The Centre for International Governance Innovation

WORKING PAPER

Economic Policy

Science and Technology Policies, National Competitiveness, and the Innovation Divide

Carin Holroyd

Working Paper No. 32
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To send comments to the author, please contact:

Carin Holroyd
Senior Fellow, CIGI
Senior Research Associate, APFC
cholroyd@cigionline.org

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John English
EXECUTIVE DIRECTOR, CIGI

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Author Biography

Carin Holroyd is Senior Fellow at CIGI, and Senior Research Associate with the Asia Pacific Foundation of Canada. She holds a Ph.D. in Political Economy from the University of Waikato (New Zealand), and has previously been a SSHRC post-doctoral fellow of the College of Commerce, University of Saskatchewan, a faculty member at the University of New Brunswick, Bishop's University and Kansai-Gaidai University (Japan), and co-president of the Japan Studies Association of Canada.

Dr. Holroyd's publications include: *Government, International Trade and Laissez-Faire Capitalism: Canada, Australia and New Zealand's Relations with Japan* (McGill-Queen's University Press, 2002); *Japan and the Internet Revolution* (Palgrave MacMillan, 2005); and, *Innovation Nation: Science and Technology in 21st Century Japan* (Palgrave MacMillan, fall 2007).

Abstract

The rapid and unprecedented reorientation of the global economy in recent decades has compounded the importance of national competitiveness and innovation strategies. Governments play a critical role in promoting science and technology, as innovation requires a level of investment not easily derived from the private sector. With much of the world's manufacturing shifting to Asia, political support in industrialized countries has moved away from heavy industry in favour of nanotechnology, biotechnology, digital enterprises, and alternative energy solutions. This paper comments on the existing methods of analysing national science and technology policies, and makes an assessment of the innovation strategies adopted by three very different countries – Japan, Canada and Nigeria. In particular, it illustrates how nations at varying stages of development have responded to modern scientific and technology opportunities and challenges. The paper concludes that the widening 'digital divide' requires a significant response from governments and international institutions in order to create greater and more equitable global prosperity.

1. Introduction

National innovation agendas and policies have become commonplace across much of the world. National governments from Finland to Australia and from Singapore to Botswana, promote aggressive plans for the mobilization of scientific and technological capacity and commercialization of scientific and technological developments. In the quarter century after World War II, countries competed through industry, adding manufacturing and processing capacity, using tariff and other regulatory measures to protect and sustain industry and counting on skilled labour and capital intensive enterprises to generate national wealth and international competitiveness. The battleground now has shifted decisively from the shop floor to the laboratory, with growing emphasis on commercialization efforts as a means of ensuring 21st century economic success. For national governments, the 21st century economy belongs to Nokia, Research In Motion and Google, not US Steel, General Motors and Massey Ferguson. In the early years of the 21st century, with much of the world's manufacturing shifting to China and other Asian countries, political emphasis has shifted from heavy industry to nanotechnology, biotechnology, digital enterprises, and alternative energy solutions. A comparative assessment of the approach to innovation in three very different countries – Japan, Canada and Nigeria – illustrates how nations at varying stages of industrial and commercial transformation have responded to 21st century scientific and technology opportunities and challenges.

In the midst of the rapid and unprecedented reorientation of the global economy, debate has arisen about the best means of mobilizing human and financial resources in the interests of national economic success. While politicians wrestle with the public policy implications of the new realities, academics and analysts have been debating the complex issue of national innovation strategies (see Holroyd and Coates, 2007). This lively, engaged and increasingly important field of inquiry speaks to the important intersection between scholarship and public policy relating to economic development. Governments are truly uncertain about how best to proceed in the current environment and, in most instances, understand that profound economic, employment and commercial changes are underway. There is widespread interest in local, regional and national success stories, and a realization that the conjunction of forces, resources and circumstances that created Silicon Valley, the Shannon economic zone in Ireland or the information technology cluster in Waterloo, Ontario, are not easily reproduced in other regions. The contemporary challenge of responding to scientific and technological developments is far from new. Over the past two centuries, major improvements in science, agriculture, communications, transportation, industrial processes, marketing, resource use, and technological innovations have transformed economies and challenged national governments to respond to the threats and opportunities. Such core innovations as universal education originated in efforts to respond to the requirements of the industrial revolution, just as the post-World War II expansion of university systems reflected the needs and aspirations of the Cold War space and arms races.

2. Modes of Analysis

The academic debate about national innovation policies provides an important foundation for considering the efforts of various national governments to ensure that their countries remain internationally competitive and prosperous in the face of rapid economic and political change. Although the pace of contemporary scientific and technological innovation has led commentators to highlight the uniqueness of the current economic transition, economists from Adam Smith and Frederick List (1904) to present day economists at the World Bank (1991) have emphasized the importance of responding to technological change and preparing the population for economic engagement through appropriate education and training.[1]

Scholarship on national innovation expanded dramatically after 1950, in keeping with the growing policy emphasis on the relationship between scientific and technological research and commercial development. Scholars put increasing emphasis on knowledge-driven economic growth, seeking to understand the role that scientific research had on the broader economy. There was interest, as well, on the diversity of national responses to the promise and challenge of scientific innovation, as some countries and regions fell well-behind, others capitalized on wealth and industrial strength to surge ahead and still others sought to catch up to the leading nations through government-led commitments to scientific innovation. As the pace of science-based innovation accelerated, the gap between the leading nations and the developing world has grown steadily wider, generating intense debate about the drivers and actions needed to promote innovation and close the knowledge gap.[2] The importance of the division between technologically rich and poor nations was popularized in the 1990s through the debate about "digital divides," referring to the

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[1] Chris Freeman (2002), assessing the earlier work of Frederick List wrote: “List’s clear recognition of the interdependence of domestic and imported technology and of tangible investment has a decidedly modern ring. He saw too that industry should be linked to the formal institutions of science and of education:

> There scarcely exists a manufacturing business which has no relation of physics, mechanics, chemistry, mathematics or to the art of design, etc. No progress, no new discoveries and inventions can be made in these sciences by which a hundred industries and processes could not be improved or altered. In the manufacturing State, therefore, sciences and arts must necessarily become popular.”

On the crucial role of Christopher Freeman’s work on the study of NIS, see Lundvall (2004).

[2] A significant part of the academic debate revolved around the best means of assessing scientific and technological achievement. For a commentary on the importance of indicators in the field, see Grupp and Mogee (2004).

slow uptake of the Internet in emerging economies and the consequent economic disadvantages that attended this shortcoming (Lu, 2001: 1-4).

Studies of national strategies demonstrated that innovative economic networks involve companies, universities, private sector research groups and government research units. This research demonstrates the manner in which policies, funding, regulatory environments and training systems are mobilized in the interest of national competitiveness and innovation (Furman and Hayes, 2004: 1329-1354; Lundvall, 1992). Research on the importance of scientific facilities, personnel and research programs illustrated that the level of innovation in a particular country is strongly correlated with the number and activities of scientific institutions (Van Looy et al., 2006: 295-310). Furthermore, national governments have over the past twenty years, placed increasing emphasis on universities as engines of scientific and technological development, adding additional economic expectations to the institutions' educational and civil society duties (Etzkowitz and Leydesdorff, 1997; Guston, 2000).

