SCHOOL OF LAW
CASE WESTERN RESERVE UNIVERSITY

Canada-United States Law Journal

Volume 15 | Issue

Article 23

January 1989

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My company is a supplier of wiring assemblies and harnesses to original equipment manufacturers ("OEMs") in the automotive, electronic and appliance industries. We are a medium-size company with plants in Canada, the United States and Mexico. One issue that we have wrestled with is the extent to which we get involved in research and development on intermediate or end products. Let me take you through our thinking process on this issue.

In business today, it is almost an article of faith that a major commitment to product research and development is essential for innovation and competitiveness. Admitting that one's company does little or no research and development is almost as much of a "no-no" as irreverence to the flag or claiming that we are not in business to make profits. Therefore, it is with some trepidation that I state that my company does not have a formal research and development strategy. In fact, we do not conduct formal research at all, though we do engage in a considerable amount of development work, but discussions about research, development and technology very seldom play a prominent role in our strategic planning meetings. Indeed, it is my conviction that for the vast majority of small and medium-sized manufacturing companies, strategies relying on conventional approaches to technology and innovation are not appropriate.

In this Paper, I propose to put forth what I believe is the appropriate stance regarding technology and innovation for the majority of firms, like mine, that are engaged in manufacturing for original equipment manufacturers in North America. The argument establishes two basic models of the role of technology in economic development: the Science-Driven Model and the Business Systems Model. I will argue that the dominant Science-Driven Model has some significant weaknesses when used as the basis for strategy development in business. Consequently, I argue that the alternative Business Systems Model should be used to guide strategic thinking about technology and business strategy. Next I will proceed to apply this model within a framework for strategy development for manufacturers of industrial products. Finally, I will turn to

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consideration of the conclusions we have reached from this line of reasoning.

I. THE SCIENCE-DRIVEN MODEL

The dominant view of the role of technology in the creation of economic wealth for a nation may be termed the "Science-Driven Model." This view holds that nations will prosper to the extent that they are capable of harnessing science and technology for the development of their industrial structures. This view has its intellectual origins in the work of Joseph Schumpeter, who in the 1930s set forth the concept that technological innovation was the dynamic component in the economy. In more recent times, this view has been reinforced by Solow's 1957 paper[1] about the impacts of technology on the U.S. economy. Solow claimed that a considerable proportion of the United States' outstanding economic performance was due to the fact that U.S. industry had been able to harness technology better than their international rivals.

In Canada, this view about the importance of science and technology to the long run well-being of the industrial sector has been adopted by the Canadian Institute for Advanced Technology, which has recently released a report entitled *Innovation and Canada's Prosperity: The Transforming Power of Science, Engineering and Technology*. A central argument of this report is that there are significant weaknesses in the scientific infrastructure in Canada and that these will hamper the country's ability to achieve international competitiveness in science-based industries such as pharmaceuticals and electronics. It holds that the achievement of international competitiveness in these types of industries is essential for the country's future economic prosperity. In the past, Canada relied on natural resources as the engine of economic development. Its manufacturing sector was nurtured by a policy of high tariffs on manufactured products, which led to the establishment of local manufacturing on a relatively small scale with a relatively high labor cost due to high wages.

At this Conference two years ago, I argued that such labor-intensive manufacturing in Canada and the United States will disappear in the contemporary low-tariff environment of international trade because it cannot compete with businesses in the lesser developed countries ("LDCs") whose wage costs are a fraction of ours. Capital-intensive manufacturing in North America is under attack from businesses based in the newly industrializing countries ("NICs") where the cost of capital is significantly lower for industries targeted for industrial development and where exchange rates are deliberately kept low to encourage exports and dampen imports. Consequently, it is strategically important for North America to shift progressively toward knowledge-intensive manufacturing where it still enjoys a competitive advantage over the LDCs

[1] Solow, *Technical Change and the Aggregate Production Function*, REV. ECON. & STATISTICS (1957).

and the NICs.[2]

The importance of developing competence in knowledge-intensive manufacturing has led many back to the notion that science and technology are important factors in the wealth creation process for the advanced nations, a view which is hard to disagree with. As generally held, this view establishes scientific knowledge as the base of a pyramid upon which the industrial superstructure of a high level economy is developed.[3] Generally developed in universities and a few highly-specialized research laboratories operated by governments or very large multinational corporations, such scientific knowledge then forms the basis for development and engineering activity which eventually finds its way into products that appear in the marketplace.

