COMPETITIVENESS IN ADVANCED TECHNOLOGY SECTORS: IMPLICATIONS FOR CANADIAN PUBLIC POLICY

Submitted by:

Jim de Wilde

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EXECUTIVE SUMMARY

The purpose of this paper is to explain the application of a Global Industry Structure Analysis (GISA) framework for the public policy issues of niche identification, and for the assessment of relative domestic competitive advantages in advanced technology sectors. Its purpose is to simplify the organization of information, not to create predictive models.

Global Industry Structure Analysis

The report sets out the implications of a global industry structure analysis for the sectors studied, and for technology issues generally. It demonstrates the importance of balancing technology push and market pull for the development of technology sectors and for the formulation of niche strategies, and makes a distinction between strategic technologies and technologies which can be directly marketed. Also discussed is the importance of consolidating areas of Canadian technological capacity where there is a reasonable chance of niche market development in the global economy, and areas where there is a potential for cross-fertilization within the Canadian technological portfolio.

Competitiveness

The report then makes some broader statements about 'competitiveness' in industrial sectors, including those sectors that are not as driven by anticipated markets. We are assuming in the Global Industry Structure Analysis, that the intended objective is to maximize the competitive presence of Canadian technology products and companies. In the final analysis, 'competitiveness' applies to products, marketed by companies, whether they are privately or publicly owned.

Sector Studies

The four sector studies (Ocean Technologies, Microelectronics, Medical Technologies, and Advanced Industrial Materials) provide the basis for implications about competitiveness, given the technological frontier, the global competitors, and the Canadian capacity in each sector. The report does not propose to make specific sectoral recommendations, but is intended to provide empirical reference points for an assessment of the competitive advantages within the Canadian technology portfolio.

Competitiveness Issues

In a review of the current 'competitiveness debates' and of the major economic, political, and business strategy analyses, the report attempts to broaden the discussion, and to put the Global Industry Structure Analysis (as applied to advanced technology sectors) in the context of the overall competitive environment of the Canadian economy.

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by

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SECTION 1: INTRODUCTION

This report develops a global industry structure framework with regard to advanced technology sectors/product-areas. It discusses the competitiveness of Canadian advanced technology and suggests implications for the way government policy can reinforce competitive advantages within the Canadian private sector. In this context, it makes some broader comments about the "competitiveness" debate in contemporary industrial democracies.

The enclosed reports on advanced technology sectors constitute an application of a global industry structure analysis framework to advanced industrial materials, microelectronics, medical technologies and ocean technologies. The framework was designed initially as an attempt to assist company managers in developing niche marketing strategies for advanced technology products. While predicting market trends in advanced technology areas has always been difficult, the explosion of growth in intellectual property-driven sectors in the 1980s required an attempt to focus this aspect of strategic thinking.

From a "sectoral" or "product-area" perspective, the perspective from which public policy assesses domestic competitive advantage, a similar exercise was necessary.. Advanced

technology sectors require different characterizations as to their sources of competitive advantage and while we believe that the unit of competitiveness analysis should always be the company, the nature of competitive advantage in advanced technology sectors requires that we assess the domestic R&D portfolio.

From the original company perspective, the identification of niches to be targeted strategically focuses advanced technology companies on market-pull as opposed to technology-push. For companies, the sustaining of competitive advantage requires that they balance these demands. Case studies in individual technology companies (not done for this report) reveal successful entrepreneurial technology companies to be characterized by their ability to do this. Unsuccessful companies (or product-areas) are frequently characterized by their tendency to rely on technology-push or their inability to secure a source of patient capital.

In applying the framework to industrial policy issues, we are aware of the two unique characteristics of the advanced technology commercialization process (to broaden the concepts to bridge public and private sector strategic issues):

a) advanced technology sectors (by definition) are producing for anticipated markets. While this seems obvious, it is frequently missed in standard economic analyses of R&D projects;

b) some advanced technology sectors are strategic technologies required to enhance the competitiveness of other user-sectors or the general economy. Their "market" therefore

is "artificial" in the sense that demand is structured not through the mass market, but through large institutional purchasers, often governments.

These two factors have frustrated both company managers in developing marketing strategies and public policy makers in trying to commercialize domestic technological assets. Arguments can be made that any project is "strategic" or "enabling". We note that the four sectors that we studied include two labelled as strategic by ISTC (microelectronics, advanced industrial materials) and two whose products are assessed directly by the marketplace (ocean technologies, medical technologies). It needs to be noted that even in these sectors/product-areas, "assessed directly by the marketplace" means, a "market" quite different from the aggregation of consumer choices which determine the relative competitive advantage of toothpaste or canned tomato soup.

In developing the global industry structure analysis (GISA), we were also aware of the difficulty in assessing intangibles that might make a particular technology a public investment even if not a strategic technology or a commercially viable product. For example, the maintenance of a research base in physics may be a public policy objective because it creates a scientifically literate set of engineers and analysts within the educational infrastructure. We believe that to be a separate issue which is best addressed in the final section of this report. Our immediate concern was to extend the GISA to public policy issues of niche identification and assessment of relative domestic competitive advantages in advanced technology sectors, so that market-pull and niche-identification issues are not excluded from the overall decision-making.

For this purpose, the GISA develops five stages in assessing the competitive capacities of Canadian advanced technologies:

1.what is the global industry structure in terms of dominance by other countries' industrial actors?

2.where are the technological frontiers in the sector?

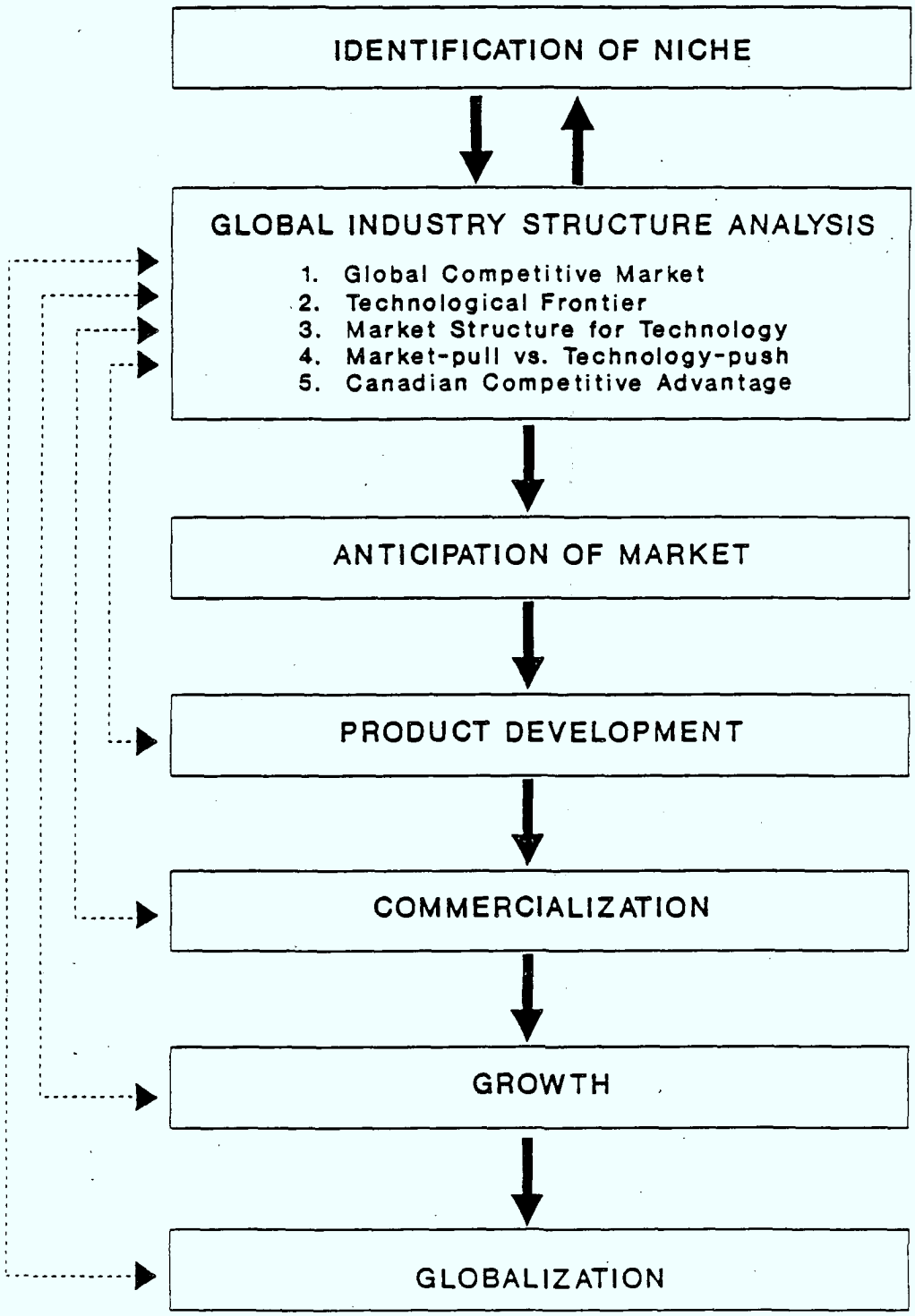
3.where is the market pulling the technology development in the sector?