The conjunction of economic circumstances – national investment in social and physical infrastructure, the availability of risk capital, supportive and effective trade and investment policies, access to natural resources, and a culture of commercial and manufacturing innovation – can create environments conducive to economic prosperity, expansion and leadership. This occurred in England in the early to mid-19th century, fueling the dynamic expansion of the British Empire, the United States at the turn of the 20th century, and Japan in the 1960s and 1970s. At other times, as with Europe during the late 19th century and again in the 1980s and East Asia in the same decade, some national governments shared in a period of expansion and growth, usually through the development of extranational policies and approaches which supported rapid economic development (Freeman, 1995: 5-24).

Economists and economic historians have endeavoured to explain national successes and failures over the years, searching for characteristics and policies which set one country apart from others (Gerschenkron, 1962; Perez and Soete, 1988).[3] As Christopher Freeman, whose work on national innovation has been instrumental in defining the field, wrote of subsequent research on successful and flawed national attempts at technological catch-up and innovation,

> All of these accounts emphasize the role of *active policies* at the national and firm level in the import, *improvement* and adaptation of technology as characteristic of successful catch-up. A study of innovation strategies in East Asia, involving a series of countries attempting to catch-up to more economically advanced nations, documented the importance of intellectual property rights and demonstrated that public R&D funding was particularly useful if a country had identified areas of industrial and commercial specialization and devoted that spending to innovation initiatives in those identified areas. (Hu and Mathews, 2005: 1322-1349)

National governments can – by creating the right conditions for investment and development – encourage innovation as a means of expanding economic activity.

In one of the more important studies in the field, Jeffrey Furman and Richard Hayes (2004) examined the experience of

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[3] Gerschenkron developed a theory of latecomer advantages through his study of German and Russian firms. Perez and Soete, focusing on long-term failure rather than success, examined the disadvantages facing economic late comers and explained the difficulties involved in adjusting to and capitalizing on new technologies.

a series of countries and their approaches to industrial innovation. The comparative study of patterns of investment, policy innovation and the training of personnel pointed to specific and important steps governments could take to encourage national economic growth. Furman and Hayes emphasize that policy statements are necessary even vital but, on their own, far from enough to mobilize commercial innovation. Other elements, including sectoral specialization, a national commitment to education and training, and substantial investment in infrastructure, must build upon general policy statements if a country expects to compete internationally. There are few nations in which, at least conceptually, this formulation is not understood.

Debate about the role of governments in promoting innovation touches on one of the central issues in the field of political economy: the matter of the role and effectiveness of governments in shaping national economic activity. For decades, a strong emphasis on Keynesian economics supported the idea that governments could and should play an activist role in managing economic developments and priorities. The neo-liberal revolution, represented intellectually by Milton Friedman and politically by Margaret Thatcher and Ronald Regan, challenged the belief in the efficacy of national leadership and favoured reduced taxes, fewer regulations, limited trade barriers, and the removal of other areas of government interference from the economy. While the free market emphasis has been credited with sparking a period of global economic prosperity, it has also undercut the economic stability of many countries and forced governments to reconsider their role in providing economic leadership and guidance (Devine, 2005: 491-517; Holroyd, 2002).

The nation has been the crucial unit of analysis in determining the strength and success of economic innovation, although recent commentators have challenged the centrality of nation-level comparisons, arguing that regional economies have superseded national systems as the key drivers in commercial transformation.[4] While some, such as Ohmae (1990) argue that the economic influences of globalization have undercut the authority of the state, others point out that national politics, particularly in liberal democracies, interfere with efforts to capitalize on site or region-specific opportunities for commercial synergy or international leadership, forcing greater attention to short-term political considerations in determining national investments. This said, many of the most impressive illustrations of commercial innovation are tied to specific regions and reflect the unique combination of companies, government agencies, universities, and investors in a particular location (DeBresson, 1989; DeBresson and Amesse, 1991). In the end, regional and national innovation strategies are not incompatible. In fact, properly constituted regional innovation initiatives are essential building blocks in the development and implementation of a national policy. Save for the smallest countries, Singapore being the best example in this field, each nation has several or many regions, all with unique strategic advantages and challenges. An appropriate national innovation strategy builds upon a series of region-specific innovation policies (Chung, 2002: 485-91).

Michael Porter's work on cluster development played a key role in sparking intellectual analysis of national economic innovation and its intersection with regional economic development.

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[4] The emphasis on regional GDP has attracted considerable attention of late, in part because of national efforts to identify areas in need of assistance and, on a broader scale, through the European Union's program of supporting less successful economic zones. For a useful Canadian perspective, with an overview of various means and methods of estimating regional GDP, see Lemelin and Mainguy (2005). For an example of global comparisons of regional GDP, using 1999 data, see Demographia: <http://www.demographia.com/db-intlppp-region.htm>. Metropolitan-level data for 2002: <http://www.demographia.com/db-gdp-metro.pdf>.

Porter (1990), who has advised governments from Canada to New Zealand and Japan on adaptations to the new economy, argued that national governments are critical to efforts at economic innovation. He strongly recommended cluster developments, calling on national and regional governments, universities and the private sector to identify commercial niches which capitalized on specific comparative advantages, and to collaborate on the exploitation of associated commercial opportunities.

Regional centres benefit, in particular, from the construction of big science facilities, touted worldwide as the cornerstone of scientific commercialization and national innovation. Synchrotrons (sub-atomic particle accelerators) have been built in many countries, as nations hope to capitalize on research and commercial opportunities in material science, biotechnology, medicine and other fields. Governments provide hundreds of millions of dollars for these facilities, hoping that the pay off in terms of basic research and commercial spin-offs will compensate for the initial investment. As Beise and Stahl (1999) explained:

> Big science installations are the epitome of national innovation strategies, combining sizeable government investment, academic engagement, national and even international collaboration, high expectations for regional economic development, and extensive plans for long-term commercial development. Promoters of these projects speak enthusiastically of the prospect for long-term economic gain and of the preparation of the region and country for global competitiveness.[5]

Governments, of course, cannot complete an innovation strategy on their own. National innovation efforts are designed to

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[5] See also Feller Ailes and Roessner (2002).

feed into the corporate system and encourage commercial transformation, job creation and improved economic performance. Innovation must therefore be a priority for companies as well as countries. Companies that fail to innovate can suddenly find themselves fighting for survival, as the North American automobile industry has discovered in recent years. National investments in basic research are designed to provide the building blocks for product and process developments. Expansion and improvement of educational systems, particularly at the post-secondary level, are intended to ensure that there are researchers, innovators and workers for the expanding and innovating companies. Trade and investment policies seek to attract capital, provide a secure and business-friendly environment for commercial expansion. Without corporations willing and able to accept the challenge of innovation, however, the innovation edifice crumbles almost immediately. Unless companies are available with the capital, entrepreneurial bent and commercial acumen necessary to capitalize on the intellectual and practical discoveries, innovators and their valuable innovations migrate to other regions or countries.[6]