Two features characterize the relationships between breakthroughs in scientific knowledge and their eventual appearance as marketable products. First, the links between a specific scientific breakthrough and the features of a particular product are many and varied. Many different research laboratories, engineering teams and product development groups are often involved; it is frequently difficult to trace all the links, let alone manage the process. Part of the difficulty arises from the fact that seldom are all the various groups involved from the same firm. Transferring the fruits of research and development between firms requires elaborate measures to ensure that property rights are not dissipated. These measures often inhibit the transfers and render them inefficient. Consequently, firms that operate on scales which enable them to keep a large part of the process internal tend to prefer internal arrangements rather than market transfers. Therein lies much of the basis for competitive advantage based on scale economies in science-driven industries.

Second, the relationship between development of scientific knowledge and commercial products makes it impossible to predict which products or industries are likely to benefit from a specific scientific breakthrough. For example, the invention of pyroceramics (originally developed for the U.S. space program) eventually found its way into oven-to-table cookware, an application that was not at all envisaged by the original scientific team, and which came about initially because of a chance social encounter between the scientist and the wife of a commercial man-

[2] These ideas were first advanced at the 1987 Canada-US Law Institute Conference. *See* Fleck, *A Look at the Future: Canada and the United States in the Future World Economic Context — Can We Be Competitive?* 12 CAN.-U.S. L.J. 345 (1987). Subsequently, they have appeared in a paper published in 1987. *See* D'Cruz and Fleck, *The Globalization of Manufacturing*, BUS. Q. 42 (Winter 1987) (published by the University of Western Ontario). They also form a central part of the argument of our recent book. *See* J. D'CRUZ AND J. FLECK, YANKEE CANADIANS IN THE GLOBAL ECONOMY: STRATEGIC MANAGEMENT OF US SUBSIDIARIES UNDER FREE TRADE (1988) (available through The National Centre for Management Research & Development, University of Western Ontario).

[3] *See* Figure 1.

ager in the business which finally launched that product. Further, a number of unrelated scientific developments may be necessary to form the basis for commercialization. The technology for dynamic random access memories ("DRAM") is based upon scientific developments in materials technology, microelectronics and quantum physics. Much unrelated scientific knowledge and their related technologies had to be brought together for the successful development of commercial DRAM memories. This feature of science-driven industries favors large firms that are organized to take advantage of economies of scope.

The model of science-driven industries[4] depicts that industrial system as a series of interrelated pyramids, with scientific innovation at the base and commercialized products at the apex of each pyramid. A system of interlinkages between the pyramids is thought to be necessary to bring about the unforeseen connections between specific science and products. Proponents of this point of view often argue that a highly developed nation needs to encourage scientific education and research on a broad basis to develop and maintain its international competitiveness. Evidence of weakness in the ability of the nation to train scientists and fund them effectively in the conduct of scientific research is viewed with great alarm by this group of thinkers. A voodoo-like quality is ascribed to scientific knowledge whose pursuit is seen as a vital necessity.

There are major weaknesses in the Science-Driven Model's view of the role of science in industrial prosperity. It is not in the nature of the scientific community to keep their discoveries secret. Like all academics, scientists measure their self-worth on the basis of peer recognition. Therefore, their goals are the publication of their scientific discoveries to the widest extent possible. Indeed, without widespread dissemination, the scientific process as we know it today would come to a standstill. Scientific know-how has become so specialized and so esoteric that only a few hundred people throughout the world truly understand issues at the leading edge. It is vitally important for these individuals to communicate with each other because they need the mutual reinforcement of such communication to continue to make progress in their work. Therefore, these leading scientists are the ones who publish their work in scholarly journals, meet each other at scientific conferences and participate actively as members of a scientific community that is surprisingly small. Over the years, the international networks of these communities have become remarkably efficient. Within weeks after the IBM Advanced Research Laboratories in Zurich announced the breakthrough in superconductivity for which they won the Nobel Prize, a laboratory in Japan announced a follow-through breakthrough. Shortly thereafter, additional breakthroughs by other research groups in various parts of the world started coming so quickly that the printed scientific journals could not keep pace

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[4] *See* Figure 1.

and leading-edge scientists started electronic self-publishing through electronic mail networks.