4.how do we assess Canada's competitive capacities in this sector?

5.what are the public policy implications for this in terms of government strategies for enhancing overall domestic competitive advantage? Does it imply the benefit of structuring consortia? How should global alliances be structured within this sector?

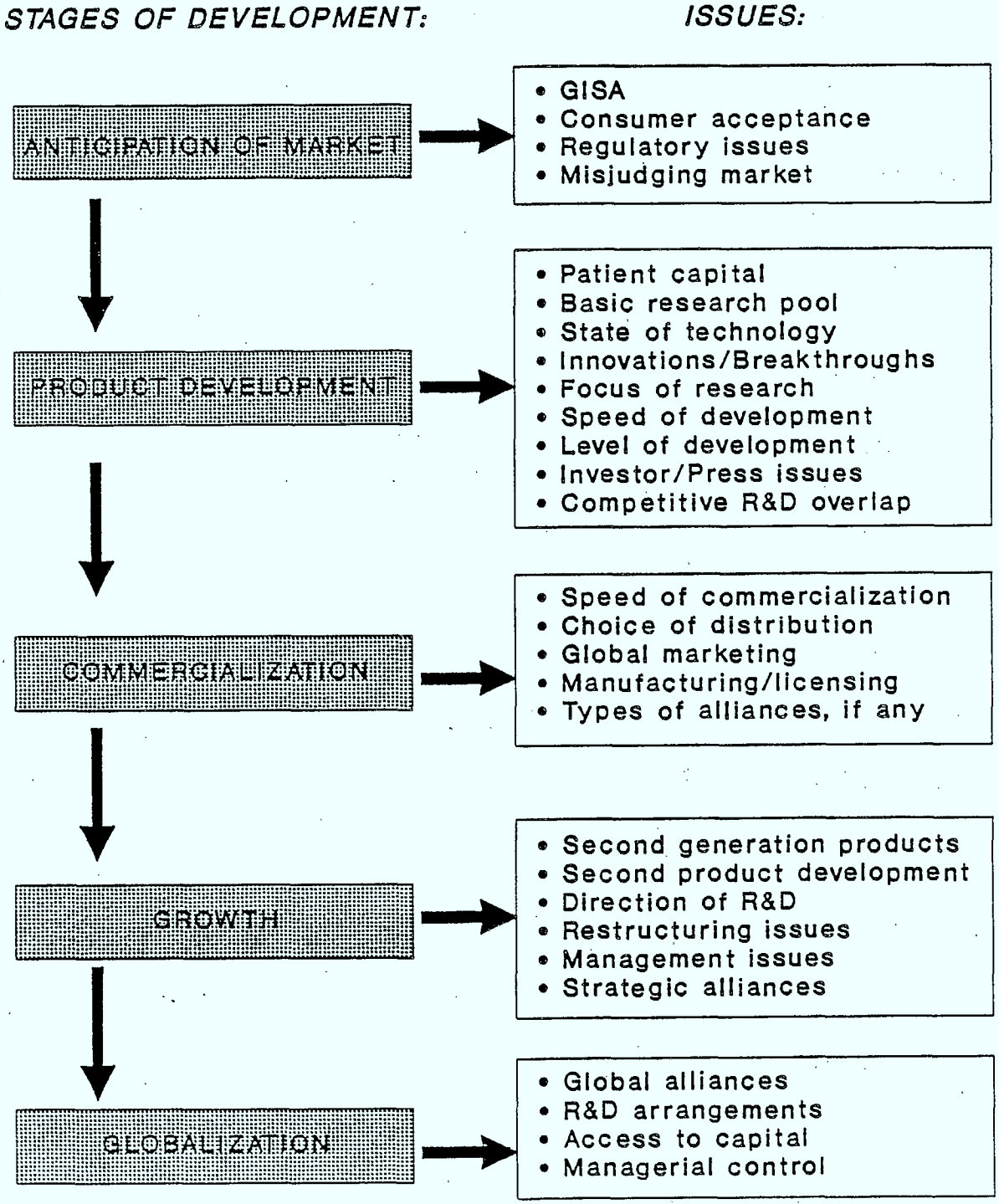
The following graphics illustrate how the framework can be used by company managers or investment decision-makers. Like all potentially useful frameworks, its purpose is to simplify the organization of information, not to create predictive models.

