Indicators of Technology-based Competitiveness: Incorporating Recent Changes in the Concept, "High-technology," and in Data Availability

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Chapter I
Introduction and Overview

Between 1988 and 1994, under a series of projects supported by the National Science Foundation, the principal authors of this report and their colleagues and students investigated the feasibility of a set of country-level indicators of international competitiveness in high-technology industries, developed such a set, and tested their reliability and validity. This stream of research first resulted in a 1991 report to NSF that described the theoretical basis for the indicators, a set of proposed composite indicators, and the results of applying these indicators to a set of 29 countries (Porter and Roessner, 1991). The promising results of this award led to a second project that developed the indicators further and, most importantly, exposed them to a set of reliability and validity tests. This project resulted in a 1995 report (Roessner, Porter, Newman, and Cauffiel, 1995), that detailed the work on the validity and reliability of a set of indicators that were developed during the project, and recommended a set of indicators that could be used in further analytical work as well as tested for use in the National Science Board's *Science & Engineering Indicators.*

The value of these indicators is evidenced by their affirmation and use by both policy and research communities. The data developed by the second project just described appeared in the 1993 volume of *Science & Engineering Indicators*, and made an important contribution to the 1995 special SRS publication, *Asia's New High-Tech Competitors* (NSF 95-309). Under a 1995 NSF purchase order, a time series of indicators based on the 1993 results was begun, resulting in a comparable data set for 1996 and 1999. Meanwhile, the results of the most recent work have been presented to a wide variety of professional audiences and have been published in several scholarly journals (Porter, et al., 1996; Roessner, et al., 1996). Our continuing review of the literature on technology-based growth in newly industrialized and industrializing countries also affirms the validity of the theoretical basis on which the indicators were originally developed. For example, the work of Michael Porter (1990), Rosenberg, Landau, and Mowery (1992), Nelson and his colleagues (Nelson, 1993), and, especially, the comprehensive review and synthesis by Mathews (1996) expand and detail the conclusions upon which our original concepts were based, adding additional empirical results since the mid-1980s, but provided little rationale for altering our original model.

This report describes the results of work intended to further advance our investigations, as well as complement the ongoing process of periodic indicator data collection and reporting. The project was begun in the fall of 1999 and proceeded in several complementary directions. Specifically, the project addressed the following tasks:

- Explore ways of including non-manufacturing industries in the definition of “high tech” and in lead indicators (Chapter II).
- Explore ways of including emerging/leading edge technologies in the definition of “high tech” and in lead indicators (Chapter III).
- Examine the feasibility and value of incorporating patent data in the lead indicators (Chapter IV).

- Conduct a variety of analyses to test existing indicators for sensitivity to different weights attached to survey vs. statistical data; sensitivity of indicator values to changes in the composition of the expert panel; predictive power of lead indicators over nine years (1990-1999) (Chapter V).
- Set up a web-based data entry and analysis system for developing survey data (Chapter VII).
- Recommend changes in indicator formulation based on the results of the above tasks (final section of each chapter).

This report presents the results of these tasks. The report is organized into chapters, each of which is devoted to a different task or subtask, and authored by a single member of the project team (with input from the others). In several instances, as indicated, these chapters have been submitted and/or accepted for publication in professional journals. An additional chapter (Chapter VI) discusses the concept of social capital and its potential use in future indicators of national competitiveness.

Publications Associated with this Study

The following publications have been developed by HTI staff working on this study. Each draws fully or significantly on the work done under the NSF grant that supported this work.

Alan L. Porter, J. David Roessner, Xiao-Yin Jin, and Nils C. Newman, "Changes in National Technological Competitiveness: 1990-93-96-99," accepted for publication by *Technology Analysis & Strategic Management.*

J. David Roessner, Alan L. Porter, Nils C. Newman, and Xiao-Yin Jin, "A Comparison of Recent Assessments of the High-Tech Competitiveness of Nations," accepted for publication in *International Journal of Technology Management.*

Alan L. Porter, J. David Roessner, Xiao-Yin Jin, Nils C. Newman, "Measuring National 'Emerging Technology' Capabilities," submitted to *Science and Public Policy*.

References

Mathews, J. "High-technology Industrialisation in East Asia," *Journal of Industry Studies*, vol. 3, no. 2 (December 1996): 1-78.

Nelson, R.R., ed. *National Innovation Systems: A Comparative Analysis*. New York: Oxford, 1993

Porter, A.L., and Roessner, J.D. *Indicators of National Competitiveness in High-technology Industries.* Final Project Report to the Science Indicators Studies Group, National Science Foundation, May 1991.

Porter, Alan, David Roessner, Nils Newman, and David Cauffiel, "Indicators of High-Tech Competitiveness of 28 Countries, " *International Journal of 'Technology Management*, **12**, 1 (1996): 1-32.

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

Roessner, J.D., Porter, A.L., Newman, N.C., and Cauffiel, D., *Implementation and Further Analysis of Indicators of Technology-Based Competitiveness: Final Report*; also Executive Summary, Technology Policy and Assessment Center, Georgia Tech, Atlanta, 1995.

Roessner, David, Alan Porter, Nils Newman, and David Cauffiel, "Anticipating the Future High-Tech Competitiveness of Nations: Indicators for Twenty-Eight Countries," *Technological Forecasting and Social Change*, **51**, 1 (January 1996): 133-149.

Rosenberg, N., Landau, R., and Mowery, D., "Introduction," in Rosenberg, Landau, and Mowery, eds., *Technology and the Wealth of Nations*, Stanford: Stanford University Press, 1992.

Chapter II
Including Non-manufacturing Industries in the Definition of “High Tech” and in Lead Indicators

by
David Roessner

Alternatives to DOC3 Definition of High-Tech Competitiveness

As yet, there is no officially sanctioned international definition of "high-tech" industries or products (OECD, 1992; *Science and Engineering Indicators*, 1998: chapter 6; Guerrieri and Milana, 1996; Grupp, 1995; Sirilli, 1997). Both the OECD and the U.S. Department of Commerce use the industry approach, in which high-tech is defined basically as the R&D intensity of the industry as measured by R&D to sales, production, or value added ratios.

OECD separates industries into high-, medium-, and low-tech categories as described in OECD (1986). Using 1980 data, OECD established their definition in 1986. A review was conducted in 1992 and the rankings remained unchanged. The six high-tech industries are:

Industry	SITC
Aircraft (aerospace)	3845
Office & computing equipment	3825
Communications equipment	3832
Drugs and medicines	3522
Scientific instruments	385
Electrical machinery	383 exc. 3832

This is similar to, but more restrictive than, DOC3, which includes space technologies and ordnance as high-tech industries, and is very close to the definition we have used consistently in our indicator work.

OECD's 1992 report notes that further work will allow industries to be divided according to their technology content, taking into consideration the direct investment in R&D but also the indirect acquisition of domestic results incorporated in: intermediate consumption, capital goods, and results of foreign R&D incorporated in imported goods. All these technology inputs must be estimated econometrically using input-output matrices (OECD, 1992: 300).