Although evidence from corporate, regional and national innovation efforts strongly suggests that broader, even global networks of knowledge sharing facilitate innovation and economic development, national innovation systems have been slow to expand internationally. There are political imperatives behind such circumstances. Governments fund research programs and facilities, hoping to encourage national scientific and technological accomplishment and commercial spin-offs. Engagement with foreign countries, by definition, runs counter to the nation-centric approach preferred by governments. Scientific and tech-

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[6] As this relates to Japanese firms, see Nonaka and Takeuchi (1995).

nological research being what it is, however, collaborations and partnerships often extend far beyond national boundaries. These researcher-centred networks, in turn, draw in corporations and private research institutes from a variety of countries. The research results are shared internationally through conferences, publications and various collaborative ventures (Carlsson, 2006: 56-67). Some countries, led by Japan, have sponsored extensive international linkages in the interests of capitalizing on the full benefit of national and international investments in scientific infrastructure. In an increasingly globalized commercial environment, where outsourced manufacturing and service operations, foreign branch plants, joint ventures, and long-term delivery contracts have become the norm, Gibbons et al. (1994) suggest that the internationalization of science and technology linkages has become integral to national innovation strategies.

As far as the global implications of this marked shift in economic priorities and planning toward innovation and big science goes, however, there appears to have been little discussion. In the early years of the Internet, politicians and global leaders spoke with concern about the "digital divide" and wondered about the future of the international economy when industrial nations had ready access to the latest communications technologies and developing nations lacked basic connections. Massive investments in Internet connectivity brought digital communications to major cities around the world. Developments in satellite communications and, more significantly, wireless telephony and wireless Internet, eliminated the need for emerging nations to invest heavily in hardwire connections and allowed for the rapid expansion of digital services into hitherto unconnected areas. But there has been little equivalent international conversation about "nano-divides" or "biotech-gaps," despite the now standard assumption that economic prosperity in the coming decades relies heavily on the ability of national economies to replace labour intensive manufacturing activity with high-technology based investments and productivity.

The potential exists, therefore, for successful high technology nations, led by Japan, Finland, Ireland, South Korea, and the United States, to make a successful transition from industrial to high-tech economies while developing and transitional states, having not caught up on the manufacturing and industrial front, fall further behind in a global economy increasingly tied to developments in new technologies. Equally concerning is the potential for gaps to emerge within developing countries themselves. In Africa, for example, the Executive Director of the National Institute for Scientific and Industrial Research in Zambia, Mwananyanda Mbikusita Lewanika (2006), argued that recent proposals to create African centers of scientific excellence "will concentrate development in just a few countries, condemning the rest of the continent to the status quo." Paul Wolfowitz, former president of the World Bank, has been urging developing countries not to ignore the importance of science and technology in reducing poverty. Speaking at a meeting of a large gathering of representatives of government, academia, the private sector and NGOs in February 2007, he said "The amount of resources that poor countries devote to science can't be zero. That would condemn poor countries to backwardness… If you want to tackle poverty, science technology and innovation must be part of the picture" (cited in Dickson, 2007a).

The integration of developing and transitional economies into the highly competitive and fast moving new economy will not be easy. Industrialized countries are investing between 1 and 3 per cent of their GDP into science and technology research. For most developing countries, matching this level of investment, let alone contributing enough to be a significant presence in the field, would be a nearly insurmountable challenge. National governments are making major investments in technological infrastructure (synchrotrons, quantum computing facilities, biotechnology laboratories) and competing aggressively to capture leading talent for academic, government and industrial research facilities. Companies entering these fields require access to large sums of risk capital, in the full knowledge that their products and services have both global markets and large numbers of international competitors. Moreover, and to a degree that most national governments do not yet acknowledge, most of the key scientific developments, particularly those arising from academic research, are not proprietary and can easily shift from the country or region of discovery to a very different location for development and commercialization.

In this environment, developing and transitional economies face formidable challenges. With a few exceptions – India being the best example and with China catching up quickly – these nations lack the financial resources and heritage of scientific and technological development to compete with the wealthier nations. Fundamental infrastructure in elementary and secondary education, secure communications systems, and internationally competitive laboratories is typically very weak. While several have marshalled the resources to invest in major scientific instruments, most lag far behind in basic, let alone advanced, scientific and technological facilities. The innovation gaps are therefore significant and serious. In most developing countries, one or more of the following circumstances prevail: low rates of high school completion, limited university attendance, weak performance in scientific and technological education, insufficient capital for major scientific investments, a prolonged exodus of researchers to the leading industrial nations, an absence of risk capital, inadequate national infrastructure for commercialization, insufficient protection for intellectual property rights, or limited numbers of skilled workers for technology-based manufacturing and processing. In short, developing and transitional nations face fundamental shortcomings in their attempts to create competitive industrial economies; they confront even greater challenges in their efforts to compete in a science and technology-drive economic reality.

Analysis of innovation policies and initiatives shows that national government policies matter, investments in social and physical infrastructure are crucial to commercial success, and corporate innovation contributes a great deal to the prosperity of the nation. Innovation policies and approaches tend to be nation-specific, in that they emerge from and respond to the unique economic, social, cultural and political system of a particular country (Edquist, 1997; Lundvall, 1992; Nelson, 1993). However, in recent years, national governments and academics have placed considerable emphasis on investigating trans-national and transferable policy elements. Governments around the world speak enthusiastically, but without context and understanding, of reproducing the Silicon Valley model in their countries.

Despite the wide-ranging enthusiasm for innovation initiatives, discussion of the lessons and pitfalls of these initiatives has been limited. It is important to know what is happening around the world, to identify the most successful approaches, and to understand the steps taken to ensure that no country is left out completely. The reality, of course, is that scientific and technological innovation has many of the same elements as all other competitive international economic processes, with clear winners and losers, and with huge, even insurmountable, problems for smaller and impoverished countries. The concerns raised by the earlier debate over the digital divide could pale in comparison to those generated by the innovation revolution. A more optimistic scenario would emphasize the rapid repositioning made possible by the development or deployment of scientific or technological implementations that could radically change the economic trajectory of hitherto poor nations.

3. A Three Country Comparison

A brief look at three countries – Japan, Canada and Nigeria – and their approaches to 21st century innovation illustrates some of the differences in starting points, resources, approaches and objectives that characterize national innovation strategies. Japan has one of the largest economies in the world and its 130 million people are almost uniformly well-off. Japan is attempting to keep its world renowned manufacturing sector vibrant and sustainable, adjusting to an aging population (with all of the implications of its changing demographic profile for the labour force, social security, and health care) and addressing the concerns which it shares with the rest of the industrialized world for the environment. Japan's decision to declare itself an "Innovation Nation" came from a need to revitalize itself and strategically determine its future. The Japanese government has supported its strategy with billions of dollars. After a decade, the national authorities declared themselves pleased with the results. As with all such programs, success is defined in specific ways. In this instance, the government drew attention to the growing status and volume of Japanese research results, four Nobel Prizes after 2000, increased technology transfer from universities to corporations, major increases in solar power attributable to newly developed Japanese technologies, a sharp growth in the number of international patents held by Japanese scientists, and very specific advances in key technological areas, including nanotechnology, biotechnology, cancer therapies and regenerative medicine (Japan, 2007; Holroyd and Coates, 2007).