CORPORATE STRATEGY FRAMEWORK FOR ADVANCED TECHNOLOGY FIRMS



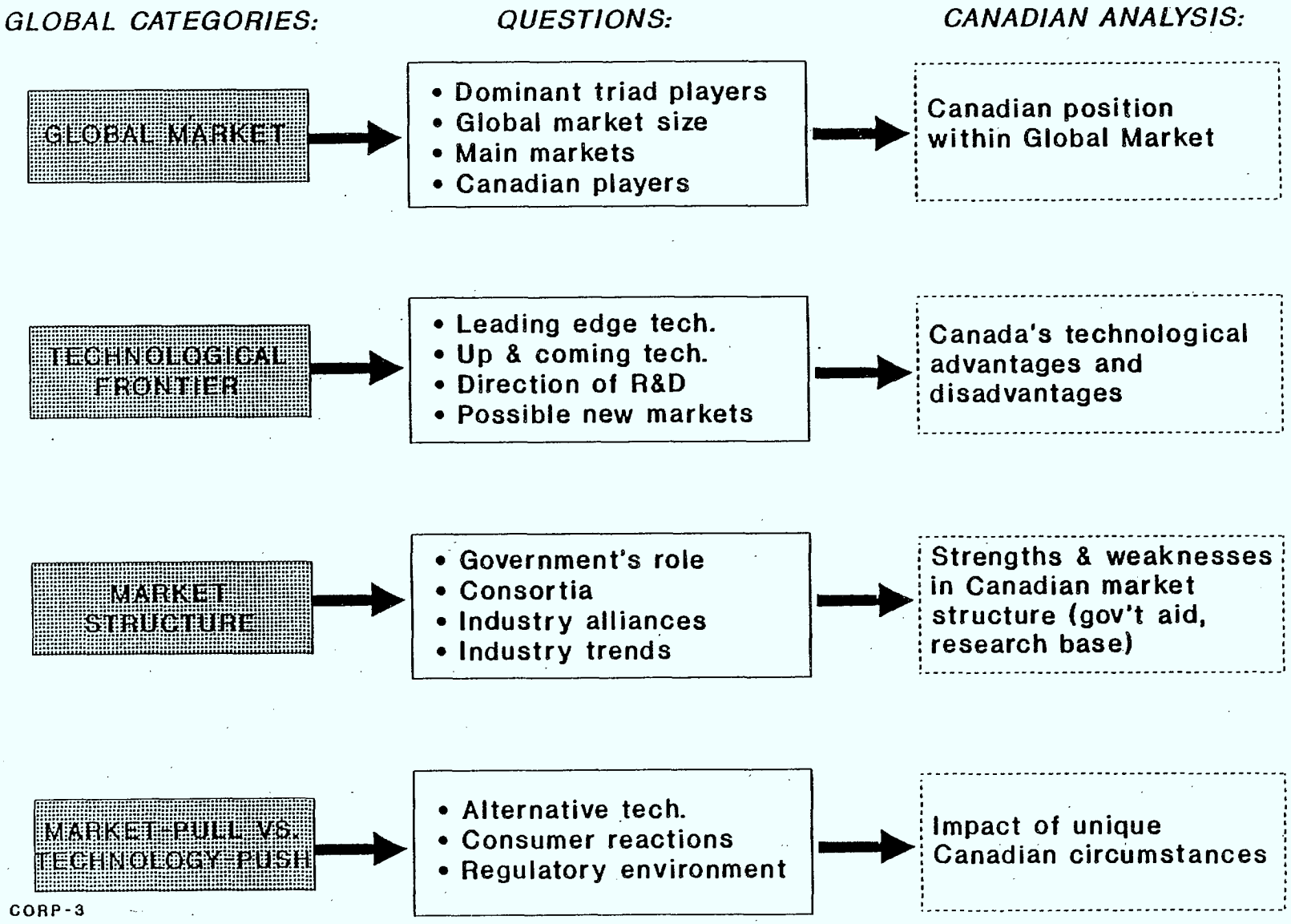
CORP-1

STRATEGIC ISSUES FOR ADVANCED TECHNOLOGY COMPANIES



CORP-2

THE GISA


GLOBAL CATEGORIES:
QUESTIONS:
CANADIAN ANALYSIS:
GLOBAL MARKET
• Dominant triad players
• Global market size
• Main markets
• Canadian players
Canadian position within Global Market
TECHNOLOGICAL FRONTIER
• Leading edge tech.
• Up & coming tech.
• Direction of R&D
• Possible new markets
Canada's technological advantages and disadvantages
MARKET STRUCTURE
• Government's role
• Consortia
• Industry alliances
• Industry trends
Strengths & weaknesses in Canadian market structure (gov't aid, research base)
MARKET-PULL VS. TECHNOLOGY-PUSH
• Alternative tech.
• Consumer reactions
• Regulatory environment
Impact of unique Canadian circumstances
CORP-3

For the strategic technology areas, the analysis produces the following conclusions in synopsis:

MICROELECTRONICS: In a global technology dominated by players who emphasize market-share over profitability, the Canadian sector is characterized by niche players who already service competitive Canadian industries, especially telecommunications. New market trends hold open the prospect for a greater number of niche markets to develop as the demand for microelectronic technology becomes more customized. The demand seems to be structured by the user-industries and individual supplier companies have particular sectoral user customers.

ADVANCED INDUSTRIAL MATERIALS: Canadian product-development in advanced industrial materials is not as extensive as in microelectronics. However, the manufacturing sectors which use the advanced industrial materials may find research into applications and adopting a source of a new design-based competitive advantage. R&D on materials offers a few small niches for Canadian materials research, but the nature of the market suggests an approach to competitiveness based on emphasizing technology diffusion and not direct invention.

For the end-product sectors:

MEDICAL TECHNOLOGIES: This is a cost-sensitive sector, influenced significantly by public policy trends in other areas of government. Globally, there are significant presences in the high-cost medical technologies areas (MRI and other imaging technologies) and there are leading corporate players in related medical care sectors and pharmaceuticals sectors. However, as innovations in medical care reflect changing concerns in health policy and consumer acceptance

of the organization of medical treatment, a large number of potential niche markets appear to have opened up. At-home diagnostic and health-maintenance technologies and patient-monitoring technologies which permit deinstitutionalized health-care are some of the more immediately identifiable market opportunities resulting form social trends. The market in these technologies is not yet structured and Canadian niche players are at no substantive disadvantage.

OCEAN TECHNOLOGIES: The sector includes a variety of product-areas in which Canadian industry has sustained a competitive advantage and where there is no dominant global player. The product-areas of the sector are disparate, ranging from autonomous underwater vehicles to ocean information systems. The sector has been driven by the needs of the oil and gas and resource industries and this may be seen, in part, as another enabling advanced technology. It can also be seen as a commercialization of Canadian robotic engineering capabilities and, as such, a key technological infrastructural investment. Given the anticipated demand for underwater technological capabilities driven by both environmental and resource development needs, however, the market structure alone suggests that Canadian technological capacities can succeed in obtaining significant market-share and even sustainable industry dominance within specific product-areas.

SECTION II: IMPLICATIONS OF SECTORAL REPORTS FOR GLOBAL INDUSTRY STRUCTURE ANALYSIS

Competitive advantage can be enhanced in advanced technology sectors by strategic identification of fits between Canadian domestic capacities and niches within the global market. Our approach has emphasized what is required for technologies to be commercialized through market-pull as opposed to technology-push. Sectoral competitive advantage can be enhanced through an appropriate fit between company capacities, public policy incentives and global market niches.

Throughout this report, we insist on the distinction between "enabling" or "strategic" technologies and technologies which are consumed by the marketplace directly. "Enabling" technologies provide an infrastructure or building-blocks, without which it will be difficult for a modern economy to compete. The judgement call about whether a strategic technology can be purchased without reducing the knowledge-value that comes from having a research capacity in the area will always be a difficult one. Advocates of strategic technologies always overstate the importance of a competitive (i.e., adequate) presence in the sector. Pure market analysis always understates the non-commercial costs that come from buying off the rack and not having an in-house or in-nation understanding of the technology.

The general sectoral and therefore industrial policy uses of the global industry structure analysis remains an instrument to focus on company/technological product-area competitive capacities. It can be extended into a relative prioritization of competitive positions within the global economy for technological areas. It does not constitute, by itself, a competitiveness policy or

an overall approach to the preconditions for enhancing the national competitiveness of a domestic economy. This requires a discussion of macroeconomic and macropolitical conditions which follows in Section V of this report.