II. THE BUSINESS SYSTEMS MODEL

It is apparent that the scientific model of the role of research and innovation in the development of a competitive advantage for business organizations does not deal effectively with the fact that the scientific community thrives on publishing its results and disseminating new knowledge as fast as it is created. Since business strategies that are heavily based on the exploitation of new knowledge lend themselves to rapid imitation if they are successful, it follows that we need a model of the processes whereby firms can develop competitive advantages out of new knowledge that is endurable.

The core of the model is the concept of the "business system."[5] The essence of a business system is that it depicts the chain of activities that need to be conducted in order to produce the eventual benefits that consumers desire at prices consumers find acceptable. It highlights the fact that some of these activities may be conducted within a single firm, whereas others may be conducted in other firms that participate in the same business system.

The shaded boxes in Figure 2 show a highly simplified version of the business system for a manufactured product which is eventually sold to the consumer. The main elements in this system are: 1) production of raw material; 2) conversion of these raw materials and the manufacture of sub-assemblies; 3) final manufacture and assembly; and 4) distribution, which includes both wholesaling and retailing. We will assume that each of these main activities is conducted by a different company, and that these companies are linked to each other through a series of contract and market relationships.

Business system analysis is concerned largely with the nature of these relationships, particularly the development and exercise of market power within the system, and the use of strategies to develop and sustain competitive advantage in the system. In other words, business system analysis addresses the working out of the five forces of competition defined by Michael Porter in his ground-breaking work on competitive strategy.[6] Porter's five forces are: 1) rivalry between firms at a particular point in the system; 2) interactions with suppliers to determine the direction and use of market power in the supplier-customer relationship; 3) interactions with buyers to determine the direction and use of market power in the seller-buyer relationship; 4) changes to the competitive balance caused by the threat of new entrants; and 5) the impact of substitutes on the business system.

Our concern is with the relationship of technology and innovation to

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5 *See* Figure 2.

6 *See* M. PORTER, COMPETITIVE STRATEGY (1980).

the working of the competitive forces. The remaining boxes in Figure 2 show the principal means by which technology has an impact on the business system. First, it is clear that basic research is a fundamental driver of the technology and innovation process; in this respect, the Business System Model is consistent with the Science-Driven Model. Most basic research is expected to come from universities and government-funded laboratories. Except in a few exceptional instances, basic research does not come from company laboratories.

Instead, the role of the company laboratories is to use the findings of basic research as input to their work, rather than as output. Thus, much of what company laboratories will be engaged in is development work, or at best a small "r" and big "D" form of innovation activity.

Further, the specific nature of the innovation activity of the firm will depend heavily on its role in the business system. It is evident that firms engaged in the production of raw material will tend to specialize in research and development that finds its output in materials technology. At the other end of the business system, firms engaged in distribution, particularly those firms that deal directly with the final consumer, will tend to spend most of their research effort on various forms of market research. Their needs are to understand changes in consumer behavior and relate them to the mix of products they offer and how they deal with their suppliers. Manufacturers involved in final manufacture and assembly of consumer products are most likely to do a considerable amount of product related innovation and development. Finally, process research, which is usually directed either at reducing costs or at improving quality, will be conducted both by the final assemblers and by their direct suppliers.

The main value of looking at the role of research and innovation through such a Business Systems Model is that it facilitates thinking about these issues in the context of the development of competitive advantage for the individual business firm. This "strategic" orientation toward research and innovation is more in accord with our concepts of how businesses compete. Thus, while the entire spectrum of research, all the way from basic research to create new knowledge right up to market research to find better ways of selling products, does take place in the business system, few if any firms will be expected to be engaged in all forms of research. Instead, firms are likely to conduct the kinds of research that are most appropriate to the development of competitive advantage in the part of the system in which they operate. Firms that participate with very narrow scopes in the business system will have a correspondingly narrow focus for their research activities. On the other hand, vertically integrated firms that are active in many parts of the business system are likely to do a wider variety of research and innovation activities.

III. Research and Development over the Life Cycle

A related set of issues develop as we consider the nature of the changes in the role of research and development over the life cycle of a product or business.[7] During the inception and rapid growth stages of the life cycle, the key strategic concerns are the development of the technology of the product itself. Getting the product to work is the fundamental task. Actually delivering the benefits that the manufacturer claims the customer will derive is often not easy. There are innumerable pitfalls and problems in implementing new product concepts. Consequently, it is appropriate that the bulk of the research and development resources of the business system be devoted to product research. The pace of technological development will be determined by the schedules and deadlines adopted by or imposed on the product research teams and by the success or failure of these teams in meeting their objectives and deadlines. It follows that those firms which dominate the product research function in the business system will dictate the research agenda during these phases. They have the leadership role for research in the system.