Canada is a wealthy industrialized country, heavily dependent on natural resource but with pockets of cutting edge scientific and technological expertise. Its population is less than a quarter of Japan's but it occupies a land that is many times larger. Canada's challenges include managing its resources (dealing with everything from the devastating impact of pine beetle on the forests of British Columbia to declining fish stocks off both the Atlantic and the Pacific coasts to the volatility of mineral prices), finding ways of adding value to those resources prior to exporting, and the need to balance its resource base with more commercial services (including research and development), manufacturing or scientific industry. The Canadian government has begun to put more money into science and technology and has expressed a desire to be at the top of the world in both its commitment to innovation and the commercialization of science. The scale of the funding Canada has committed to research and development, however, lags well behind competitor nations like Japan.[7]

In contrast to Japan and Canada, Nigeria is extremely poor. Nigeria faces basic challenges that are markedly different from Japan or Canada: feeding and clothing its population, assuring access to clean water and maintaining basic infrastructure. Little has happened so far on the innovation front in sub-Saharan Africa, but academics and consultants are urging countries in Africa to recognize the importance of science and technology innovation in economic planning. Nigeria now has some promising initiatives underway. It lacks, however, the resources for the range and

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7 Canada's investment in research and development hovers under 2 per cent of GDP. Japan's investment, in contrast, has been consistently above 2.5 and has exceeded 3.0 per cent of GDP in recent years. A small number of other nations, including Sweden, Israel and South Korea invest at comparable levels of Japan. The United States usually commits around 2.5 per cent of GDP to the area. Nigeria, like most developing countries, has traditionally devoted a miniscule amount of its small GDP, around 0.1 per cent, to research and development. For additional details, see NationMaster.com: <http://www.nationmaster.com/index.php>. For comparisons among wealthier nations, see OECD, "Main Science and Technology Indicators, December 2006".

scale of projects of Japan or Canada. For Nigeria, as for other emerging nations, analysts agree that being part of global science and technology advances and having an innovation strategy are key to future economic prosperity.

Japan

Since the 1970s, Japan has been recognized internationally as a leader in scientific and technological innovation. This is the country, after all, that spearheaded miniaturization, just-in-time manufacturing, quality circles, and robotics. In the middle of a prolonged recession following Japan's famed "bubble economy" period of expansion, the country's leaders sought a strategy for economic renewal and international competitiveness. Not surprisingly, it committed itself to a national innovation strategy. In 1995, Japan declared it would become an "S&T nation" and enacted the Science and Technology Basic Law, and the first of three Science and Technology Basic Plans. This began a period of broad and deep reforms designed to modernize and revitalize the management and research structure of universities and to encourage greater government-industry-university collaboration. Working closely with industry and regional authorities, the government determined to re-energize the economy over the long-term through a focus on science and technology (Holroyd and Coates, 2007).

The First Science and Technology Basic Plan (FY1996-2000) increased government expenditure on research and development and focussed on the creation of a new R&D system. Total government expenditure exceeded ¥17 trillion (US$155 billion). Competitive research funds were dramatically increased, including support for 10,000 PhD students and post-doctoral fellows, and the promotion of industry-academia-government collaboration began in earnest. In 2001, the Second S&T Basic Plan

(FY2001-2005) highlighted the key objective of promoting and prioritizing basic research. The amount of competitive research funding was doubled and again collaboration was enhanced. Japan announced that it aimed to have 30 Nobel Laureates within the next 50 years. (Japan currently only has about a dozen Nobel Laureates about the same number as Australia while the United States has over 175 and Germany over 90.)

The First and Second Basic Plans sought to solidify the foundation of science and technology in Japan. Public opinion polls, surveys of researchers – particularly female and younger scientists – and international comparisons of R&D funding and academic results were undertaken to determine what Japan required to become an advanced science and technology-oriented nation. In January 2001, the Council for Science and Technology Policy (CSTP) was established within the Cabinet Office. Chaired by the Prime Minister, it is composed of 14 members, including six cabinet members heading ministries closely related to science and technology and seven executive members drawn from industry and academia (Japan, 2007).

The Third S&T Basic Plan, launched in March 2006, called for a total expenditure of 25 trillion yen or annual government R&D spending of about US$40 billion for five years. The plan aims firstly to return the benefits of scientific and technological innovation to society by enhancing the quality of life of its citizens and by commercializing the discoveries that have already been made through earlier R&D investments. The Third Plan focuses on commercialization of technologies and public education about recent discoveries. Its major policy goals are to achieve a quantum leap in R&D, make breakthroughs in advanced science and technology and in sustainable development, develop Japan's reputation as an innovative country and create a healthy aging society with assured security.

Within its overall strategy, the government identified four priority fields: life sciences (including biotechnology), information technology, environmental research and nanotechnology/materials science. Several secondary priorities, including energy, *monozukuri* (manufacturing) technology, scientific and technological infrastructure and frontier science (outer space and oceans) were also identified. The Third Plan continues efforts to promote research among young and female scientists, attract more foreign researchers, spur senior scholars and developers to further action, and strengthen industry-academic-government collaboration. The government also emphasized patents and patent management, the funding of research through competitive grants and maintaining a national system of evaluation.

A cornerstone of Japan's innovation effort was a major reorganization of the Japanese university system which began in 1998. One of the objectives of the reorganization was to encourage greater university-industry collaboration and thus broaden the impact of academic research. This was a lofty ambition – to make the Japanese national universities more responsive, more independent and less like branches of the national government – and the government moved rapidly. Measures such as the Law to Promote the Transfer of University Technologies allowed academic researchers to engage in commercial activities as consultants, researchers, managers and even owners, thus breaking a long-standing formal division between academia and the commercial sector. The initial results have been impressive. Between 1999 and 2005, the number of university start-up companies increased from 28 to over 1,100. University technology licensing offices expanded from 16 in 2000 to 39 in 2005.

The government also began to develop industrial and knowledge clusters. In 2001, the Ministry of Economy, Trade and Industry (METI) launched an industrial clusters initiative, hoping to revitalize regional economies in the process. There are now 17 clusters involving 250 universities and close to 6,100 companies. They range in size from projects like the Shikoku Techno Bridge (300 companies and five universities collaborating in the health, welfare and environmental fields) to the Tokai Project to Create Manufacturing Industry (770 companies and 30 universities). The Ministry of Education, Culture, Sports, Science and Technology (MEXT) launched an Intelligent Clusters Project in 2002, creating 12 groups designed to enhance connections between academic knowledge and industrial development.

Japan has emerged as a world leader in government-led scientific and technological development. Its investment in research is among the highest of the industrialized nations and the leadership provided by national politicians remains impressive. The corporate world, even more importantly, invests heavily in both pure and applied research and has provided world-leading and commercialized products in fields as diverse as photovoltaic cells, nanotechnology, industrial and domestic robots, mobile Internet, and biotechnology. The country's stronger and more consistent economic performance in recent years is due, at least in significant measure, to a pattern of national innovation and the commercialization of science and technology. Perhaps of even greater significance, the country's large investments in pure science and in academic-government-industry partnerships have established a foundation for the hoped for long-term economic transformation and competitiveness.