Recently several analysts have developed and/or employed alternatives to these industry-based definitions of high-technology. Guerrieri and Milana (1996), for example, note that "high-technology trade" can be defined and quantified in several ways. They describe two broad sets of measures: (1) indicators of technological inputs such as R&D to sales ratio or ratio of S&E to regular employees; high-tech industries are all those sectors characterized by ratio higher than a given threshold value. All traded products included in these industries are classified as high-tech, and this is the approach used by OECD and the U.S. Commerce Department. A second approach uses more detailed product data and relies upon evaluation of industry experts to determine the technological content of the various products. Analysts judgments are then used to determine whether a product is high-tech (Abbott, 1991). The industry method uses objective criteria, but its high level of aggregation leads it to assume that all products falling within a high-tech industry are high-tech, which is demonstrably not the case. The second, product-based method is more accurate because it is based on a list of individual products, yet it relies entirely on subjective judgment. Guerrieri and Milana use an intermediate classification system of the two alternative methods. First they define high-tech industries as those with R&D to sales ratios higher than 4% (following OECD 1985). Then they associate with each high-tech industry thus defined a list of traded products defined at the five-digit SITC code level. Finally, they asked a group of experts and analysts to determine the actual technological content of the individual products associated with high tech industries. Then data on imports and exports of high-tech products were aggregated using the SIE World Trade Data Base and UN trade statistics (Guerrieri and Milana, 1996: 228). Product-based definitions of high-technology offer some advantages, but these are offset by the cost and reduced reliability of relying on expert panels. Still, there may be other alternatives, and some modifications of the product-based approach might offer promise.

Including Non-manufacturing Industries

NSF's periodic surveys of industrial R&D performers (conducted by the Census bureau) were redesigned in 1992 to increase firm sample size and update industry classifications. The new method "better reflects the widening population of R&D performers among firms in non-manufacturing industries and small firms in all industries" (U.S. National Science Foundation, 1996: 48). This resulted in a revision upward of 14% in industry R&D performance for 1991 ($14.7B), of which $11.7B of the $13.7 B increase stemming from the enlarged sample design was reported for non-manufacturing industries. The 1996 report cited above observes that listing all services together, while providing finer classification of manufacturing, is archaic. Moreover, it reiterates the well-known point that R&D expenditures do not capture the utilization of new technology. Finally, the report points out that the relative quantity of R&D measured for services, in comparison to manufactures, is dependent on how R&D is defined. NSF expanded its coverage of the non-manufacturing sector in its surveys; consequently, non-manufacturing firms as a group comprised approximately 25% of the total industrial R&D performance in 1994 compared with an estimated 11% share in 1988.

Sirilli (1997) discusses the Oslo manual and the latest CIS[1] survey using the manual as basis for survey design. The Oslo manual was revised in 1996; one change was to orient data collection to increasingly knowledge-based characteristics of technology and innovation. In particular, services were explicitly targeted for investigation in these innovation surveys. "This implies some revisions in the definition of technological innovation and innovation activities so as to make them applicable both to manufacturing and service firms" (Sirilli, 1997: 288). Archibugi and Pianta (1996) call specifically for an expanded definition of high-technology:

[1] The CIS is the EU-sponsored Community Innovation Survey, first carried out in 1993-94. It is a survey of firms, not innovations.

> "While most efforts so far have been confined to the manufacturing industry, the CIS survey is now being tested for the inclusion of service industries, which are major users of innovations, namely information technology. Here, the very concept of technological innovation has to be clarified, and progress must also be made on the criteria for the classification of service activities."

They note also that software represents a major area of innovation across manufacturing and service industries, but presents a particular problem because it is covered by copyright rather than patent protection (Archibugi and Pianta, 1996: 464).

HTI "output" indicators (TS, TE, RTC) are export-based measures of current competitiveness. Industries included in these measures are based on the DOC3 definition, and are confined to manufacturing only. As industrialized economies and some of the newly-industrializing nations evolve, service industries represent a growing proportion of GDP. In the U.S., the service sector's share of GDP grew from 49 percent in 1959 to 64 percent in 1997. This growth has been driven largely by "knowledge-intensive" services that incorporate science, engineering, and technology in the services or their delivery: communication services, financial services, business services, educational services, and health services. In the U.S., these industries grew at 4.6 percent annually during 1980-97, compared with 5.1 percent annually for high-tech manufacturing (*S&E Indicators*, 2000: 7-6).

A majority of the R&D activity in service industries in the U.S. seems to be related to information technology. NSF data suggest that a lower-bound estimate is that 49.7 percent of service sector R&D is by communications services and computer-related services firms. Further, in 1991, 82.6 percent of U.S. total investment in IT hardware was by private service sector industries (Leech, et al., 1998: 17-21). Service industries in the UK and other advanced nations of Europe also account for large proportions of total national investment in IT (Evangelista, Sirilli, and Smith, 1998: 5).

Miles (1994) classifies information services by industry and market, as follows:

Market	Industry
State	General government, broadcasting
Consumer	Entertainment
Mixed	Real estate, telecommunications, banking, insurance, legal services
Producer	Engineering and architecture services, accountancy, miscellaneous, professional services

These industries are major users of information technology. Miles concludes that some of these services are at the forefront of innovation, and the new IT-based services such as software and telecommunications are triggers to innovation across the economy rather than passive recipients of innovation from manufacturing (Miles, 1994: 252). OECD (1999: 18) defines knowledge-based industries as those that are relatively intensive in their inputs of technology and/or human capital. Alic (1994) also argues that knowledge-based services are critical to the foundation and infrastructure that undergird the production of high-value-added manufactured goods.

Thus, a strong case can be made that any definition of competitiveness in high-tech industries should include selected non-manufacturing industries and, in particular, service industries that can be characterized as knowledge-intensive. Two questions arise:

- How should high-tech service industries be defined operationally so that reliable data covering a sufficient range of countries are available?
- How should national activities related to high-tech, non-manufacturing industries be incorporated into the Georgia Tech model of high-tech competitiveness?

We consider the first question first.

Defining High-Tech Services

World Bank, World Development Indicators 2000.

World Development Indicators 2000 provides data for all HTI countries on commercial service imports and exports. Data are provided for 1980 and 1998, in millions of dollars and percent of total services for three categories of commercial services: transport services, travel services, and other commercial services. *Commercial service*s imports/exports are total services imports/exports minus imports/exports of government services not included elsewhere. The three components of commercial services are defined as follows:

Transport covers all transport services performed by residents of one economy for those of another and involving the carriage of passengers, freight, etc.

Travel covers goods and services acquired from an economy by travelers

Other commercial services include such activities as insurance and financial services, international telecommunications, and postal and courier services; computer data; news-related service transactions between residents and nonresidents; construction services; royalties and license fees; miscellaneous business, professional, and technical services; and personal, cultural, and recreational services (World Bank, 2000: 209, 213).

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Given the above discussion of the nature of knowledge-intensive services, it would appear that the most relevant category of commercial services for incorporation into the HTI model would be other commercial services, since it includes most of those services mentioned as particularly knowledge-intensive. The following table lists, for all HTI countries except Taiwan, total commercial service exports, other commercial exports as a percentage of total commercial exports, and dollar value of other commercial exports. The face validity of these export data, indicated by the ranking of HTI countries, seems sufficiently high to warrant further investigation of inclusion of these exports in the definition of high tech exports used for TS, TE, and RTC.