However, experience from a wide range of industries suggests that successful strategies are more likely to be developed and implemented when superior technical research activity is adequately supported and coupled with market research. Technical considerations have to be tempered with concerns about how the eventual consumer views and values individual aspects of the benefits of various product characteristics. This linkage between research and development and market research tends to be most effective when the producer of the final product or service assumes the leadership role in product development.

During the maturity and decline stages of the product life cycle, strategic emphasis has to shift from product development to efforts directed at cost reduction and quality improvement. The product characteristics and market demand stabilize, and the pace of change in product features slows. Competitors now shift their attention to techniques which reduce the delivered cost of the product. Sometimes delivered cost reductions are accomplished by shifting channels of distribution. Mass distribution channels usually operate at lower margins by eliminating many of the services offered by specialist retailing channels.

More frequently, cost reductions are effected by concentrating an improving effectiveness and efficiency in manufacturing processes. Suppliers and manufacturers of sub-assemblies are called upon to deliver cost savings. This leads to an increased emphasis on process research and development, frequently combined with a reduction of emphasis on product research. At the same time, leadership of the research and develop-

[7] See Figure 3 for a depiction of a typical product life cycle.

ment agenda shifts from final producers to participants in the upstream components of the business system.

IV. Role for Supplier Firms

It is at this stage that supplier firms can come to play a leading role in research and development. Supplier firms who operate in the upstream segments of a business system should focus their research and development resources on process research.[8] The priorities for their research and development program should include cost reduction and quality enhancement. The latter is particularly important in helping their customers reduce their own cost. Low quality levels from suppliers are a major impediment to cost reduction in final production. The further downstream a quality problem in sourced components is discovered, the more costly it is to detect and rectify the problem. The appropriate place to deal with quality of components and sub-systems is where they are produced — in the supplier's plant. Further, advanced techniques for cost reduction in final assembly — such as just-in-time manufacturing ("JIT") and assembly automation — are impossible to implement without near-perfect quality levels from suppliers.

The focus on process development aimed at cost reduction and quality enhancement at the supplier level will not be successful unless it is closely coordinated with product development efforts at the supplier's customer. Every change in product characteristics and specifications has the potential to disrupt the supplier's efforts to control costs and quality. Hence, frequent communication and a rich network of contacts between the supplier and the industrial customer are of vital importance. The supplier must be able to anticipate the customer's plans for changes in products in order to develop its plans for corresponding changes in its own manufacturing process.

Far-sighted suppliers have developed a formal process for managing this interaction. Known as "manufacturability analysis," this process allows the supplier not only to anticipate changes in customer requirements but also to contribute toward the development of specific product characteristics. In a typical manufacturability analysis, the customer will submit advanced design information and prototypes to the supplier for evaluation. The supplier then proceeds to conduct production engineering work on the proposed design in the same manner that it engineers its regular production runs. In addition, the supplier also produces a full-blown quotation for regular production of the proposed design.

As this work proceeds, potential problems in the specifications are identified, particularly those which can lead to cost or quality problems. Suggestions for changes in the specifications are developed and discussed with the customer. While it is rare for most suggestions to be accepted

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[8] *See* Figure 4.

straight away, they can and do lead to further design work at the customer's end so that the final specifications that emerge are better suited to the manufacturing environment in which they will be made.

Such changes in the product development process cannot be successful without a radical revision to the procurement strategies of major industrial firms. Conventional procurement management relies heavily on practices such as multiple sourcing and competitive bidding by suppliers to maintain cost discipline in procurement. Purchasing managers are evaluated on the ability to secure cost reductions and to discipline suppliers with quality problems. The net result of this mode of procurement can be the development of an adversarial relationship between buyers and suppliers. Quite simply, both sides may end up hating each other and looking for every opportunity to get the better of the other in the relationship.

The new mode of collaborative development calls for a very different type of relationship. Cooperation, rather than conflict, becomes the dominant operating mode. The supply relationship becomes a "strategic alliance." Such alliances are directed at the joint development of competitive advantage within the business system. They are long-term in nature, with the benefits and costs to both parties spread over a number of transactions. In the old mode, each procurement contract is treated as an independent transaction. In the new mode, the focus is on the relationship and total program rather than the individual transaction. Both parties look to their long run advantages with the confidence that neither will seek to unfairly exploit advantages in the short run.