The intention is to provide some empirical reference point for discussions about (a) how to assess the performance of Canadian enabling/strategic technologies, and in the future, to be able to have a more rigorous non-market calculation as to the benefits accruing from investments in strategic technologies; (b) to assist industrial policy thinkers in identifying and assessing potential niche strategies for Canadian sectors/product-areas, as company strategists must do in linking marketing and R&D; (c) to have an empirical method of looking at the relative strengths in the Canadian technological portfolio and the potential for cross-fertilization within it.

Some general conclusions about the global industry structure framework emerge from the sector reports and move the yardsticks on these conceptual issues:

TECHNOLOGY FRONTIERS: In the four sectors, two of which are enabling sectors (microelectronics and advanced industrial materials) additional criteria must be applied when assessing the role public policy must make in using them to enhance competitiveness. The technological frontiers in advanced materials and microelectronics leave only small niches for Canadian products to be commercialized. Their role overall for the competitiveness of other sectors which they "enable" cannot be overstated. Accordingly, niche companies with orientations towards Canadian telecommunications and automotive companies could prove

competitive, with a capacity to export their expertise to comparable industrial sectors elsewhere.

The nature of research in both sectors, however, is such that it is highly centralized in U.S., Japanese and, in both sectors to a lesser extent, European companies. Motorola, Hitachi, Kyocera have enormous patient research capacities in the long-term R&D into new chips and advanced materials. This makes it important to assess the role of Canadian research more in terms of what level of research commitment is required to sustain Canadian capacities in the development of niches in Canadian industrial markets.

In ocean technologies, and medical technologies, where the sector is defined by products that compete for final use, the technological frontiers reveal some interesting and significant niche opportunities. The commercialized ocean technologies industry has no dominant player and fits into overall robotics development. The technological frontiers are defined by research into ocean management, the mixture of environmental and resource development technological capacities. Medical technologies is a broader frontier, including product-areas where U.S., Japanese and European companies have considerable advantages for patient long-term research (GE Medical, Siemens and Hitachi or CAT-scanners and MRI). The technological frontiers in other areas (home diagnostics, new technologies of patient monitoring) suggests other frontiers which are not as well staked out. Where the technological frontier is one which covers a broad number of potential products and the market has not structured an industry or product-area dominant player, obviously the potential for export niche strategies for a country with a small domestic market increases.

GLOBAL MARKET-PULL: The market in microelectronics and advanced materials is being driven by the industrial users, looking for respectively faster capacities and more durable, lighter, energy-efficient materials in large industrial production. For medical technologies, the market is increasingly cost-sensitive and oriented towards preventive and health-sustaining rather than disease-treating demands. This market is particularly sensitive to public policy incentive,s encouraging different trends in the consumption of medically-related-product-areas. The market in medical technologies is extremely fast-moving, causing significant issues like the boundary-line between regulated and unregulated products (is a cosmetic which claims to reduce the likelihood of skin cancer a pharmaceutical product?). However, the market for new medical technologies that help monitor health, diagnose diseases and deinstitutionalize medical treatments seems to be growing while the market for institutionally-purchased high-cost technologies may be restrained by cost-conscious public policy decision-making. The market for ocean technologies is at the borderline between environmental management and resource development.

Assessing anticipated markets for advanced technology products is crucial to the success of a company strategy. Similarly, for industrial policy makers, the need to have some technique for assessing market-pulls within technological areas remains crucial to effective economic management. Investors and managers in the technology product-areas correctly emphasize the "artificial" nature of market forces, the demand-structure of government procurement (in sectors/product-areas like space technologies, advanced industrial materials), the capacity of industry leaders to play for market-share as distinct from any particular short-term market (in areas like microelectronics). Nevertheless, future demand-structures can be assessed, and at the very least, the need to assess future demand-structures can be demonstrated to those developing R&D strategies.

GLOBAL COMPETITORS: The competition in microelectronics and advanced industrial materials is considerable. The competition in large medical technologies is also considerable. However, there are no dominant players in ocean technologies, at-home diagnostics or niche markets in other areas of medical technologies.

CANADIAN CAPACITY: Competitiveness requires that one neither overestimate nor underestimate Canadian capacity. Canadian capacities in niches in ocean technologies, medical technologies and telecommunications-servicing microelectronics are considerable. Just as the niche in urban transportation technology (not included in this study) has established a market-leading position, similarly areas like alternate energy (not included in this study) and nuclear technologies (not included in this study) should not be underestimated.

The global industry structure analysis approach therefore enables us to assess strategies within sectors/product-areas of Canadian technology with a more realistic understanding of the capacities of companies in that sector to compete in the global economy. As more cases develop illustrating how analysts calculate the technological frontier and how marketing strategists assess anticipated demand, companies will be able to do more than a hit-and-miss approach to the commercialization of R&D. For industrial policy decision-makers, the implications of this affect the way key industrial policy choices are calculated. The implications of this for five public policy decisions is now elaborated on:

a) what does this mean for the decision about establishing collaborative R&D?

b) what does this mean for decisions regarding how global alliances are structured?

c) what does this mean for overall strategies of market-niche identification?

d) what does this mean for overall strategies for commercialization of R&D?

e) how can public policy promote competitiveness through disseminating knowledge?

COMPETITIVENESS STRATEGIES: COLLABORATIVE R&D/CONSORTIA: Consortia work when there is a global niche that is currently not being targeted because of a fragmentation of domestic capacity. This seems to be the case in ocean technologies, at-home diagnostics, and probably alternate energy (e.g., solar technologies) where research capacities are fragmented, and where the global industry structure reveals a potential for competitive advantage through the establishment of Canadian niche players. While collaborative R&D may make sense in order to sustain a domestic capacity in pure science, the commercial opportunity is to use consortia to galvanize domestic capacities to target niche markets.

COMPETITIVENESS STRATEGIES: GLOBAL ALLIANCES: In areas where Canadian research has areas of expertise but lags behind established global marketing networks, alliances can facilitate the commercialization of a Canadian technology. This applies to microelectronics, pharmaceutical biotechnology and probably to some areas of aerospace technologies. Therefore, the public policy decision is whether alliances should be encouraged from positions of strength (well-capitalized Canadian companies negotiating real alliances) or whether the market should sort out the benefits (Lumonics-Sumitomo, Connaught-Merieux). Our contention is that an alliance should be sought after by Canadian technology companies and negotiated in a way which

maintains the Canadian company control, if the sector/product-area is one in which there is a competitive Canadian presence. All R&D-driven sectors have some international connections; the question is how they are structured and managed in order to maintain strategic control. Control comes from maintaining a stable capital-base, something which the Alberta and Quebec governments have done for their technology-based firms as they globalize.

COMPETITIVENESS STRATEGIES: TARGETING NICHES: The public policy question of targeting niches comes from situations in which there is no clear global market leader and a niche has emerged, e.g., at-home diagnostics. One could argue that Canadian cable television, Canadian hydroelectric engineering, Swiss pharmaceuticals, Finnish cellular technologies, and Canadian urban transportation developed in this manner.

One could also argue that a number of deficit-expanding industrial failures came from mis-targeting niches and allowing technology-push arguments to be justified by the vague language of "targeted niches". In all of these successful "targetings", there was some reason to believe that the competitive capacity existed and was worth commercializing. To try to target niches without a rigorous global industry structure analysis is to guarantee many expensive disappointments. Conversely, new product-areas need to be designed for the future Canadian advanced technology industrial portfolio and the market cannot always anticipate demand for new technologies, preoccupied, as it should be, with sorting out present-tense demands.