	Commercial service exports 1998

COUNTRY	Total, $Million	"other" commercial exports (%)	"other" commercial exports ($M)
USA	239957	46.3	111100
JAPAN	61795	59.5	36768
GERMANY	78903	53.4	42134
UNITED KINGDOM	97616	55.9	54567
FRANCE	84627	40.5	34274
NETHERLANDS	51633	47	24268
ITALY	66621	39.3	26182
SWITZERLAND	25795	58.1	14987
SWEDEN	17675	49.3	8714
SPAIN	48729	23.8	11598
IRELAND	6586	42.7	2812
CANADA	30281	49.5	14989
AUSTRALIA	15812	26.6	4206
SOUTH AFRICA	5109	25.2	1287
NEW ZEALAND	3651	17.8	650
RUSSIA	12937	25.2	3260
POLAND	10890	34.2	3724
HUNGARY	4870	35.3	1719
CZECH REPUBLIC	7366	30.3	2232
SINGAPORE	18243	50.4	9194
SOUTH KOREA	23843	32.3	7701
TAIWAN			
MALAYSIA	10690	55.8	5965
CHINA	34171	40.8	13942
THAILAND	13074	32.3	4223
INDONESIA	4340	2	87
PHILIPPINES	7465	76.7	5726
INDIA	11067	57.3	6341
MEXICO	11937	21.8	2602
BRAZIL	7083	55.1	3903
ARGENTINA	4507	9.1	410
VENEZUELA	1297	4.5	58
ISRAEL	8980	47.1	4230

OECD Science, Technology and Industry Scoreboard 1999: Benchmarking Knowledge-based Economies.

OECD (1999) includes several categories of service industries in their definition of "knowledge-intensive" industries. In addition to the usual manufacturing industries, they include the following ISIC Rev. 2 service classifications:

Div 72: communications
Div 8: finance, insurance, real estate and business services
Div 9: community, social and personal services.

The 1999 Scoreboard provides data on real value added in these industries, 1987 through 1996, for the OECD member countries, Mexico, and South Korea. If such data were available for all HTI countries they would offer a promising additional or substitute component of a lead indicator such as PC. Also, national exports in these ISIC code classifications could be added to existing manufacturing exports in ISIC classifications used in current HTI high tech output indicators.

WEFA

WEFA, formerly Wharton Econometric Forecasting Associates (www.wefa.com), has assembled industry and trade data for 68 countries over the period 1980-1997. Using data from UNIDO, UN SNA, Statistics Canada, OECD, and individual country sources, WEFA provides national production and trade data (measured in millions of 1997 U.S. dollars) for five knowledge-based (high-tech) service industries: communication services, financial institutions, business services, educational services, and health services. The production data could be used to supplement manufacturing data production figures in the lead indicator, PC, and the export data could be used to supplement the existing manufacturing-based definition of high tech exports used in previous HTI analyses.

The WEFA data that we could obtain from S&E Indicators 2000 and from staff at NSF, which has a subscription to WEFA data, suggest some strengths and weaknesses. WEFA production and trade data cover 68 countries, although we do not know whether that includes all the HTI countries. The data are historical, with data going back to 1980, at least for the countries reported in Indicators and from NSF. They are continually updated by WEFA, including filling in gaps with estimates and revisions based on changes in inputs from each country source and on changes in WEFA's macroeconomic model, which is the basis for their industry-level data. Still, there are large differences from year to year, even on a country such as the U.S. whose sources one would think would be pretty solid. For example, the NSF WEFA table shows U.S. production in 1997 for all high-tech service industries as $3,301,798.8; S&E Indicators Table 7-5 shows U.S. 1997 for 5 knowledge-based industries (same 5 industries as the NSF table) as $2,062,145.4. In contrast, the difference for Canada is nowhere near that large ($186,770 vs. $144,591). This is a potentially promising source, though, and should be explored in greater depth.

Incorporating High-Tech Services into the HTI Model

The significance of growth and innovation in non-manufacturing industries for competitiveness could show up in both lead indicators as well as indicators of current competitiveness. Given the high-tech export basis for our measures of current competitiveness, it makes sense to consider expanding the industries included in the definition of high-tech to include knowledge-intensive services. This could be accomplished readily using available data as discussed in the previous section, and past HTI data could be updated using UN export data and the SITC codes identified by OECD. Alternatively, if export data are available at reasonable cost from WEFA (or at no cost from NSF), the value of total exports for five knowledge-intensive service industries could be added to the UN export data. Finally, the World Bank's data on "other commercial exports" could be used. A next step would be to assemble and compare data from these three sources and compare their accessibility, reliability, country coverage, and availability for each of the previous HTI data years (1990, 93, 96).

Current HTI lead indicators incorporate data on national production of EDP equipment as one dimension of productive capacity, PC. Conceptually, the idea is that productive capacity precedes exports and in that sense production of EDP precedes conversion of some proportion of production into exports, thus enhancing high-tech competitiveness. Production of knowledge-based services, as measured by WEFA, could serve as the non-manufacturing analog of EDP production, an industry whose output enhances innovation and productivity in many other key industries in the economy. If WEFA data were the only source of production information for knowledge-based services for HTI countries, for purposes of consistency it might be desirable to use the same source for export data used to enhance HTI output indicators.

References

Abbott, Thomas A. "Measuring High-technology Trade: Contrasting International Trade Administration and Bureau of Census Methodologies and Results," *Journal of Economic and Social Measurement*, vol. 17 (1991):17-44.

Alic, J.A. "Technology in the Service Industries," *International Journal of Technology Management*, **9**, 1 (1994): 1-14.

Archibugi, Daniele, and Mario Pianta, "Measuring Technological Change through Patents and Innovation Surveys," *Technovation*, 16 (9) (1996): 451-468.

Evangelista, Sirilli, G., and Smith, "Measuring Innovation in the Services," IDEA paper No. 6, the STEP Group, 1998.

Grupp, H. "Science, High-technology and the Competitiveness of EU Countries." Cambridge Journal of Economics, vol. 19 (1995): 209-223.

Guerrieri, P. and Milana, C. "Changes and Trends in the World Trade in High-Technology Products." *Cambridge Journal of Economics*, vol. 19 (1995): 225-242.

Leech, David P., Link, Albert N., Scott, John T., and Reed, Leon S. *The Economics of a Technology-based Service Sector*. Arlington, VA: TASC, Inc., January 1998. Planning report for the National Institute of Standards and Technology, Program Office, Strategic Planning and Economic Analysis Group.

Miles, I. "Innovation in Services," in M. Dodgson and R. Rothwell, The *Handbook of Industrial Innovation*. Brookfield, VT: Edward Elgar, 1994.

National Science Board, *Science and Engineering Indicators 2000*. Arlington, VA: National Science Foundation, NSB-00-1

OECD, *Science, Technology and Industry Scoreboard 1999: Benchmarking Knowledge-based Economies*. Paris: OECD, 1999. http://www.oecd.org/dsti/sti/stat-ana/prod/scorebd_summ.htm

OECD, *Patent Data as Science and Technology Indicators: Using and Interpreting Patent Data in Practice*. Paris: OECD, DSTI/STIIUSTP/NESTL (92)2, 1992.