Canada

Canada is well-known internationally for its impressive endowments in natural resources and has long been viewed as a "hewer of wood and drawer of water." While this image obscures an impressive historical tradition of industrial development in

Ontario and Quebec, the manufacturing base in Canada has long been dependent on extremely strong ties with the United States, particularly in the automotive sector and in the export of natural resources over the past four decades. While the country has made strides in several emerging science and technology-based fields, including information technology, pharmaceuticals and biotechnology, it remains politically and economically dependent on the exploitation of natural resources and the export of raw materials, largely to the United States. Given the uneven nature of the natural resource economy, a much stronger currency, and the recent rapid decline of central Canadian manufacturing due to competition from Asia, national and provincial politicians have been eagerly searching for an alternate foundation for job creation, industrial expansion and sustained prosperity. Like other industrial nations, Canada turned to the innovation agenda.

Beginning in the 1990s, Canada began to demonstrate growing concern about the country's long-term economic prospects, particularly in the area of international competitiveness. Former Prime Minister Jean Chrétien (1993-2003), supported by key ministers Paul Martin and John Manley, made significant commitments to a national innovation program. Mr. Chrétien declared, over-optimistically as it turned out, that Canada would become one of the top five nations in the world in the percentage of GDP devoted to science and technology investment. New programs and a variety of industry-academic partnerships provided several billions of dollars in additional investment, most of it directed to science and technology. As a major report by the Canadian Council of Academies (2006), *The State of Science and Technology in Canada,* recently concluded, "by international standards, Canada is strong in the production of scientific knowledge (journal publications), relatively weak in commercially tangible innovation (patents) and quite dynamic in the early stages of commercialization of inventions arising out of research." The report concluded that Canada was holding its own in the highly competitive work of science and technology R&D but that other countries, including Japan, were investing more heavily and were gaining comparative advantage.

Canada has a comparatively small economy and its investments of hundreds of millions of dollars in scientific infrastructure pale in comparison to the commitments made by Japan, the United States and other nations. Nonetheless, the imperative for Canada is clear. The Canadian Council of Academies (2006) report concluded: "Looking forward – as Canada's population matures – it can be said that innovation and the productivity growth that innovation generates is the only assured and sustainable way to keep Canada's prosperity and quality of life abreast of its peers." Canada invests slightly under 2 per cent of GDP in R&D, and this is due largely to a concerted "catch-up" effort launched by the Chrétien government, mostly in the form of the university and hospital-based Canada Foundation for Innovation, the Canada Research Chairs program, and expanded funding for the Canadian Institutes for Health Research and the National Science and Engineering Research Council. Only once – in 2001 – has Canada's investment in R&D exceeded 2 per cent of GDP. Importantly, the substantial commitment of government funds for scientific and technological research has not been matched by funding from the private sector, leaving Canada with one of the highest levels of government supported research in the world and a less than impressive track record on the corporate side.

In May 2007, the Canadian government launched a new policy entitled *Mobilizing Science and Technology to Canada's Advantage,* its new science and technology strategy. At the launch, Canadian Prime Minister Stephen Harper pointed out that Canada has been lagging behind other G7 nations in commercializing new technologies. He went on to say "No country can remain prosperous and healthy without reinvesting a substantial portion of its wealth in science and technology,… "[It] fuels innovation, sustains good jobs and rising standards of living and underlies improvements in medicine, communications and family life" (Vrbanac, 2007). In this, Prime Minister Harper echoed statements made by governments the world over.

The strategy discusses the need to translate knowledge into commercial applications, position Canada "at the leading edge of important developments that generate health, environmental, societal, and economic benefits," attract highly skilled people to the country and encourage science and technology collaborations across the private and public sectors and the academy. To this end, the government's priorities are to be guided by four core principles: "promoting world-class excellence, focusing on priorities, encouraging partnerships and enhancing accountability." More specifically, tax rates on new business will be lowered to the lowest in the G-7, the private sector will develop and lead new research networks and the government will support large research and commercialization centres in sectors in which Canada has serious potential to achieve world-class results. Sectoral priorities were identified as being environmental science and technologies, natural resources and energy, health and related life sciences and technologies and information and communications technologies.

The Canadian debate about scientific and technological innovation has escalated at an interesting point in the country's history. Unemployment rates have been lower than at any point in 30 years, the value of the Canadian dollar has risen dramatically, national and provincial debt has fallen to among the lowest level in the industrialized world, and several regional economies (Southwest British Columbia, Alberta, Saskatchewan, and parts of Ontario) are expanding rapidly. The areas in greatest economic difficulty, particularly rural and northern Canada and the Maritime provinces, are not known for scientific and technology investments and remain heavily dependent on government transfers. The government and several provincial governments, led by Ontario, supported by a small but vocal scientific and high technology corporate community, are pushing aggressively for additional research and development investment, but in an atmosphere of national economic complacency. Unlike Japan in the mid-1990s, when the country's malaise generated widespread support for new approaches, Canadian political leaders are attempting to redirect the national economy at a time when most Canadians are pleased with the country's economic performance.

Nigeria

Nigeria faces profoundly different challenges than do Japan and Canada. The most populous country in Africa, with a population of close to 140 million, the nation has experienced frequent political upheaval, ethnic tensions, severe environmental problems related to uncontrolled resource development, and serious problems with foreign debt (now largely alleviated). Nigeria, like Canada, has sizeable oil and gas reserves and has the economic potential to break out of the economic distress that has paralyzed sub-Saharan Africa in recent decades. But like its neighbouring countries, Nigeria has suffered through prolonged periods of political turmoil and has struggled to cope with systemic corruption and administrative difficulties. On the standard measures of the foundations for scientific and technological innovation – literacy, high school graduation rates, university attendance, reliable infrastructure, respect for the rule of law and intellectual property rights – Nigeria fares poorly compared to the leading industrial nations.

According to Carlo Petrobelli (2006), an academic and consultant who has written extensively on industry, technology and trade in developing countries,

> the biggest policy gap in Africa is perhaps the lack of official appreciation of how important technology development is to manufacturing growth and competitiveness. Institutional mechanisms for evaluating and setting science and technology priorities are rare – national strategies largely consist of statements of good intent that are over-ambitious and rank low in governments' priorities.

These problems are exacerbated by a lack of scientists. UNESCO estimates that there are about one in ten thousand people. Many Africans who do graduate with engineering or science degrees migrate to other countries (Lewanika, 2006).[8]

However, there are promising developments emerging in Africa, with Nigeria offering an example of the continent's dreams for economic competitiveness. Plans are afoot for a series of African Institutes of Science and Technology (AISTS) – also known as Nelson Mandela Institutes – designed to recruit Africa's best students and scholars to address the problems facing the continent. The first AIST, offering undergraduate and graduate programs and supporting scientific and technological research, is to open in conjunction with Nigeria's Abuja Technology Village, a cluster of research organizations and companies. (The other sites are likely to be in South Africa and Tanzania.) The Nigerian government has already contributed over US$30 million of start-up funding and a large parcel of land near Abuja, the capital of

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[8] According to Algeria's Foreign Minister Mohammed Bedjaoui some 23,000 African university graduates leave the continent each year, contributing to a massive African brain drain that many argue adds to the economic crises (Sawahel, 2006).