From the sectoral reports, it is clear that market-niches do exist. From this level of analysis, however, the commercial decision as to whether Canadian private sector capacities can exploit

them remains a decision to be made. There is a niche in ocean technologies, in commercial use of robotic submersibles. Similarly, there is a niche in at-home diagnostic technologies. In other sectors, not studied for this report, there is a niche in solar technologies and in small-scale use of nuclear technologies. An identified niche does not guarantee commercial success, but if one does not exist, then the criterion for backing a sector/product-area needs to be strategic.[1]

COMPETITIVENESS STRATEGIES: COMMERCIALIZING R&D: In all sectors, respondents constantly emphasize the difficulty of commercializing new technologies. Proponents of market solutions correctly point out that the market should sort out whether the niche anticipated is real, but if a new technology isn't commercialized, not because investors are skeptical, but because there is no long term venture capital in the system, then the market verdict is never afforded a chance.

Competitiveness in advanced technology sectors requires attention to this. It is beyond the scope of this report to assess the relationship between capital market behaviour and the competitiveness of Canadian advanced technology sectors. However, it is important to reiterate that the issue of effective corporate finance structures is frequently mentioned as a prerequisite to the effective management of globalization/strategic alliances. It should also be pointed out that the successful commercialization of already-existing technology requires interest from the investment community.

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[1]**Note:** Obviously, a niche can be found if one breaks a product-area down into a small enough component-unit. Software engineers can customize programmes for a company, the ultimate niche market. The presumption here is that a global market niche is a more significant market opportunity made possible by the structure of global competition and demand.

SECTION III: IMPLICATIONS OF SECTORAL REPORTS FOR THE WAY WE LOOK AT TECHNOLOGY SECTOR COMPETITIVENESS

The injection of the criterion "competitiveness" into an assessment of advanced technology investments is complicated by the manner in which company strategy and investment analysis literature treats advanced technology sectors. One can generate conditions for a competitive "economy", i.e., the maximum utilization of resources within a single industrial portfolio in order to achieve success as rewarded by the global market (export-production). One can generate conditions for market dominance within sectors and product areas where there is a defined market (canned tomatoes made with subsidized agricultural produce will be more "competitive" than canned tomatoes whose price includes the full cost of purchasing the agricultural product). In defined-market sectors and product-areas, calculations about competitive advantage can be made by adjusting the various factor conditions (labour cost, material cost, distribution networks) or by repositioning the product in terms of purchase criteria like quality. A company can choose to compete on cost and define its marketing strategy that way or it can choose to compete on quality and redefine its market position.

In anticipated-market sectors and product-areas, the company strategy and investment criteria are different. Therefore, the public policy analyst is left with a set of arguments about:

a) maximizing the technological infrastructure in order to increase the chances that a niche product will develop through some collaboration between players and research components within the domestic sectors;

b) picking winners based on the assessed potential for commercializing R&D currently being undertaken;

c) providing unfocused patient capital to R&D-driven sectors in the hope that the process of commercialization will target specific market niches out of the resulting new technologies.

There are a number of differentiating characteristics of sectors and product-areas. At-home diagnostics are an anticipated market product area which will focus on the mass market. Pharmaceutical biotechnology will be marketed to specialists who have to be convinced of the superior quality of new medical treatments. No individual consumer buys a space station. Some technology sectors overlap, being both enabling or strategic technologies (e.g., advanced industrial materials, microelectronics) and being specific product-areas (new ceramics, miniaturized circuitry). Some can be generated by "big science" (e.g., ocean robotics, rocket-launching technologies), some are more entrepreneurial (software development, biotechnological research). Some can be influenced by government structuring of demand (e.g., medical technologies like CAT-scanners, space technologies) and some need to rely on an accurate reading of demand in the marketplace (at-home diagnostics, educational software, solar energy).

Marketing New Technologies for Anticipated Demand:

In other sectors not studied in this report, the volatility of energy pricing has always made the commercial potential of alternate energy technologies difficult to assess. The technology product market history is filled with ill-timed combinations of product and demand. Fax technology was

possible for years before being commercialized. Xerox abandoned the technology which was to provide the market with Apple computers. Company strategies need to create demand, but from a company perspective, the anticipation of the nature of demand is a key gamble.

For example, the Montreal firm Videotron has a technology which allows viewers to pick the angle from which they want to watch a football game or key in on a particular player. It is pioneering the market in interactive video. We also can project ahead to a home telecommunications/entertainment software technology which allows us to order a viewing of Casablanca or reruns of favourite episodes of Night Court or Mister Ed. Such technology can also be used to provide educational programming for children. What we don't know is how the mixture of intellectual property protection and regulation will influence the development of these new industries.

In five years time, it will be commonplace for home diagnostic products to be available to monitor a consumer's cholesterol level or provide a reliable check on AIDS. In five years time, it will be possible for microrobotic technology to inspect the inside of nuclear reactors to verify cracks or weak spots. If we know this, why can't we pick the companies which are going to develop them, either as investors or as public policy makers? Why can't we "pick winners and losers" in the language of the familiar debate about industrial policy? A California company with a band-aid type chemical that measures exposure to ultraviolet light for tanners should have a large market. However, it is difficult to measure this demand as the product requires the development of new consumer habits, new regulatory norms (is it a medical product?), and a public strategy for assessing liability issues in health products.

We can detect broad trends in the development of new technologies, but not the specific currents within them. For example, the market for home diagnostic products will develop around (a) ease of use; (b) reliability; (c) regulatory acceptance. How will the innovation take place? Will it be driven by a simpler technique for diagnosis or by a process in which the consumer has greater confidence? Will it be marketed directly or as a medical product?

The market for micromachines has several possible applications, each of which will drive a different technology for miniaturization. The medical applications include what Kenzo Inagaki, MITI's deputy director of industrial machinery division, compared to "shrunken men zipping through veins to destroy cancer or repair damaged tissue". Without the essential knowledge of miniaturization (acquired through basic research), and the production of the advanced materials necessary to manufacture these microrobots (developed as a strategic technology), there will be no product development.

In these cases, anticipating the market structure continues to create considerable problems for company strategists and public policy makers. There is no magic formula for balancing market-pull and technology-push. Successful strategies require only that they constantly be balanced. Technological innovation can create new market opportunities. As we see in the case of ocean industries, one robotic technology may change the potential market for submersibles. If the infrastructure in robotic diving is there, changing strategies for global mining companies may produce a new set of market demands.

What does this mean for a Canadian industrial policy decision-maker or, indeed, anyone concerned with the development of a Canadian capacity in these sectors? It identifies critical distinctions between these sectors and suggests how Canadian companies should adapt to the opportunities presented. The pattern of health product consumption in Canada is directly related to the public health care system. This means that there is an opportunity to pioneer an innovative distribution system which would enhance the competitive advantage of Canadian home diagnostic companies. While Canadian companies cannot match the state-of-the art R&D in miniaturization which exists in Japan, specific niche applications can be found which can enhance the competitive advantage of individual Canadian sectors, e.g., nuclear plant monitoring and maintenance. The task is not for Canadians to try to become world leaders in each industrial sector, but instead to discern our capacity within the global industry structure and adapt technological innovations to potential sources of Canadian competitive advantage.