Sirilli, Giorgio. "Science and Technology Indicators: The State of the Art and Prospects for the Future." in Gilberto Antonelli and Nicola De Liso, eds. *Economics of Structural and Technological Change*. New York: Routledge, 1997.

U.S. National Science Foundation. *National Patterns of R&D Resources: 1991*. Washington, DC: National Science Foundation, NSF 96-333.

World Bank, *World Development Indicators 2000*.
http://www.worldbank.org/data/wdi2000/index.ht

Chapter III
Incorporating Emerging or Leading-Edge Technologies[2]

by
Alan Porter

Given the rapid rate at which technological change can occur, the incorporation of industries or product groups into the high-tech category based on their current standing (e.g., R&D to sales ratio) may reduce, for our purposes, the predictive value of indicators so based. Thus we propose to explore various ways of defining and incorporating what might be termed emerging or leading edge technologies into our lead or input indicator set. Leading edge technologies are those that show strong promise of becoming major contributors to the competitive position of nations, but as yet have not been fully developed. Examples might include microelectronic-mechanical systems, genetic engineering, and metallocene catalysts.

In one recent effort to distinguish such a category of products, Grupp (1995) developed a table that lists R&D-intensive product groups in two categories: leading-edge and high-level. For each product group, the type(s) of government intervention typically associated with that product group for EU member countries is noted. High-tech is all products with R&D intensities above the industry average of about 3.5% of sales. The leading edge is derived from a frequency analysis of R&D intensities and allocated at 8.5% of sales. Bibliometric data on science production were assigned by the affiliation of the first author. Patent indicators were assigned by residence of first inventor. Grupp used the Science Citation Index for natural sciences, engineering, and medical technology. He found that the correlation between production of science and engineering publications and trade success in leading-edge technology was significant, but there was no significant correlation with high-level products. Grupp then went on to analyze citation rates. He found a significant correlation between citation rates and trade success in leading edge products, and for high level products as well. "Whenever the publications of a specific country are cited frequently then the cited country is more successful in foreign trade in high-technology" (Grupp, 1995: 218). Grupp's approach is of course subject to the weaknesses of existing industrv-based definitions that rely on highly aggregate, resource input data. Other techniques based on electronic data bases of scientific and engineering publications were explored in the present study, as detailed below.

In the current study we focused on R&D activity measures as the most attractive candidate to tap “emerging technology” readiness. Obviously, the presence of research activity in these frontier areas is not a sufficient condition to assure later effective innovation. However, the premise is that countries with such activity should be better poised to proceed into emerging technology product, process, and service commercialization. “Bibliometrics” (counts of literary activity) on R&D appear most suitable candidate measures, with certain considerations:

- we want a broad, relatively simple measure
- the measure should remain available over time

[2] In slightly altered form, this chapter has been submitted for publication to *Science and Public Policy*.

- citations are really only accessible for the *Science Citation Index* and this does not appear "technological" enough for our purposes
- research expenditures (current) across our 33 nations would be tough to obtain for emerging technologies
- patents, while of great interest, seem less apt to anticipate path-breaking emerging technologies out to a 15-year horizon (but possible patent measures could be very interesting too).

Our current investigation suggests intriguing tradeoffs among candidate national patent measures:

1) patent applications anywhere (home or abroad)
2) patent applications in the country by nationals
3) patent applications in the country by foreigners

The advantage of patent applications over patents issued is the considerably reduced lag time. Measures #2 and #3 offer attractive complementarity between a nation's indigenous capabilities (#2) and its attractiveness as a market (#3); disparities between the two can be astounding (Canada – 4,192 patents filed in 1997 by nationals vs. 50,254 by foreigners).[3] Measure #1 is especially attractive as an indicator of indigenous capabilities with external technological commercialization intent. We briefly compare patent with publication measures for our countries later.

Given these considerations, we focus on publication counts for national emerging technology measures. *Publication counts* offer several advantages as measures -- we can:

- tabulate these measures on a timely basis from available electronic R&D abstract databases.
- have full coverage of our country set.
- adapt to changing technology topics over time.
- pull out topical comparisons of interest in addition to overall composites.

On the other hand, some disadvantages lurk:

- We have to compile these ourselves
- Matching abstracts to "emerging technology" categories is not clear-cut
- Defining what should be targeted as "emerging technologies" is not clear-cut
- R&D publication databases reflect significant time lags (i.e., on the order of a couple of years from conduct of the research to its capture in these abstract databases)
- These databases favor English language publications.

"Emerging technologies" need to be specified. We seek something more specific than general R&D. Which technologies are considered to have greatest economic transformation potential? RAND Corporation analyses (Popper et al.,1998) offer helpful perspectives, most notably from their survey of corporate leaders. Their issues of most concern address "how

[3] Organization for Economic Co-operation and Development, *The Measurement of Scientific and Technological Activities Using Patent Data as Science and Technology Indicators, Patent Manual 1994*, Paris, 1994.

technology enhances functionality and fits into a larger business process." That said, their priority *current* emerging technologies include:

- Software
- Microelectronic and telecommunications technologies
- Advanced manufacturing technologies
- Materials
- Sensor and imaging technologies

The RAND group also address "*Over the Horizon: Technologies in Evolution and Revolution*." Major emerging technology classes are:

- Software
- Computer hardware (data storage, displays)
- Manufacturing equipment used to make computer components (lithography)
- Communications technologies
- Biotechnology (relating to medicine, agriculture, the environment, communications
- Materials (making old materials new ways; environmentally friendly materials)
- Energy (considerably fewer mentions)

We start with the first six of these RAND "Over the Horizon" areas, albeit recognizing the desirability of an ongoing classification scheme (there is no assurance that this RAND Science and Technology Policy Institute activity will be regularly redone). We choose not to include "energy" because it received considerably fewer mentions by the business leaders responding to the RAND inquiries. Data resources for publication tabulations must be determined. We favor use of established *databases* as filtered and focused collections. Excellent R&D databases are available. We propose to use two databases that together cover "technology" R&D publication very effectively -- *INSPEC*[4] & *EI Compendex*[5]. Depending on the elaboration of science-based and biomedical technologies, we would consider extension to *MEDLINE* and *Science Citation Index* in the future.

Given general targeting to the RAND categories, we need to determine how to identify "emerging technology" records in the two databases. We considered searching on explicit terms in keywords (subject index terms) and/or titles, but decided this was too detailed and problematic. There are so many specific communications technologies, biotechnology tools and applications, advanced materials, etc. Instead, we favor use of the database *class codes* to get national counts on publications in approximate target areas.

[4] ***INSPEC*** – Our analyses emphasize abstract records from the past 5 years (just over 1.5 million records). *INSPEC* is produced by IEE (http://www.iee.org.uk/publish/inspec/about.html). It abstracts articles from over 4000 science & technology journals, plus about 2000 conference proceedings, and other technical sources. The database includes physics, electrical engineering, communications, computing, and information technology.

