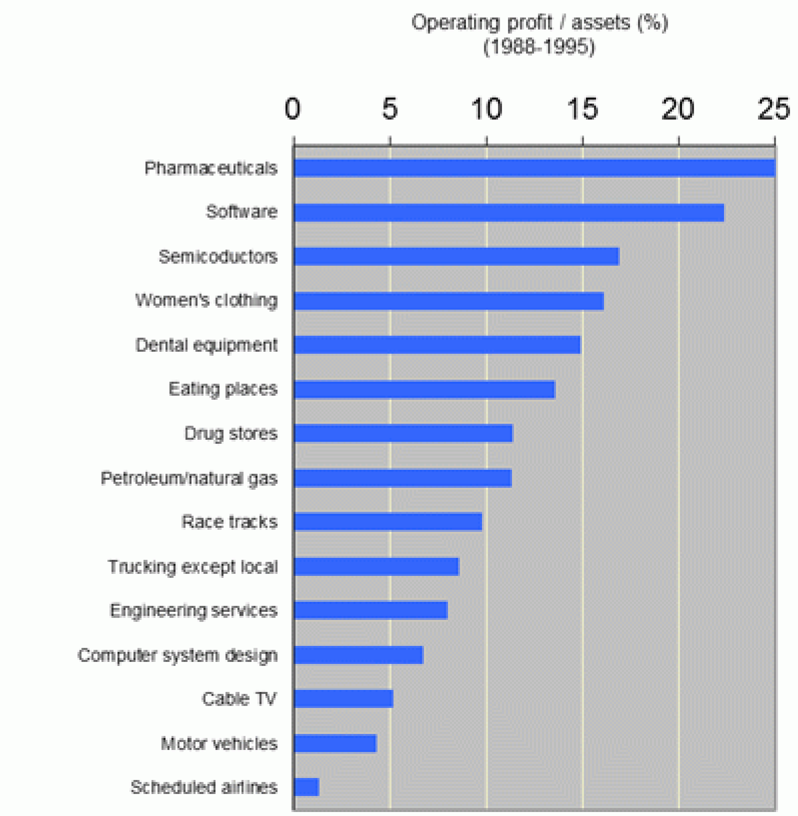

Figure 10.2 Profitability differences across selected U.S. industries (data from Compustat).

Why is this so? A partial answer is contained in the notion of competitive forces developed by Michael Porter (1985). The products or services offered by an industry sector are usually the result of a long chain of value-adding transformations required to convert natural resources into the final product or services. Thus, the industrial structures of an economy consist of all the transforming sets of industrial value chains that connect nature to customer (Betz, 1998).

According to Porter (1985), value is the amount buyers are willing to pay for what the firm provides them. From an accounting viewpoint, what the firm gets from its customers is *revenue*. Hence one can measure the value of a commercial activity by the corresponding revenue. An activity's profitability is determined by the amount the revenue obtained from it exceeds the costs incurred in performing it. This is called the *margin*.

Figure 10.3 shows the typical structure of a value chain of an industry segment. The part of the industry associated with each of the value-adding steps can be viewed as a distinct *industry sector*.

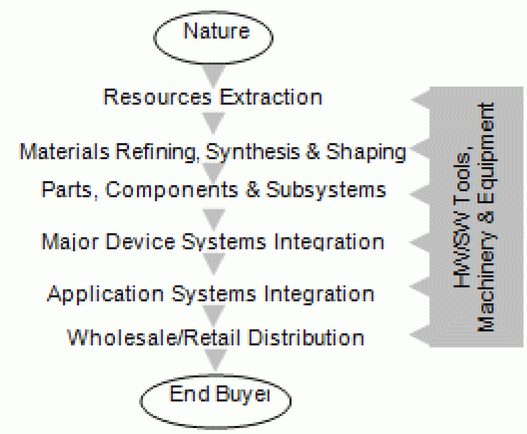

Figure10.3 Industrial value chain, adapted from (Betz, 1998).