Contrast these two strategic challenges. In home diagnostic technologies, the products exist, but need to be successfully commercialized. In microrobotics, a need has been detected, but the technology has to be produced which is consistent with the anticipated markets. In the home diagnostic technologies example, the problem is one of marketing, in the micromachines sector/product-area, the problem is one of identifying where the technological frontier is and who has the capacities to organize research in that direction and commercialize it effectively.

Anticipated market sectors/product-areas require that private and public sectors have in their complementary roles some sense of where the technological frontier is evolving and how global market-pull will commercialize these new technologies. In medical technologies, the cost-

constraint required by publicly-financed health-care systems constrains the marketing strategies of the major medical technologies companies like Siemens and GE Medical. New technologies may be justified as "basic research", or in terms of conventional arguments like "spinoff" and "infrastructure", but the market potential is likely to be constrained by these fiscal realities. Similarly, social trends towards personal life-style control and monitoring affect the market in health-care products.

Based on judgements like these, one can make certain niche identifications in the area of medical technologies. The market-pull for ocean technologies is directly affected by resource-pricing and demand. Resource shortages will accelerate the demand for deep-sea mining and prove to be a market-driver for new technologies in ocean exploration. A revitalizing manufacturing sector will likely accelerate demand for a design-based competitive strategy involving materials substitution and accelerating the demand for adoption of advanced industrial materials.

From these four sectors, our conclusions are that Canadian capacities in ocean technologies constitute a technological portfolio which can establish a niche competitive presence within the global market. The demand-structure of the industry suggest the need for a fusion of company and R&D capacities. Medical technologies contains some product-areas in which Canadian niche capacity is considerable. However, the global linkages required for effective commercialization are much greater given the global industry structure and the state of the technological frontier. Advanced industrial materials offers a different set of implications for competitiveness strategies. While individual company R&D strategies have established specific Canadian capacities, the competitiveness aspects of the technology are affected more by the role

it can play in enabling other sectors to redefine their competitive position through a design-based competitive advantage. Microelectronics, as driven by the telecommunications sector, has already established a consortium-based strategy.

SECTION IV: GLOBALIZATION AND INDUSTRY SECTOR COMPETITIVE ADVANTAGE

Competitiveness has developed as a concept in response to the analysis of globalization. Globalization has produced a complex new set of market decisions highlighted by three new phenomena. After all, there is nothing new about international trade, nor export-oriented company strategies. Japanese and European companies have long pursued export-oriented marketing strategies; the recognition of this by U.S. and Canadian company managers has often been confused with the phenomenon of globalization. What is new is a global market-structure characterized above. This makes speed of response a fundamental prerequisite to competitiveness.

The debate about competitiveness is old. The debate about competitiveness in a global economy is new. Competitive performance can be enhanced by a variety of factors and differs dramatically from sector to sector. Competitive advantage for a brand manager at Proctor and Gamble is different from competitive advantage for INCO, different still from competitive advantage for Boeing, Raytheon or Morton Thiokol, different still from competitive advantage for Lavalin, different still from competitive advantage for Microsoft, Cognos, or Lotus, different from Magna or GM Canada. This statement still produces considerable debate in the economic and business strategy literature, while broad preconditions for competitiveness can be defined (e.g., healthy capital markets with low and predictable interest-rates benefit all companies with innovative long-term strategies), specific industry and company situations require different mixes of company strategy and domestic public policy in order to create sustainable competitive advantage.

While the categories can be broken down further, there is an obvious difference between producing for a defined mass market (P&G), producing for institutional consumers (Boeing, Bombardier), or producing for anticipated markets (technology companies with strategies for commercializing R&D). Individual consumers do not buy mass transit systems or jet airliners. Neither individual consumers nor institutional consumers (usually, but not always, governments) know whether they want to buy technologies which do not exist in a commercial application yet.

Targeting Niches and Measuring Industry-Leader Dominance:

Competitiveness also risks posing the problems in a way which exaggerates the claims. If IBM is the market leader in technological capacity, then the extreme logic dictates there can be no competitive niche players in the industry. If Boeing is the market leader in wide-body jets, then there can be no competitive niche players in the aerospace sector. Obviously, this is not the case.

Having said that, niche technology strategies can only be generated around technologies which identify some market-demand. In the successful Canadian urban transportation technology sector, one of the major reasons Bombardier developed was because it was pursuing an export-oriented strategy, targeting the global market (people-mover systems at Disney World). Similarly, Lavalin-UTDC has successfully targeted market niches in developing countries. These are not areas where Canada has a natural competitive advantage through a sophisticated local market. Nonetheless, the global industry structure was set up in a way which oriented other urban transportation companies towards their domestic market and created a global market

opening for Canadian firms, especially in the absence of a strong U.S. presence (mass transit being a relatively low priority within U.S. public sector expenditures).

The highly competitive Canadian television industry has developed as a result of the concentration of public sector spending on public broadcasting creating video production technologies that are competitive, but not fully commercialized. Similarly, the success of cable companies like Rogers and Videotron is a reflection of a "coherence" between company strategies and public policies in the establishment of a cable television industry. Other sectors in which Canadian competitive advantage has developed include energy technologies (pipelines and hydroelectric construction technologies) where domestic demand was clearly a factor in disciplining and stimulating a competitive market. The real world of decision-making does not lend itself to neat boxes. It should be pointed out that the most successful Canadian consumer products companies (McCains, Provigo) have long pursued export-oriented marketing strategies which have enabled them to utilize high quality management and transform their domestic strengths through an export-oriented strategy.

In examining the global industry structure framework, public policy decision-makers can make a better assessment of Canadian industrial and technological portfolio assets. This is not a question of picking "winners and losers" except in the sense that the market does it every day. It is a question of picking long-term winners and ensuring that the patient investment enables the private sector to commercialize and market the next generation of product-areas and sectors. It is worth pointing out in this context that the tired debate about whether or not government can pick winners can be dealt with in a single sentence: conventional public policies have identified

as many winners as the market has, especially in advanced technology sectors where public investment financial constraints are fewer. The government has earned a bad reputation for its inability to deal with its losers, something the private sector does much more effectively. Until this problem is dealt with, there will understandably be scant interest or confidence on the part of the private sector in any public policy attempt to apply global industry structure analysis to technological investment decision-making.

SECTION V: THE "NEW" DEBATE ABOUT COMPETITIVENESS IN THE CONTEXT OF GLOBAL INDUSTRY STRUCTURE ANALYSIS

There is nothing new about a debate on economic competitiveness. The new question is given the dynamics of global competition, what, if anything, can public policies do to enhance the competitive performance of industrial sectors in Canada? Before formulating the answer to this question, it is important to point out that economic competitiveness is a prerequisite to fiscal capacities. In simpler terms, someone has to pay the way. Fiscal frameworks that attract confident (long-term) international investors are a prerequisite to competitive industrial policies. To pit one argument against the other is to risk trivializing the issues of global competitiveness.

In the technology sector studies, we examine routes to enhancing competitiveness in specific sectors. Competitiveness can be enhanced through enabling technologies which are more accessible to other industries. A standard example is that the relative quality of Barbados' telecommunications system gives it a competitive advantage over other Caribbean states in acquiring foreign investment. The decision by American Express to locate its processing facilities in Barbados added substantially to the wealth-generation of the Barbadian economy and the employment base. This illustrates the relationship between enabling technologies and competitiveness. This did not result in any added competence in innovating new telecommunications technology in Barbados, but is a straightforward example of the relationship between enabling technology and domestic economic competitiveness.