[5] ***EI Compendex*** (also called *Engineering Index*) **--** is produced by Engineering Information (http://www.ei.org). It abstracts articles from about 2600 journals, conference proceedings, and technical sources **--** for 1995-1999, over 1.1 million records. It covers all engineering disciplines.

Time frame presents another set of choices. For what time periods do we tally publication activity? We favor recent activity, but with reasonably robust measures. Examination of counts, by country, over time, confirms that annual tallies work satisfactorily for general emerging technology categories. We further focus on *"hot" R&D areas* -- i.e., those that show both strong recent, and increasing, research interest. The rationale is that technology, especially emerging technology, is increasingly science-driven (Lane and Makri, 2000). Hence, active research and development efforts appear highly salient to developing emerging technology capabilities. In our initial empirical analyses, we operationalize this by computing two measures. First, we include only technology class codes for which some ten percent, or more, of the total articles occur in the most recent full year (of those published in journals or presented at conferences since 1969 for *INSPEC* and since 1970 for *EI Compendex*). Second, we calculate the ratio of publications in a technology category in the most recent full year (1999) to those three years earlier (1996). Scanning our emerging technology categories, we find a ratio of at least two to be an effective screen. We recognize that changes in class code terminology can affect this determination, but such changes should align roughly with technologies being perceived as emerging and important by these technical databases. We also experimented with limiting analyses to class codes containing at least 10,000 records. Instead, we found that we could explore sub-classes of the *INSPEC* and *EI Compendex* codes to select "hot" ones, then recombine these to constitute reasonably robust emerging technology measures.

Initial Empirical Results

We examined the *INSPEC* and *EI Compendex* class codes to identify those relating to the first six "Over the Horizon" RAND categories noted. We then tallied "hits" (records) for each category to see which met the "hot" technology tests mentioned [our threshold levels for recent (ten percent in the most recent year) and increasing (two times the publications of three years ago) evolved through this empirical exploration]. These initial examinations used partial thesauri for the *INSPEC* and *EI Compendex* class codes, so they are not exhaustive; we will reexamine before determination of final measures for use in High Tech Indicators for 2002. However, as will become clear, this does not seem to matter much.

Table III-1 presents the results. For this analysis, "manufacturing equipment used to make computer components" was combined with "advanced materials" to approximate "advanced materials pertaining to computer/communications manufacturing." This has some intuitive appeal, but, more critically, we did not identify manufacturing technologies meeting our "recent and growing" R&D criteria. This reduces our target emerging technologies from six to five.

Table III-1. Exploration of Emerging Technologies in *INSPEC* and *EI Compendex*

[“ENGI” = *EI Compendex*]

Over-the-Horizon Technologies	tallies about Jan 20, 2001	**INSP** Codes	**ENGI** Codes	**All Years Total**	**1999**	**1996**	**Percent 1999/total**	**Ratio 99 to 96**	**Use?**
	ENGI database (1970-2000)			5.3 million	219128	239899			
	INSPEC database (1969-2000)			6.7 million	328994	322153			
Software	software	c61$		440974	36414	35246	8.26%	1.03	y
	Info Sci & Documentation	c72$		80982	7941	4468	9.81%	1.78	
Computer Hardware	Data Comm Equip & Techniques	c56$		106027	7308	6665	6.89%	1.1	
	comp peripheral equip	c5540		15008	88	387	0.59%	0.23	
	Analog & digital computers & sys	c5470		19659	1598	1382	8.13%	1.16	
	prnt circ, thin & thick films, hybrid ICs	b22$		52265	2398		4.59%		
	Semiconductor devices & mtls	b25$		289028	19705	19565	6.82%	1.01	
	Telecom	b62$		290421	18363	17007	6.32%	1.08	
	elec components & tubes		714	180000	1981	460	1.10%	4.31	
			714.$	117635	23233	8141	19.75%	2.85	
	semiconductor devices & ICs		714.2	103034	20276	7319	19.68%	2.77	y
Comm technologies	waveguides		714.3	11095					
	elec-opt comm		717	40089	1692	589	4.22%	2.87	
	opt comm		717.1	10796	1940	707	17.97%	2.74	y
	opt equip		717.2	4214	855	397	20.29%	2.15	y
	light, optics & opt devices		741	231873	4401	1414	1.90%	3.11	
	light optics		741.1	109186	22848	6586	20.93%	3.47	y
	non-linear optics		741.1.1	9082	1788	424	19.69%	4.22	y
	fiber optics		741.1.2	15016	3335	1048	22.21%	3.18	y
	opt devices & systems		741.3	77733	15770	4006	20.29%	3.94	y
	Holography		743	8064	377		4.68%		
	Holographic applications, etc.		743.$	2642	389		14.72%		
	Semiconductor lasers		744.4.1	11546	1966	850	17.03%	2.31	y
Advanced Mtls. for Comp./Comm. Tech.	Rare metals - some of		543.$	<10,000					
	Si, Tellurium & Zirconium		549.3	23982	4835	1378	20.16%	3.51	y
	Elec & Thermionic Mtls		712	99214	26	18	0.03%	1.44	
	Semiconductor Mtls		712.1	28064	6110	1882	21.77%	3.25	y
	Thermionic Mtls		712.2	1183	35		2.96%		
Biotech	Bio Mtls, Engr, ?		461.$	86070	17109	6409	19.88%	2.67	
	Bioengineering		461	107605	194		0.18%		
	Biomed Engr		461.1	26125	5072	2120	19.40%	2.39	y
	Biol Mtls		461.2	31100	5904	2620	19.00%	2.25	y
	Biomechanics		461.3	7271	1647	545	22.70%	3.02	y
	Human Engr		461.4	10609	1466	544	13.80%	2.69	
	Human Rehab Engr		461.5	3069	732	337	23.90%	2.17	
	Medicine		461.6	20109	4276	2217	21.30%	1.93	
	Health Care		461.7	6994	1519	617	21.70%	2.46	
	Biotech		461.8	10069	1875	778	18.60%	2.41	y
	Biology		461.9	16154	4350	850	26.90%	5.12	y
	Biol Equip		462	38448	5	7	0.00%	0.71	
	Biomed Equip (gen)		462.1	5745	886	501	15.40%	1.77	
	Biomaterials		462.5	5537	768	598	13.90%	1.28	

The top few rows show the overall database scope. These two databases capture a significant portion of the world's open literature (journal papers and conference papers) concerning technology R&D. Each year the two databases together capture about 500,000 new contributions.[6]

Table III-1 conveys the sense that the dual criteria work -- a sizable percentage of a technology's R&D published in the most recent year (the current "10%" value would need to be reexamined as a database expands) and strong growth (i.e., double the number of articles of three years back). For present analyses, we override these in some instances. Most notably, we include "software," even though the growth criterion is violated badly, because this seems a vital emerging technology domain. Future refinement will be needed to handle such anomalies. In general the dual criteria helpfully screen out mature from emerging elements within these technology categories.

Examination of Table III-1 yields interesting observations. All of the communications technologies identified as "emerging technologies" are optics-related (i.e., those flagged with a "Y" in the last column). The biotechnology set is appealing; it requires elimination of certain *EI Compendex* classes that appear different in nature -- general health and medical, and human engineering -- even though they meet the dual criteria. Our resulting "emerging technologies," excepting software, derive exclusively from *EI Compendex*. We will revisit why *INSPEC* categories seem not to meet our criteria, since *INSPEC* generally tends to be more research oriented than *EI Compendex* (which exhibits more applied research and engineering development). This may reflect different rates of classification code revision by the two databases.