At Fleck Manufacturing we have put this approach to work by deciding that we are not going to compete in research and development or hard engineering on products, but instead we will concentrate on the soft engineering or process development. We will build our strengths on quality, cost and service. We are working hard to establish collaborative relationships with our customers of the type that I have outlined.

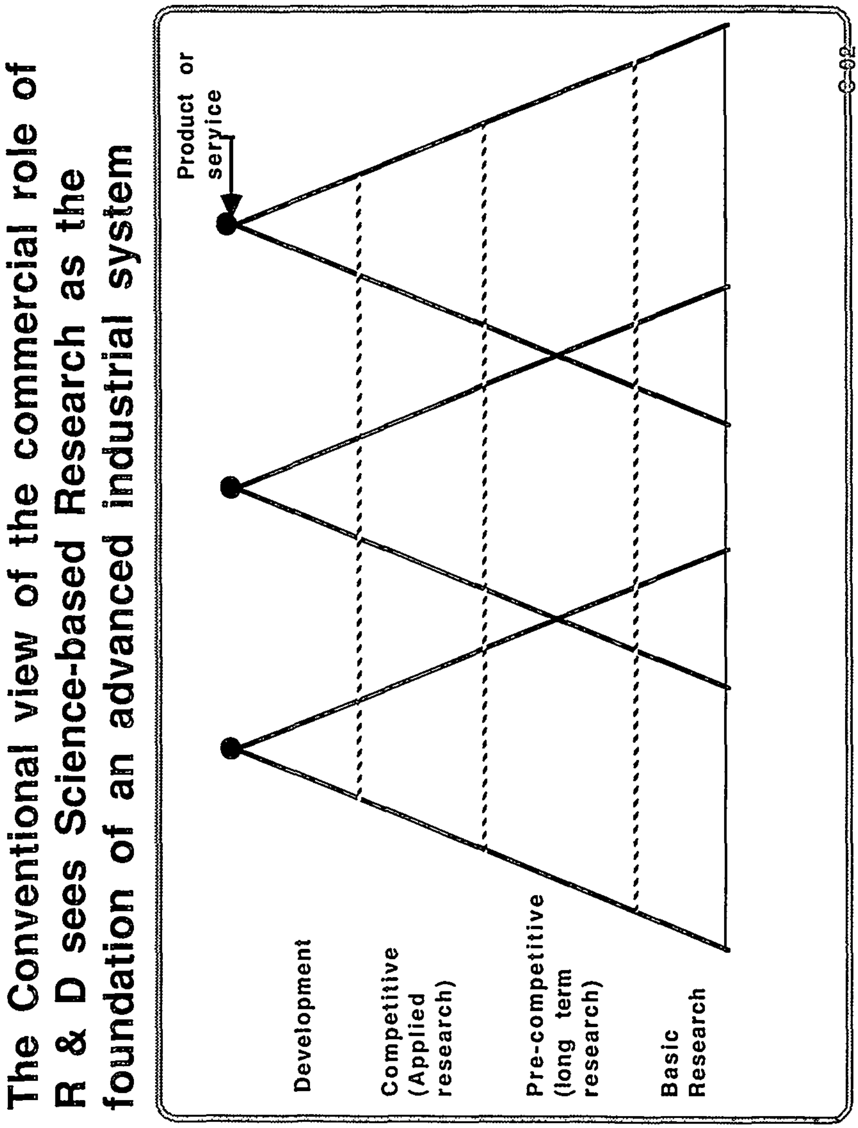
The Conventional view of the commercial role of R & D sees Science-based Research as the foundation of an advanced industrial system
Product or service
Development
Competitive (Applied research)
Pre-competitive (long term research)
Basic Research

Figure 1

The role of research and development varies with a firm's position in the Business System in which it participates