The inputs required for the first industry sector, Resources Extraction, are the raw materials drawn from nature. This sector is the seller to the next sector—'Materials Refining, Synthesis, & Shaping'—which, in turn is the seller to the next sector, the "Parts, Components & Subsystems" sector. This pattern of buyer-seller relationship continues until we reach the "End Buyer" at the end of the industry's value chain. In each case, the sellers as well as buyers (final consumers) could be individuals, business firms, or governments. Often the same buyers or sellers might be involved in other industrial value chains. A separate industry sector supplies the tools (hardware or software), machinery, and equipment needed for each of the industry sectors within the industrial value chain.

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Venuvinod's 37-year teaching career included long stints at Regional Engineering College, Warangal, India; Hong Kong Polytechnic; and City University of Hong Kong. At the last institute, he was the founding Head of the Department of Manufacturing Engineering and Engineering Management. He also became the university's Chair Professor of Manufacturing Engineering. During his 25-year stay in Hong Kong, he frequently visited mainland China to collaborate on several projects.

Venuvinod retired from active service in 2002. However, he continues to be associated with City University of Hong Kong as an Emeritus Professor. In 2004, he co-authored a book on rapid prototyping (published by Kluwer Academic Publishers). In 2001, he started the International Organization for Developing Universities (IODevUni) which engaged over 22 engineering colleges in Hyderabad, India, in a range of activities promoting the growth of technology, innovation and entrepreneurship (TIE).

In 2010, Venuvinod set up tecinnovent.com to act as an international forum for discussing TIE-related issues. There are many ways you can participate. You may comment on TIE-related books including the present trilogy or offer teaching support material (e.g., local case studies). You may recount your entrepreneurial experiences. Or, you can initiate discussions concerning the promotion of TIE in your region and workplace. It is all up to you.
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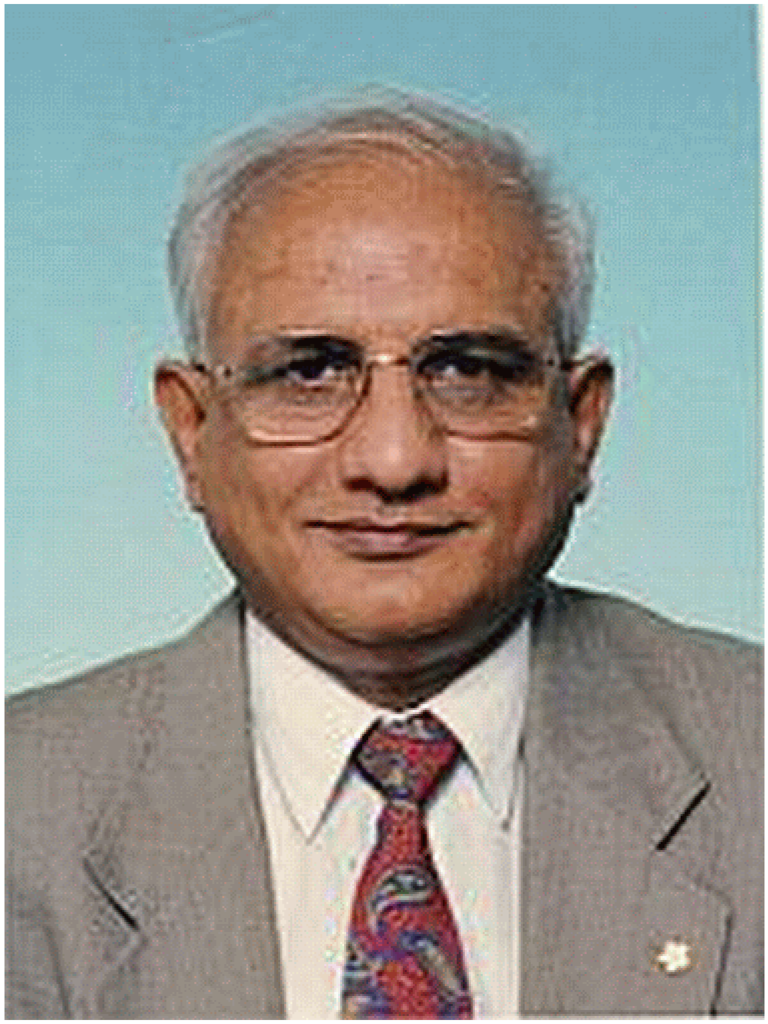

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