If, in the future, we include both relevant *INSPEC* and *EI COMPENDEX* codes for certain emerging technologies, there could be significant duplication. We often see these two databases giving 20% or so overlap on certain topics. We would expect duplication rates to be generally comparable for countries, so this should not bias either national or temporal comparisons. We need to beware that counts could overstate activity where they combine results from both databases. (This is not a problem in the present tabulations since each component is measured in only one or the other database.)

We wondered how badly database biases (especially toward English) might distort country comparisons. To address this issue we ran a four-country tally on two emerging technologies -- software and advanced computing/communication materials. We prepared tables presenting the results for 1998, 1999, and 2000 for India, China & Hong Kong, Thailand, and Brazil. These four nations touch a range of possible concerns. China poses language and inclusion concerns (Hong Kong separately searched and included; Taiwan not considered here). India provides contrasting familiarity with English. Brazil poses strong language concerns – the possibility that Portuguese would be less likely to be indexed in *INSPEC* and *EI Compendex*. Thailand is of interest because the counts are so low.

We listed the leading institutions and publication outlets for each of the four countries. We then asked knowledgeable persons from these countries: 1) how much significant publication from

[6] As of January, 2001, when these tallies were made, the year 2000 activity was not fully indexed. The *EI Compendex* tally for the year 2000 was 176,022 (vs. about 230,000 for 1998 or 1999); the *INSPEC* tally was 230,009 (vs. about 325,000 for 1998 or 1999). That is why we are using 1999 as our most recent full year in this analysis.

their country would they estimate occurs in journals or conferences not included? and 2) do you know of important R&D organizations likely to publish elsewhere that we seem to be missing? Table III-2 tabulates the sense of the responses. We interpret these reviews as reassuring. Certainly we will miss some important R&D due to database coverage emphases, but it does not appear severe. Furthermore, coverage should be relatively comparable for a given country over time so that within-country comparisons should be good. Concerns about "classes" of important R&D institutions not represented well do not seem qualitatively different than would be the case in countries such as the U.S.

Table III-2. Observations on National Coverage

	How much publication appears to be missed (based on journals & conferences included)?
India	fair amount -- but respondent points to theses (this is not a real national bias)
	not very much -- points to 1 international & 1 Indian technical series
	likely that most are covered; all significant publications would be in English
	only a little; all significant research in India published in English
China	20-40% seems not to be collected by *INSPEC* and *EI COMPENDEX*
	don't know extent of loss of Chinese language publications; many researchers do publish in international journals
	a little
Thailand	very little
	very little
	little
	a lot (but we inferred considerable institutional loyalty coloring this person's response)
Brazil	20-25% missed
	very little
	several locally important contributions, but all those most important globally are included in these periodicals
	Are we missing the work of significant R&D organizations?
India	technical reports from government, semi-governmentt agencies, corporations (this is not a national bias)
	no
	not applicable
	surely abstracted in INSPEC and EI COMPENDEX
China	most important R&D organizations like to publish in places abstracted, especially into *EI Compendex*
	maybe military R&D institutes don't publish some
	not applicable
	not applicable
Thailand	not applicable
	all important R&D organizations seem to be included
	notes 3 Thai annual journals and proceedings
Brazil	lists 10 organizations apt to publish in Portuguese, less likely to be abstracted in *INSPEC & EI Compendex*
	lists 3 organizations not appearing in our list
	some good Portuguese journals probably not abstracted

Note: Each line summarizes an observation of one reviewer from that country upon reviewing our tallies of emerging technology R&D publications for these countries.

An intriguing sidenote to this exploration was our surprise at the relative software-related publication from China and India. We would have hypothesized that India would dominate because of its English language usage and its extensive software development activity. Not so: overall in *INSPEC*, we identified 12,766 software-related papers from China (and Hong Kong) versus 2,713 for India. The disparity appeared even greater most recently as we found 1,920 Chinese software publications in 2000 versus 133 Indian. So, at least in this instance, international literature contributions do not seem heavily determined by English language usage.

A mundane, but difficult, issue concerns how best to identify country of authors. Both *INSPEC* and *EI Compendex* only provide the institutional affiliation and country of the first author. In some (few) cases country is not indicated. These do not present major "indicators" problem for us, but users of these measures should recognize there is some loss of information -- we won't tally "all" a country's R&D. Certain countries provide particular challenges. The UK, for instance, may also be indicated as England, Scotland, Northern Ireland, or Wales. However, just finding the string "Wales" in the affiliation field does not guarantee the UK -- it may reflect New South Wales, Australia. This requires development of country thesauri for *INSPEC* and for *EI Compendex* to capture most national records while minimizing noise. We have developed initial such thesauri. Changing country designations -- e.g., USSR, EAST GERMANY -- could cloud historical tracking. In the case of Hong Kong, we extract its records separately, then combine with China for most purposes.

Results are interesting. Table III-3 shows the counts for our 33 countries. The first column shows each country's total number of articles and conference papers abstracted by *EI Compendex* for 1999. The following five columns break out each of our five emerging technologies. The last two columns sum these, with or without software included (since "software" does not meet our dual criteria of recent and growing R&D activity).