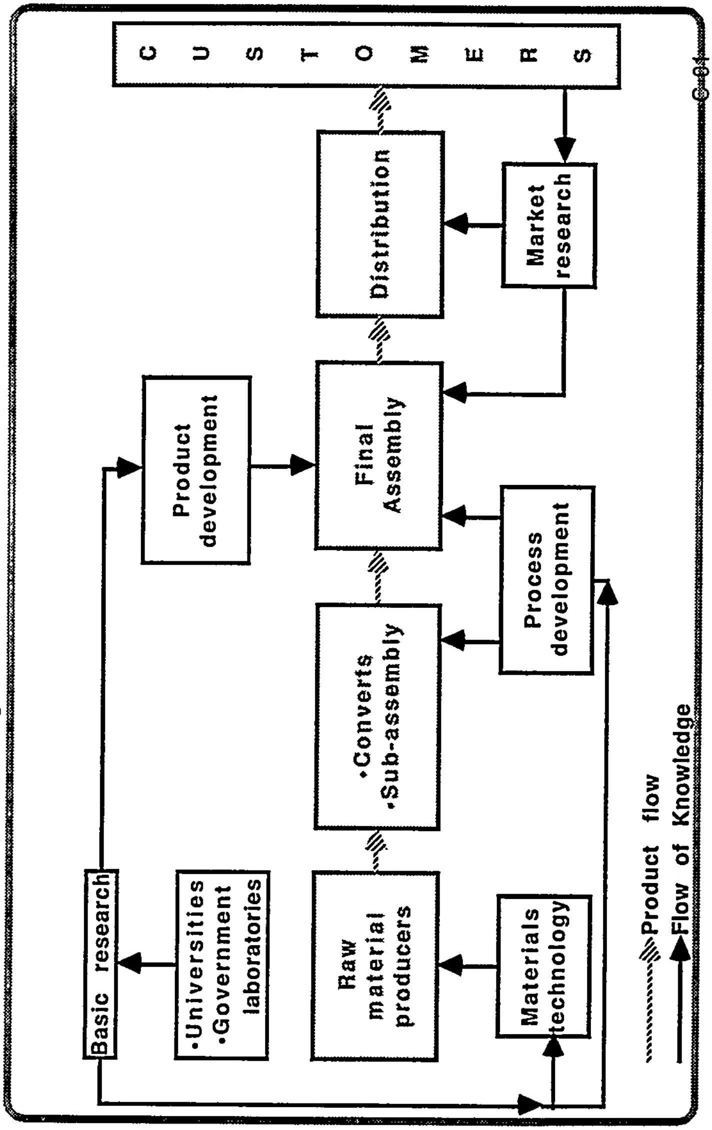

Figure 2

As a product proceeds through the product life cycle, the role of research and development changes