Nigeria and a city of close to 1.8 million people. Abuja Technology Village's vision is to cluster research facilities with local and international companies and recreational and housing complexes. Abuja Technology Village is likely to focus on information and communications technology, biotechnology, media technology, multimedia services and medical technology. Also affiliated with the AIST-Abuja campus will be the Gulf of Guinea Institute (G2I). Scheduled to open in the fall of 2008, the G2I will offer teaching and research on science and engineering specific to the oil and gas industries.

Former Nigerian President Olusegun Obasanjo was strongly in favour of science and innovation. In 2001, he launched Nigeria's space program and pledged ongoing financial support to it. The point of the program was not to place a Nigerian on the moon nor develop a space defence program. Rather, the program is "intended to make use of what space research has already established in areas such as remote sensing, weather forecasting and satellite communication" (Raufu, 2003). The government committed an estimated US$13 million to its first remote sensing satellite, Nigerian Earth Observatory Satellite dubbed NigeriaSat-1, which was launched in October 2003. (Foust (2003) notes that the NigeriaSat-1 was cheaper than a traditional satellite which costs more than $300 million but a significant cost for Nigeria with an annual budget in 2003 of about $3 billion and over $30 billion in foreign debt.)

Obasanjo viewed the country's science and technology projects as integral to his agenda for Nigeria's social and economic reform. In 2006, he committed to providing a US$5 billion endowment, drawn from the country's substantial oil revenues, for science and technology research. Obasanjo's plans called for the endowment fund to be supplemented by donations from individuals and corporations. He began the creation of a National

Council for Science and Technology (a Nigerian version of the US National Science Foundation) to distribute the funds and thereby limit the potential for misappropriation (*Nature,* 2006). The National Council was intended to be independent and to provide grants both to individuals and to universities and research organizations on a competitive basis. It would also be responsible for funding research groups and establishing research universities (UNESCO, 2005).

On numerous occasions, former President Obasanjo expressed his determination for Nigeria to become one of the top economies in the world by 2020. To do so, he said, Nigeria absolutely had to invest in science and technology. Nigeria had an impressive endowment of natural resources, but over 70 million of its people lacked access to clean water. The government hoped to use science and technology to tackle the country's various social problems and to diversify the Nigerian economy. Nigeria is in the process of selecting areas of technology on which to focus. As of May 2007, three of these – information technology, biotechnology and space science – have been chosen and work is underway (Dickson, 2007b). The government has also focused on the education system. It is sending science and mathematics kits to hundreds of elementary and secondary schools. Six Nigerian universities have been chosen to be centres of excellence in science and technology (UNESCO, 2006).

In April 2007, Obasanjo's eight year presidential term came to an end. He was replaced by his personally selected successor, Umar Musa Yar'Adua, a former chemistry lecturer. While Nigerian scientists and others hope that President Yar'Adua will continue the science and technology reforms started by his predecessor, concerns over the legitimacy of the election have left many nervous. Yar'Adua's science background and that of his Vice President (Goodluck Ebele Jonathan has a masters degree in hydro and fisheries biology and a doctorate in zoology), are reassuring signs that Yar'Adua's government will continue to work to improve Nigerian science, technology and innovation. In his public statements, Yar'Adua has stated that he will continue Obasanjo's work including the space and satellite programs. In May 2007, Nigeria launched a communications satellite NIGCOMSAT-1 in southwest China. (Nigeria bought the Chinese satellite and launching service rather than developing its own.) The satellite has the potential to "improve e-commerce and government efficiency by promoting the development of the digital economy in the continent" said the Nigerian minister of science and technology, Turner Isoun. The satellite could also improve the business climate and be of value for telemedicine and rural telephony (Adelaja and Scott, 2007). Nigeria has also indicated it hopes to launch more satellites – NIGCOMSAT-2 by 2009 – over the next fifteen years (Babalola, 2007).

Nigeria's range of domestic challenges could well be addressed through the application of science and technology. Major issues include the development of a regular power supply, improved food preservation technologies, decreased maternal and infant mortality, advanced healthcare provision and the provision of clean water. While there are those who question the idea of a poor country investing heavily in high technology, it is important to appreciate the transformative possibilities introduced through innovation. To provide but one example, a 2005 study out of the London Business School concluded that, "an increase of 10 mobile phones per 100 people in African developing countries would increase GDP growth by 0.6%" (Anderson, 2007). Mobile phones, as the report explained, allow farmers to check crop prices online, enable people to make inquiries by phone and even bank online, thus saving days of traveling, and eliminate many of the bribes people are often forced to pay while in transit.

Nigeria faces all of the challenges of the developing world, and struggles to compete internationally while coping with problems of deeply entrenched poverty, political instability, and major health crises. The country has, through its oil and gas reserves, the resources necessary for major scientific and technological investments and is a critical part of a sub-Saharan initiative to stimulate innovation across the region. Unlike Japan and Canada, where the educational, political and legal fundamentals are solidly in place, Nigeria is attempting to create a 21st century economy on top of a very uncertain foundation. That the country is investing heavily in this area, and that it is part of an international effort to stimulate economic growth and diversification through science and technology illustrates the reach and nature of the global innovation movement.

Virtually all countries, from Japan to Nigeria, have expansive plans for scientific and technological innovation. It is important to appreciate, however, the formidable challenge that a nation like Nigeria faces when competing against a middle-tier country, like Canada, let alone a world leader, like Japan. To underpin its commitment to scientific research, the government of Nigeria tripled its budget in the area of science and technology between 1998 and 2004 to about $38 million. While an impressive increase, it obviously pales in comparison to the $30 billion committed annually by Japan to its science and technology innovation agenda.

4. Addressing the Innovation Gap

If trends in innovation continue along the same trajectory, the gap between nations will inevitably grow. The lead established by countries like Japan and the United States will continue. More sector-focused industrialized countries will be competitive in selected fields, like Finland and its communications technology sector. Many countries, even those like Nigeria that are struggling to catch up, may well be left far behind. The amount of money involved in nanotechnology, biotechnology, ubiquitous computing and other large scale scientific research is simply beyond the reach of poorer nations. Contemporary science also works most effectively with international partners; much of the science and technology research of the 21st century is being done collaboratively and across borders. However, such collaborations will likely take place among scientists from a small number of nations, leaving many other countries out of the innovation enterprise.

The obligation for wealthier nations to promote international innovation and to encourage the involvement of scientists from less well-off nations has not been widely debated. But if there is a return to a kind of "nation-first" economic planning model, the potential for an innovation-divide could easily grow dramatically over the coming decades. Perhaps there is a role for an international scientific governance institution that helps ensure access to basic scientific infrastructure and recent discoveries for all countries. The scale and nature of the investment required for such an institution to be successful and to reach effectively into many of the poorer nations would be daunting. Universities and think tanks also play a role in ensuring access to research results, the increasing digitization of material makes sharing information much easier and the current debate about insisting on open access to government-funded research results has the potential to increase the flow of cutting edge scientific and technological developments to scientists the world over. National governments currently spending billions on scientific infrastructure projects, however, are likely to lose enthusiasm for innovation altruism if and when the economic benefits of major research investments are realized in other countries.