Table III-3. National "Emerging Technology" R&D Publication Activity for 1999

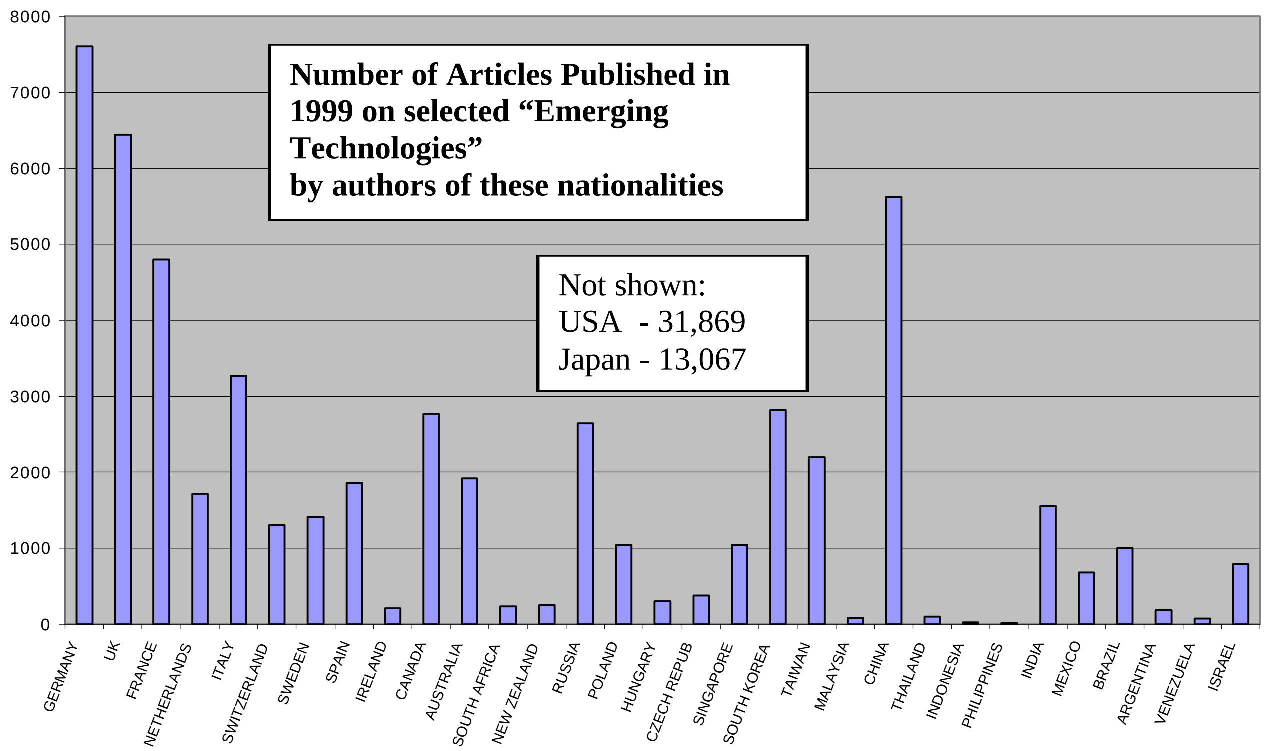
Counts	*ENGI* total #	Optical Comm *(ENGI)*	Comp Hdwr *(ENGI)*	Semi Mtls *(ENGI)*	Biotech *(ENGI)*	Software *(INSPEC)*	Sum (mix)	Sum "4 ET's" *(ENGI)*
USA	57479	8790	6591	2224	4637	9627	31869	22242
JAPAN	22686	4527	2808	1870	1042	2820	13067	10247
GERMANY	11616	2375	1216	852	634	2520	7597	5077
UK	11349	1720	839	489	710	2681	6439	3758
FRANCE	8397	1588	817	548	411	1436	4800	3364
NETHERLANDS	2886	483	261	120	261	588	1713	1125
ITALY	5652	990	550	304	300	1122	3266	2144
SWITZERLAND	1959	403	268	108	130	393	1302	909
SWEDEN	2798	360	269	151	233	397	1410	1013
SPAIN	3553	599	261	206	177	616	1859	1243
IRELAND	222	48	37	10	21	96	212	116
CANADA	6469	716	417	165	484	982	2764	1782
AUSTRALIA	3594	521	165	113	222	897	1918	1021
SOUTH AFRICA	666	49	39	31	35	80	234	154
NEW ZEALAND	560	50	8	11	54	125	248	123
RUSSIA	5182	1421	341	315	305	264	2646	2382
POLAND	2115	437	160	136	77	227	1037	810
HUNGARY	665	84	37	33	55	88	297	209
CZECH REPUB	671	152	42	35	49	93	371	278
SINGAPORE	1873	311	249	110	68	307	1045	738
SOUTH KOREA	4975	918	665	348	142	748	2821	2073
TAIWAN	4608	576	610	219	191	598	2194	1596
MALAYSIA	211	26	13	1	6	35	81	46
CHINA	13890	2292	757	550	366	1656	5621	3965
THAILAND	217	20	8	3	13	50	94	44
INDONESIA	62	8	4	5	6	2	25	23
PHILIPPINES	35	5	0	0	2	3	10	7
INDIA	4462	575	266	279	207	229	1556	1327
MEXICO	1257	309	120	78	76	95	678	583
BRAZIL	2169	312	126	109	109	339	995	656
ARGENTINA	521	79	12	32	24	41	188	147
VENEZUELA	196	26	6	12	8	19	71	52
ISRAEL	1564	270	94	64	125	238	791	553

Detailed class codes consolidated into the counts shown appear in Table 1. "Optical Comm" here corresponds to "Comm Technologies" in Table 1; Comp Hdwr is Computer Hardware ; Semi Mtls is Advanced Materials for Computing/Communication Technologies; Biotech is Biotech; Software is Software.
"Sum" adds the five separate emerging technologies. "Sum - 4 ET's" excludes software.

Figure III-1 depicts the results for the sum of the five emerging technologies (next to last column of Table III-3), leaving out the "research superpowers," U.S. and Japan, to improve scaling. The most striking observation concerns China's strong presence -- it is one of the emerging technology research powerhouses, along with Germany, UK, and France. Figure III-1 suggests one could identify tiers in research activity on emerging technologies:

- superpowers -- U.S. and Japan
- research powerhouses -- Germany, UK, China, and France
- strong players (i.e., those with over 2,000 annual publications) -- Italy, South Korea, Canada, Russia, Taiwan
- solid presence -- 11 countries with 670- 2000 annual publications -- Australia, Spain, the Netherlands, India, Sweden, Switzerland, Singapore, Poland, Brazil, Israel, Mexico
- laggards (i.e., those with about 200-400 annual publications) -- the Czech Republic, Hungary, New Zealand, South Africa, Ireland, Argentina
- those lacking critical research mass (i.e., <100 publications) -- Thailand, Malaysia, Venezuela, Indonesia, and the Philippines

Figure III-1. Emerging Technology Publication Activity by Country



Keeping in mind that the 33 countries profiled are chosen for their high tech proficiency or promise, these results raise concerns about the ability of those without a critical emerging technology research enterprise to participate early and strongly in attendant technology-based competition in the future. [Note also that the 33 countries selectively sample the heavily industrialized and industrializing nations; they do not cover all such countries.] Possibly most notable in this apparent weakness is Malaysia which scores strongest among the "Asian Cubs" on our High Tech Indicators, close on the heals of "Tigers" -- Singapore, South Korea, and Taiwan. However, were one to place stock in a measure of emerging technology R&D activity, the gap from

Malaysia to the others becomes pronounced.

In constructing an indicator, one faces choices in how best to normalize the data. Note the tremendous range for our 33 countries in the sum of their annual emerging technology R&D publication activity -- from 10 papers for the Philippines to almost 32,000 for the U.S. -- over 3 orders of magnitude. One might consider per capita (or per scientist & engineer) metrics, but High Tech Indicators prefers total national activity measures as more salient to export competitiveness. High Tech Indicators relies heavily on "S-scores" -- scaling the 33 countries on a relative basis with the leader on a particular variable as "100." S-scores for the sum of emerging technology publications in 1999 reflect the huge disparity in activity levels. For instance, pegging the U.S. as 100, the Philippines score as 0.03 (last column of Table III-4).