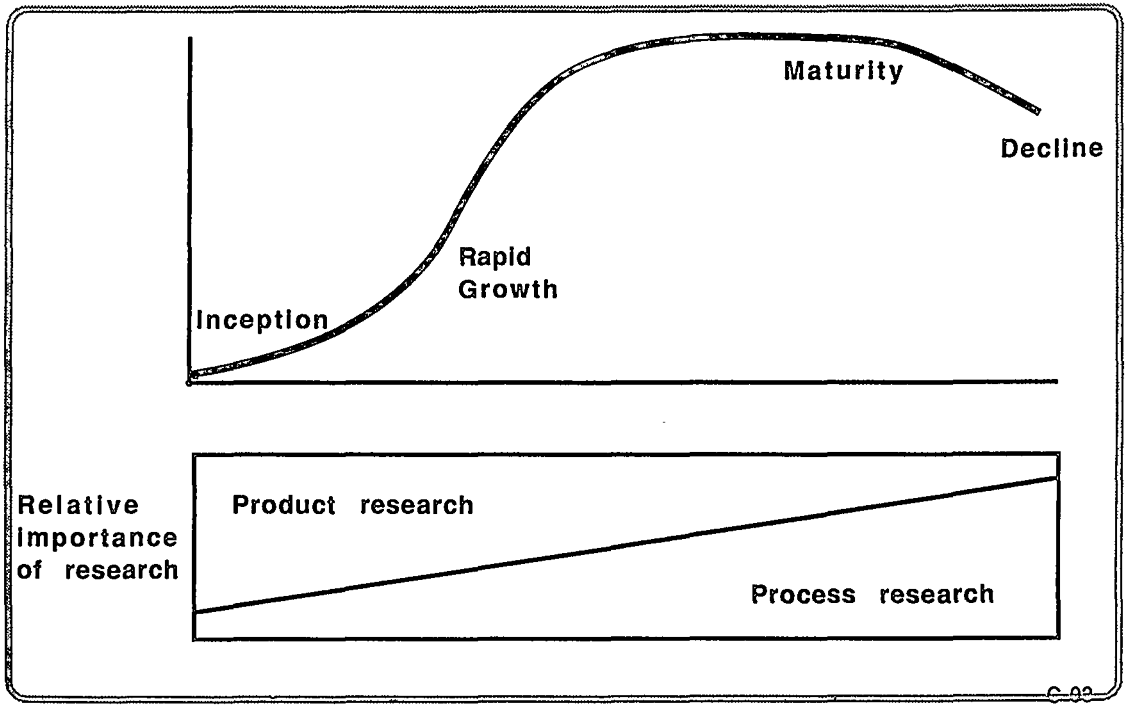

Figure 3

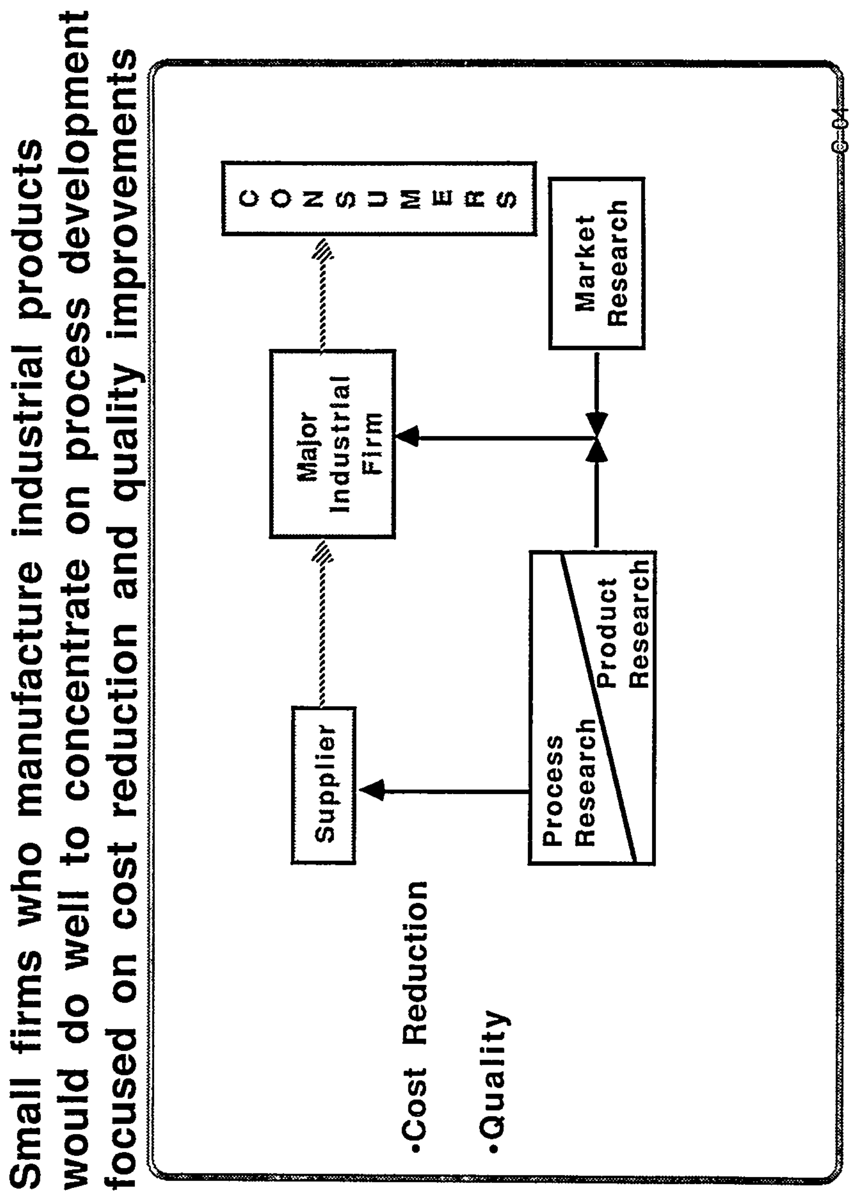
Small firms who manufacture industrial products would do well to concentrate on process development focused on cost reduction and quality improvements
•Cost Reduction
•Quality
Supplier
Major Industrial Firm
CONSUMERS
Process Research
Product Research
Market Research

Figure 4