Countries face differing challenges as they struggle to decide how best to position themselves in the innovation game. For all of them, however, the development of an innovation agenda remains a challenging undertaking. Governments have to decide how much money to invest in research and development while balancing competing demands for what are seen as limited funds, even in the wealthiest of countries. This decision is made more difficult by the enormous costs of entry into many scientific sectors and the fundamental importance of foundational infrastructure (education systems, laboratories and specialized facilities) to science and technology research. Weak laws on patents and intellectual property can undercut the innovation process dramatically, as can the absence of the venture capital required to bring products to market. There is a particular problem with the mobility of researchers and of knowledge. Discoveries will not always be commercialized where they were first made, thus stripping the supporting country of the anticipated benefits of the scientific investments, and major difficulties remain with the commercialization of science.

Selecting specific scientific sectors for national investment is also difficult and remains part fortune telling, part gambling, part educated decision-making. Scientists generally favour support for pure, curiosity-driven research, with the practical results uncertain and likely to be realized in the long-term. Politicians expect quick results and generally support initiatives with strong commercial potential. Government officials are then forced to identify those sectors which they believe hold the most potential for their particular nation. Few countries have the resources to invest across a broad range of the major science and technology research areas let alone support comprehensive academically-driven investigations. Smaller countries select research areas promising the most relevant and timely return; less wealthy nations focus on fields of investigation promising the greatest benefit for the smallest investment. Nigeria, for example, made its selections – information technology, biotechnology and space –

with the hope that the research and the infrastructure will provide the country with improved prospects. For the governments of poor nations, there is a constant tension between giving money to ameliorate desperate circumstances or trying to build and plan for a better future. The Nigerian government's investments on science and technology have been lauded in some quarters but harshly criticized in others.

Middle-rank countries, like Canada, have their own challenges in determining an appropriate innovation plan. Each of these nations sees science and technology strategies as a way to develop a more competitive and sustainable economy through the commercialization of science. Governments hope that innovation will be a magnet for talented immigrants and will improve the lives of their citizens. But determining sectoral priorities without being sidetracked by political considerations and deciding the kinds of policies and programs that "inspire and assist" their citizens "to perform at world-class levels of scientific and technological excellence" are not easy tasks (Canada, 2007). Even the wealthiest countries, like Japan, have struggled to develop strategies to best position themselves. Japan's efforts over the last decade resulted from the belief that without a strategic plan, substantial long-term funding and stronger links between industry and academia, the country would have little chance of becoming "Innovator Japan."

Poorer and middle-ranked countries face formidable challenges competing with the largest investors in science and technology. Canada, let alone Nigeria, does not have the resources to make the same level of investments as Japan. This means that Canadian investments have to be highly selective and strategic. But limits on national spending do not mean that countries are unable to integrate their activities with the international scientific and technological effort. Connections between individual scientists and laboratories and the leading research facilities can provide researchers and corporations in the developing and mid-tier nations with access to much of the most recent developments in the field. Many international projects welcome participation by researchers from a range of nations even if their governments can contribute little financial support. Basic scientific discoveries save for those in selected and highly proprietal fields, like pharmaceuticals, start in the public domain or move quickly into general circulation. It is indeed possible and extremely important for countries, like Nigeria, to keep abreast of the latest innovations, particularly if specific steps are taken to forge and sustain links between leading research countries and facilities and those in the developing world (Séguin et al., 2006: 1602-3).

The ethical debates that surround much of today's science – everything from stem cells to cloning to the use of the Internet for gambling, pornography and identity theft – also complicate matters. Science knows few boundaries. New discoveries are made and the results widely circulated before many of their implications have been even discussed or fully understood. The prospect of rogue science and technology nations is now very real. These countries, operating in science the way that other nations acted in areas like shipping and offshore banking, can offer unscrupulous scientists opportunities far removed from ethical review panels, intellectual property laws, political oversight of research, and tight environmental controls on research activities. These nations of convenience for scientific research, offering more flexible legal and ethical rules, could easily distort the shape of 21st century science, unleash highly undesirable or disruptive innovations, and undermine the major investments that national governments have made in this area.

The central theme of this working paper – science and technology innovation as a major factor in international political and economic development – brings together several of the major issues in international political economy in the 21st century. This issue highlights the debate about the role of government and state-commerce interaction; few of the major investments in large-scale science can or have been made by the private sector. It emphasizes the continuing discussion about the competitiveness of nations, the global restructuring of manufacturing and the challenges facing industrial nations, as countries the world over struggle to respond to the rise of industrial China and India and seek to maintain current levels of prosperity. The theme emphasizes the growing challenges of raising the economic prospects for emerging nations; those who wondered how the poorest countries would respond to the challenges of freer global trade in manufacturing have difficulty imagining these same states competing in the fields of synchrotron science and nanotechnology. The innovation conundrum draws attention to the impact of the new economy on the global economic order and adds a major agenda item to the debate about appropriate strategies for addressing the social, environmental, and economic needs of the world. Moreover, the changing pace of innovation and the increasing difficulty in determining the likely commercial outcome of innovation investments clearly presents national and regional governments with perplexing choices as they endeavour to support and create competitive economies. Even as governments are pressed to increase their commitment to the area, it is too early to determine the benefits of the investment in the science and technology, let alone the commercialization of research results.

Future research is required on the international and political dimensions of national innovation strategies. Scientific and technological innovation is no longer a matter for scientists, companies or universities but has, instead, become a cornerstone of the debate about the prosperity of nations. The widely held belief that innovation is essential for countries to become or remain competitive has been largely untested but many of the recent developments in scientific and technological infrastructure remain to be realized in commercial and economic terms. Nonetheless, there is a strong international consensus that innovation is the single most important element in the emerging global economic contest. Charting this global debate, and looking specifically at the efforts to draw emerging economies into the innovation enterprise, holds significant potential as a field of inquiry. In the frenetic and uncertain conditions of the early 21st century, with massive scientific and technological transfor-mations looming in the near future, politicians and government officials are right to be concerned with such issues as productivity, scientific innovation, and related competitive conditions. Countries that fall behind, research has shown, face formidable challenges in attempting to catch-up. The cost of failure could well be substantial indeed. The national foundations and support for scientific and technological innovation are, to the 21st century, what manufacturing capacity and access to natural resources were in the 19th and 20th centuries. Defining the innovation dilemma and documenting the innovation divide promise to be important elements in understanding the shape of international governance, national policy-making, and the economic prospects for nations in the coming decades.

Works Cited

Adelaja, Abiose and Christina Scott (2007). "Satellite launches boost African communications," *SciDevNet,* 18 May.

Anderson, Tatum (2007). *BBC News,* 19 February.

Babalola, Semiu (2007)."In with the new: Nigeria's 'science' president," *SciDevNet,* May 29.

Beise, M. and H. Stahl (1999). "Public research and industrial innovations in Germany," *Research Policy,* vol. 28, no. 4 (April): 397-422.