The route to competitiveness varies from sector to sector and domestic organizational capacity to domestic organizational capacity: Each sector is different and makes different demands of public policy in order to be competitive. France developed a competitive rail transportation industry because of a centralized decision-making system in transportation and industrial policy. The U.S. rail transportation industry has declined because it lacks that centralized organizational decision-making system. Conversely, the French computer industry became a cycle of inefficient subsidies because of the attempt to centralize and direct R&D within the sector; the U.S. industry, as documented by George Gilder in Microcosm, was successful precisely because the decentralized organizational structure of the Silicon Valley competitor combined with dynamic venture capital markets suited the needs for growth in this sector.

The approach used in our technology sector studies suggests that Canadian organizational capacities will have to be developed to create the vehicles for competitive commercialization of ocean technologies and medical technologies. The dissemination mechanism for microelectronics seems to be increasingly coordinated as a result of both public and private initiatives. The relationship between advanced industrial materials and the consuming manufacturing sector lacks a formal collaborative mechanism which would facilitate this organizational dynamic.

The new competitiveness debate is a response to the awareness that globalization has changed the dynamics of company strategy. The global market is characterized by:

a) interconnected capital markets, made possible by the computerization of financial transactions;

b) the increasing percentage of world trade that takes place in innovation-driven, intellectual property-protected sectors. In these an innovation in Basel can render less competitive a company in Vancouver; and

c) a global information network which communicates news instantly through satellites and faxes.

This reality has dramatically changed the dynamics of company competitive advantage and the public policies required to sustain domestic company advantage.

Competitive industries originate in different ways, with different sources of advantage. The success of the Canadian aluminum industry, the Swiss pharmaceuticals industry, the Italian footwear industry are all a result of a combination of conditions: public policy (hydro availability, industrial patent-protection, trade protection), local capacities in labour and concentrated knowledge. But competitive advantage is an elusive category. It is important to understand the relevance of the earlier discussion (in Section II) of market niches for company managers. Reebok and Nike, for example, companies within the "declining" or non-competitive North American footwear industry, export successfully to Italy, the so-called industry leader.

These observations are important for more general public policy debate about competitiveness. Formulas should be viewed with great suspicion. It would be a mistake to conclude that sources of competitive advantage are the same from sector to sector, or that the preconditions for the success of a product-area at Proctor and Gamble is the same for the successful development of competitive advantage for Boeing or Northern Telecom. It would be equally as significant an

error to treat anticipated-demand markets as being influenced by the same factors as consumer goods markets. Our current public policy debate is constructed on a number of dubious assumptions. A pure economic point of view is that Canada should concentrate on areas where there is a traditional advantage. But, by this logic, there is no reason why Switzerland should have three multinational pharmaceutical companies (Hoffman Laroche, Sandoz, Ciba-Geigy), or Finland a worldclass cellular telephone company (Nokia).

The conventional business school line that companies compete, countries don't, is worth emphasizing. Companies have to discover market niches, commercialize laboratory research, structure production in order to maintain advantages over competitors. This gives rise to the "fiscal framework" approach, emphasizing overall economic conditions, encouraging governments to concentrate on cost of capital, access to new sources of investment, tax regime stability and other factors which encourage business development. Undoubtedly, this is correct as far as it goes, and undoubtedly it contributes to an analysis of the circumstances under which companies become competitive in established or mature industries. Most sectors want cheap capital, predictable taxes and a stable labour market as they expand. The debate regarding necessary preconditions for creating sustained competitive advantage becomes more complicated when one differentiates sectors.

Consumer goods companies, large industrial products companies, and advanced technology companies need different circumstances under which to compete effectively. The mass market differentiates between Kelloggs and Nabisco and competitive advantage can be structured by appealing to criteria of consumer choice. No individual consumer buys wide-body jets or mass

transit systems, however, and the circumstances under which competitive advantage is generated in aerospace and urban transportation is correspondingly different.

There are many theoretical analyses of country/regional competitiveness that have been formulated in the last few years. There are nine major arguments which, in our view, grasp elements of the economy competitiveness issue and should extend the analysis of the competitive strategies of Canadian technology sectors/product-areas outlined here:

(1) Porter, with his emphasis on competition between domestic producers and sophisticated consumers producing local factor advantages. Porter's analysis is helpful for demand-led sectors, but does not attempt to differentiate anticipated-market sectors and product-areas, or address the problems that define competitive advantage for advanced technology sectors (The Competitive Advantage of Nations by Michael Porter);

(2) Ohmae, with his emphasis on globalization and the management of global linkages, emphasizes global knowledge-networks and the negotiation of collaborative R&D between technological front-runners focuses on globalization but underestimates the role of domestic conditions in establishing patient capital markets and therefore contributing to the commercialization of R&D (Kenichi Ohmae, The Borderless Economy & Triad Power);

(3) Reich emphasizes the importance of domestic intellectual capital in determining large scale and long-term competitive advantage, but does not deal with the organizational

dynamics required to structure the management of intellectual capital in knowledge-driven sectors. In moving away from "industrial policy", Reich has correctly focused on scientific literacy and investment in intellectual capital, but he neglects the issues of capital market structures which are required to sustain innovative companies' competitive advantage (Robert Reich, The Next American Frontier);

(4) Thurow emphasizes the advantages of collaborative R&D in making innovation-driven sectors more efficient, but focuses on "big science" sectors, like the space industries sector to make the argument (Lester Thurow, The Zerosum Society);

(5) Katzenstein focuses on the coherence of government and industry strategies to explain the niche strategy successes of the Swiss watch industry and the Austrian steel industry. Katzenstein has the most integrated explanation of competitive advantage, by focusing on the compatibility of company and state strategies in pursuing export niche markets. This analysis is particularly relevant for governments with small domestic economies which are pursuing export market strategies (Peter Katzenstein, Corporatism and Growth);

(6) Zysman explains similar export-oriented successes by analyzing the congruence of capital markets capacity and company strategies in explaining German and Japanese competitiveness. For Zysman, the dynamism of domestic capital markets and their capacity to finance adjustment policies determines the overall success or failure of domestic economies (John Zysman, Government, Markets and Growth);

(7) Olsen explains competitive advantage by a Schumpeter-style "gales of creative destruction" which produces the preconditions for new sector growth. Competitiveness is determined by the capacity of economic systems to deal out declining sectors. Olsen explains German and Japanese competitiveness by the extent of the destruction of their manufacturing base during the Second World War (Mancur Olsen, The Rise and Decline of Nations);

(8) Gilder emphasizes the entrepreneurial ethic, generalizing from the experience of the California semiconductor industry. For Gilder, competitiveness is undistinguishable from entrepreneurship, but his case study chooses a very decentralized sector and generalizes from it (George Gilder, Microcosm);

(9) Ellsworth looks at the role of capital markets in determining whether or not company strategies can have a long-term orientation required for new sector economic growth. He explains declining U.S. competitiveness in terms of the emerging "casino economy" of short-term capital market decision-making (Richard Ellsworth, "Capital Markets and Competitive Decline", Harvard Business Review, 1987).