Canada (2007)."Mobilizing Science and Technology to Canada's Advantage." Ottawa: Industry Canada. Available at: <http://www.ic.gc.ca/cmb/welcomeic.nsf/vRTF/PublicationST/$file/S&Tstrategy.pdf>

Carlsson, Bo (2006). "Internationalization of innovation systems: A survey of the literature," *Research Policy,* vol. 35, no. 1 (January): 56-67.

Chung, S. (2002). "Building a national innovation system through regional innovation systems," *Technovation,* vol. 22, no. 8 (August): 485-91.

Council of Canadian Academies (2006). *The State of Science and Technology in Canada.* Ottawa: Council of Canadian Academies.

DeBresson, Chris (1989). "Breeding Innovation Clusters: A Source of Dynamic Development," *World Development,* vol. 17, no. 1: 1-6.

DeBresson Chris and Fernand Amesse (1991). "Networks of Innovators: A Review and Introduction to the Issue," *Research Policy,* vol. 20, no. 5 (October): 363-79.

Devine, Sean (2005)."The Viable Systems Model Applied to a National System of Innovation to Inform Policy Development," *Systematic Practice and Action Research,* vol. 18, no. 5 (October): 491-517.

Dickson, David (2007a). "Invest in science, says World Bank president," *SciDevNet,* 16 February.

______ (2007b). "Science Needs Democracy to Thrive," *SciDevNet,* 2 May.

Edquist, C. ed. (1997). *Systems of Innovation: Technologies, Institutions and Organizations.* London: Pinter Publishers.

Etzkowitz, H. and L. Leydesdorff, eds. (1997). *Universities in the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations.* London: Pinter Publishers.

Feller, Irwin, Catherine P. Ailes, and J. David Roessner (2002). "Impacts of research universities on technological innovation in industry: evidence from engineering research centers," *Research Policy,* vol. 31, no. 3 (March): 457-74.

Foust, Jeff (2003)."Space technology and the developing world," *The Space Review,* no. 27 (October).

Freeman, Christopher (1995). "National Innovation Systems in historical perspective," *Cambridge Journal of Economics,* vol. 19, no. 1 (February): 5-24.

______ (2002). "Continental, national and sub-national innovation systems - complementarity and economic growth," *Research Policy,* vol. 31, no. 2 (February): 191-211.

Furman, Jeffrey and Richard Hayes (2004). "Catching up or standing still? National innovative productivity among 'follower" countries, 1978-1999," *Research Policy,* vol. 33, no. 9 (November): 1329-54.

Gerschenkron, Alexander (1962). *Economic Backwardness in Historical Perspective.* Cambridge: Harvard University Press.

Gibbons, Michael, et al., eds (1994). *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies.* London: Sage Publications.

Grupp, Hariolf, and Mary Ellen Mogee (2004). "Indicators for national science and technology policy: how robust are composite indicators," *Research Policy,* vol. 33, no. 9 (November): 1373-84.

Guston, David H. (2000). *Between Politics and Science: Assuring the Integrity and Productivity of Research.* New York: Cambridge University Press.

Holroyd, Carin (2002). *Government, International Trade and Laissez Faire Capitalism: Canada, Australia and New Zealand's Relations with Japan.* Montreal: McGill-Queen's University Press.

______ and Ken Coates, (2007). *Innovation Nation: Science and Technology in 21st Century Japan.* London: Palgrave Macmillan.

Hu, M. and J. Mathews, (2005)."National innovative capacity in East Asia," *Research Policy,* 34: 1322-49.

Japan (2002). *Third Basic Science and Technology Basic Plan.* Tokyo: Cabinet Office, March.

______ (2007). "Council for Science and Technology Policy," *Bureau of Science and Technology Policy.* Tokyo: Cabinet Office. Available at: <http://www8.cao.go.jp/cstp/english/about/administration.html>

Lemelin, André and Pierre Mainguy, (2005). *Estimating regional gross domestic product (RGDP), 1997-2000.* Quebec City: Institute de la statistique de Quebec.

Lewanika, Mwananyanda Mbikusita (2006). "Centres of excellence: not ideal for African science," *SciDevNet,* 13 December.

List, Friedrich (1904). *The National System of Political Economy,* original 1841. London: Longman.

Lundvall, Bengt-Ake. (1992). *National Innovation Systems: Towards a Theory of Innovation and Interactive Learning.* London: Pinter Publishers.

______ (2004). "Introduction to 'Technological infrastructure and international competitiveness by Christopher Freeman," *Industrial and Corporate Change,* vol. 13, no. 3 (March): 531-9.

Lu, Ming-te (2001)."Digital divide in developing countries," *Journal of Global Information Technology Management.* vol. 4, no. 3: 1-4.

Nature (2006). "A Foundation for Africa," Editorial, vol. 442, no. 7102 (3 August): 486.

Nelson, Richard R.., ed. (1993). *National Innovation Systems: A Comparative Analysis.* Oxford: Oxford University Press.

Nonaka, Ikujiro, and Hirotaka Takeuchi (1995). *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation.* New York: Oxford University Press.

Ohmae, Kenichi (1990). *The Borderless World Power and Strategy in the Interlinked Economy.* New York: Harper Business.

Perez, C. and L. Soete (1988). "Catching up in technology: entry barriers and windows of opportunity," in G. Diso et al., eds. *Technical Change and Economic Theory.* New York: Pinter Publishers, 458-79.

Pietrobelli, Carlo (2006)."Fostering Technological capabilities in sub-Saharan Africa," *SciDevNet,* November.

Porter, Michael E. (1990). *The Competitive Advantage of Nations.* New York: Free Press.

Raufu, Abiodun (2003)."Nigeria to Go Up, Up and Away," *IslamOnline.net,* 7 August.

Sawahelm, Wagdt (2006). "Konare says Western immigration policies are harming Africa," *SciDevNet,* 5 April.

Séguin, Béatrice, Peter A. Singer and Abdallah S. Daar (2006). "Scientific Diasporas," *Science,* vol. 312, no. 5780 (16 June): 1602-3.

UNESCO (2005). "Nigerian President pledges US$5 billion towards National Science Foundation," Press Release, Science Policy and Sustainable Development, 23 May. Available online: <http://www.unesco.org/science/psd/focus/iab.shtml>

______ (2006). "Director-General Opens the Inaugural Meeting of the Nigerian Science and Technology Education Funds Mobilizing Committee," Press Release, Office of the UNESCO Director General, 16 May.

Van Looy, B. and K. Debackere, et al. (2006). "Scientific capabilities and technological performance of national innovation systems: An exploration of emerging industrial relevant research domains," *Scientometrics,* vol. 66. no. 2: 295-310.

Vrbanac, Bob (2007). "Prime Minister Launches New Technology Strategy in Waterloo," *Waterloo Chronicle,* 23 May.

World Bank (1991). *World Development Report,* 1991. New York: Oxford University Press.

Internet Resources

Demographia
<http://www.demographia.com>

NationMaster.com
<http://www.nationmaster.com/index.php>

OECD - Main Science and Technology Indicators, December 2006 <http://www.oecd.org/dataoecd/49/45/24236156.pdf>

SciDevNet
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