The analysis in sections I,II of this report are empirical, based on the capacities of the Canadian sector/product-area and the competitive structure of the global technology and market. The preconditions for sustained competitive advantage in these and other sectors requires a variety of conditions. In examining the analyses and data of those who have been trying to explain the origins of competitive advantage, the most powerful arguments come from Ohmae with his

understanding of how global market-demand is refocusing company strategies; Thurow with his understanding of how collaborative R&D is required to sustain an infrastructure in emerging technologies; Zysman with his understanding of how capital markets that facilitate restructuring, adjustment and patient investment are required for the organization/strategy fit to operate in a manner that sustains competitiveness, and Katzenstein with his understanding of the role of government-private sector coordination in the pursuit of targeted export strategies and the implications of this for sustained competitive advantage. Empirically, all competitive economies seem to have three common characteristics, operationalized by different policy instruments appropriate to domestic capacities:

a) an entrepreneurial culture where new organizations are accelerated in their formation and reformation, what we call a bias for innovation within the social decision-making framework. This can be manifested in bankruptcy and competition laws, in the pattern of social adjustment, and most significantly, in the breadth of the stake that people have in new innovations. If there is no common stake in new technologies then the public policy process will be resistant to investment in these areas. The medical technologies industry could benefit from an investment of union pension funds which would create a common interest in the development of a new technology;

b) dynamic "venture" capital markets, by which we mean the accessibility of risk capital to new ventures, not simply for new start-ups, but for commercial technologies which may require patient investing before a return is yielded. The difference between venture

capital for technologies and venture capital for new start-ups is important to understand if the competitive situation of new technology firms is to be analyzed;

c) a degree of "coherence" between government policy as it affects capital markets and patient investing and as it itself constructs technological infrastructures and the company strategies of key players within the domestic industrial portfolio. If the policies lack coherence, the resulting inefficiencies derail long-term investment strategies. Export-oriented national strategies unite business and government in the establishment of long-term planning horizons. The European countries with small domestic economies (e.g., Finland, Austria, Switzerland) have pioneered this type of "coherence". Canada, similarly with a small domestic market, has not developed at a national level such long-term export-oriented economic strategies.

We are assuming in the global industry structure analysis that the intended objective is to maximize the competitive presence of Canadian technology PRODUCTS and COMPANIES. Competitiveness, in the final analysis is always a product marketed by a company, whether that company is privately or publicly owned. Enabling technologies can facilitate Canadian companies marketing products in a more competitive way, even if the emphasis of government in promoting enabling technologies is less to invent new products than to facilitate the adoption of technologies. The familiar example that office computer systems are utilized between 10 and 30% of capacity makes the point that this enabling technology could enhance company productivity and overall competitiveness if appropriate computer systems were utilized at 60 to 90% of capacity. The key to the overall competitiveness of the domestic economy is not, in this

case, to invent a new technology but to design an improved learning-system for the adoption of existing technology.

COMPETITIVENESS STRATEGIES: DISSEMINATING KNOWLEDGE: The mandate of this report was to use a global industry structure approach to niche strategic planning and use it to focus competitiveness issues within Canadian technological product-areas and sectors. Having emphasized this, it is essential to underline that in dealing with technologies and competitiveness, the existence of "enabling technologies" introduces the separate category of analysis which we have been developing in this report. Even if there is no competitive advantage in Canadian advanced industrial materials development, the knowledge about manufacturing gained from SOME TYPES OF R&D in the sector produces a public good of considerable value.

The contention here is that there is an important distinction between R&D required for the technological infrastructure (which may or may not be what scientists call basic research) and R&D intended to produce products for which the global market has a demand. It is this distinction between which often confuses public policy makers about technology-push and market-pull, and makes it difficult to assess the commercial value of enabling technologies. It should be emphasized that the concern in this report is not to address the question of how strategic technologies should be financed, but to examine, consistent with the global industry structure analysis framework, ways that market opportunities in advanced technology product-areas can be assessed. For a competitive economy, the first thing which needs to be done is to differentiate between sectors/product-areas which should be market-sensitive and those which are intended to facilitate in the development of other sectors in Canadian industry, and which

are therefore "strategic". For strategic technologies and for advanced technology sectors generally, we remain convinced that the single most important (emphasize, not only, but single most important) thing government can do is to accelerate the development of scientific literacy in the marketplace, in industrial users, and in opinion leaders, especially the financial community. In order to emphasize the relevance of our report, it should be added that at that point, the "scientifically literate" decision-makers will then have to make private and public sector judgment calls about the relative competitive advantage of Canadian technologies given their assessment of the global industry structure in that technology.

CONCLUSION

These factors determine how successful a national economy will be and influence the competitive environment of individual technology sectors. In each of the technology sector studies, we are conscious of the domestic technology portfolio and how that portfolio can be commercialized in a manner which increases the chances of competitive advantage accruing to the Canadian sector. We are arguing that R&D alone is not a precondition for the development of competitive advantage because if it were, there would be few Canadian sectors in which R&D $ spent would be adequate to purchase a place in the global industry structure. We are arguing that competitiveness comes form a variety of sources in individual sectors and that government strategies can enhance or retard this competitive advantage. We are arguing that niche identification is possible for both government policy makers and company strategists, as they balance the domestic technology portfolio capability, the competitiveness factors in the general environment, and the global industry structure within which the product must compete.

Our purpose is not to pick winners and losers as the market must do, but to suggest ways that public policy involvement with a sector can enhance the competitive capacity of a sector. Battery research may prove to be more commercially rewarding than solar panelled-housing. However, the Canadian technology portfolio may be more capable of advancing a solar-heated housing product development than a battery research product. Our intention is to develop a framework to fit technology portfolio with global industry structure and in so doing make the criteria for technology sector competitiveness more central to our approach at developing new technologies.

The view that there is a single model for competitiveness is, we think, misleading except at the level of general conclusions regarding the development of niches. The global industry structure framework enables us to see strengths and weaknesses in our domestic technological portfolio. It cannot provide an investment analysis concerning individual companies. However, it can provide a dimension to debates about competitiveness. Unless advanced technology company managers find a way to balance technology-push and market-pull in their identification of strategic opportunities, their competitiveness will be reduced. Unless public policy decision-makers find a way to do the same in their assessment of industrial restructuring and investment priorities, the competitive advantages of the Canadian technological portfolio will not be maximized.

NOTE: *As was emphasized in Section V, this report is intended only to assess one dimension of competitiveness. The discussion in section V goes beyond the parameters of this report in order to answer many of the questions concerning the development of sustained competitive advantage that inevitably and appropriately arise within any specific empirical context.*

It should also be emphasized that throughout this report, we try to use the expression sector/product-area interchangeably. The framework is intended to help assess competitive position of products aimed at anticipated markets. The boundary line between product-area and sector blurs rapidly. Apple founder Stephen Jobs has argued that the frontiers of biotechnology and microelectronics are the same and many working on biochips would implicitly agree. Similarly, in discussing ocean technologies, we have ended up with a discussion of robotics capabilities. Medical technologies, advanced industrial materials and microelectronics intersect in the development of microrobotics. Lasers can either be seen as an end-product or an enabling technology for medical practice, space technologies, etc. We acknowledge the importance of sectoral boundaries for research classifications and for investor analysis. However, increasingly, technological innovation will make obsolete the previous generation of sectoral categories. For simplicity, we have therefore used sector/product-area to focus the question of Canadian competitive capacities within the global industry structure.