Table III-4. National "Emerging Technology" R&D Publication Ranks & Average S-score for 1999

Ranks	ENGI	Optical Comm (ENGI)	Comp Hdwr (ENGI)	Semi Mtls (ENGI)	Biotech (ENGI)	Software (INSPEC)	Average S-score (5 ET's)
USA	1	1	1	1	1	1	100.00
JAPAN	2	2	2	2	2	2	44.65
GERMANY	4	3	3	3	4	4	24.32
UK	5	5	4	6	3	3	19.15
FRANCE	6	6	5	5	6	6	15.37
NETHERLANDS	15	15	15	16	10	13	5.30
ITALY	8	8	9	10	9	7	9.72
SWITZERLAND	19	17	13	17	17	15	4.05
SWEDEN	16	18	12	15	11	14	4.56
SPAIN	14	11	15	13	15	11	5.64
IRELAND	28	28	25	27	28	23	0.65
CANADA	7	10	10	11	5	8	8.83
AUSTRALIA	13	14	18	19	12	9	5.33
SOUTH AFRICA	24	27	24	26	26	27	0.76
NEW ZEALAND	26	26	29	28	24	22	0.69
RUSSIA	9	7	11	7	8	18	9.34
POLAND	18	16	19	14	20	21	3.55
HUNGARY	25	24	25	24	23	26	1.03
CZECH REPUB	23	23	23	23	25	25	1.31
SINGAPORE	20	20	17	20	22	17	3.06
SOUTH KOREA	10	9	7	9	16	10	8.64
TAIWAN	11	12	8	12	14	12	7.02
MALAYSIA	30	29	27	30	31	30	0.22
CHINA	3	4	6	4	7	5	18.21
THAILAND	29	31	29	31	29	28	0.25
INDONESIA	32	32	32	32	31	33	0.08
PHILIPPINES	33	33	33	33	33	32	0.03
INDIA	12	13	14	8	13	20	6.16
MEXICO	22	21	21	22	21	24	2.12
BRAZIL	17	19	20	18	19	16	3.10
ARGENTINA	27	25	28	25	27	29	0.63
VENEZUELA	31	29	31	29	30	31	0.20
ISRAEL	21	22	22	21	18	19	2.47

We consider two bolder alternatives -- ranks and logarithms. These certainly reduce the skewness, but reinforce the sense of high correlation across the five emerging technology areas. For ranks, correlation of each emerging technology with each other for 1999 publication, across countries, ranges from 0.90 (software with semiconductor materials) to 0.99 (optical communication with semiconductor materials), with a mean of 0.95. For logs, the mean is again 0.95, with a range of 0.89 (software with semiconductor materials) to 0.98 (optical communication with computer hardware). Rank and log data for the 33 countries show strong correspondence. Raw counts (S-scores give the same correlations) show a similar mean correlation of 0.95, ranging from 0.90 (software with biotech) to 0.98 (three pairs).

Moreover, these emerging technology emphases are strikingly similar to overall activity level in the *EI Compendex* database (Table III-1). Correlations of raw counts for *EI Compendex* with each of the five emerging technologies average 0.97 (range of 0.93 to 0.99). Correlations of ranks with each of the five also average 0.97 (range of 0.95 to 0.99). In terms of indicator development, this lack of discrimination among the emerging technologies and with overall engineering R&D publication is somewhat discouraging.

As mentioned, we are also developing patent measures, and these can differ dramatically with each other. We compared non-resident patent applications[7] for 1997 with our measures. Correlations of the patent S-scores with our S-scores ranged from 0.42 for biotech to 0.51 for software – much lower than the publication intercorrelations just noted. Patent S-scores correlated more highly with R&D publication ranks (ranging from 0.68 with optical communications to 0.76 for software. Ranking moderates the extremes of the publication statistics. In fact, we would not expect these measures to correlate highly – this patent measure reflects market attractiveness, while our publication measures get at indigenous generation of emerging technology developments.

On the other hand, patent applications by nationals of one country anywhere (home or abroad) better reflects indigenous development activity. This measure correlates very highly with our five emerging technology publication rates – from 0.84 for semiconductor materials to 0.98 for biotech. This broadly distributed measure (ranging from 576 Argentine patents in 1997 to 1.5 million American ones) mirrors the extreme distribution of R&D publications across countries. (This patent measure correlates much less with the toned down publication rank measures – ranging from 0.50 to 0.54).

For rank data, the overall R&D publication patterns reaffirm the similarity in national emphases across the five emerging technology categories. Table III-4 shows that the U.S. ranks #1 for all; Japan, #2 for all (as well as for overall *EI Compendex* publication in 1999). In general, R&D activity levels across these five emerging technology categories are very similar. Some interesting variability does surface:

- Russia ranges from 7th (optical communication) to 11th on four of the five, but lagging at 18th on one (software).
- India surprisingly shows strongest at 8th (semiconductor materials) to weakest at 20th(software).
- South Korea peaks at 7th (computer hardware), ranging down to 16th (biotech).

[7] Organization for Economic Co-operation and Development, *The Measurement of Scientific and Technological Activities Using Patent Data as Science and Technology Indicators, Patent Manual 1994,* Paris, 1994.

- Taiwan shows as a steady 12th to 14th on four of the five, showing notably higher on computer hardware (8th).
- Canada seems surprisingly strong at 5th on biotech and 8th on software, ahead of its placement on the other three (10th or 11th).
- Australia shows relatively high variability, with 9th on software and 12th on biotech, but only 18th and 19th, respectively, on computer hardware and semiconductor materials.

Observations

"Emerging technologies" don't stay constant. One advantage of the proposed approach is that the set of emerging technologies would be continually adapted to seek "frontier" technology R&D. The dual criteria of strong recent emphasis and growth in activity provide good bases for this adaptation. In this initial exploration, we augmented these with judgment based on categorical intent (e.g., excluding human engineering from biotechnology, and including software despite failure to meet the dual criteria).

The level of specificity for "emerging technologies" could be set broader or finer (consider Table III-1). We think the current algorithm is at about the right level for national comparisons. Each additional class adds about 50 searches (33 countries plus tricky country designators – e.g., UK includes England, etc.). Once searches are finalized, we should be able to write a macro (script the steps) to perform a large set of searches and the subsequent analyses quickly and repeatability. This could be used to generate periodic updates (e.g., every year) to alert to pronounced national initiatives in particular emerging technologies. Differential activity measures (showing extent of change over time for each nation) might prove indicative of shifting R&D emphases.

We plan to average relative national standing for these five emerging technologies (last column of Table III-4) to report this as a measure of national emerging technology capability. We considered the possibility of differential weighting for the five component categories; however, the overall similarity among the five for these countries obviated the need for special weighting. This measure of research activity in five emerging technologies would become a component of our Technological Infrastructure "High Tech" Indicator for 2002. In future years (e.g., 2005), the specific technological classes would be revised to reflect most recent publication emphases. The current tabulation incorporates some 16 specific technological classes of research publication from *EI Compendex* and *INSPEC* relating to five emerging technologies. Our 33 nations account for 80-90% of the research publications in the four 1999 *EI Compendex* samples. This is surprisingly high, considering we don't include all the OECD countries.

For each of these four emerging technologies (not including software), 1999 accounts for 20-21% of the total records from 1970-2000. The ratio of hits in 1999 to those in 1996 is 2.7 for biotech, 3.46 for optical communications technology, 3.36 for semiconductor materials, and 2.77 for computer hardware. In contrast, the software category shows a ratio of 1.03. So, the amount of publication in these "over the horizon" technology categories has increased about 3-fold from 1996 to 1999. That's hot. The steady research level in software could warrant further examination of changes in topical emphases and approaches within this category. [While class codes and total records abstracted change over time, the changes over this time period were quite moderate.]

But, to what degree does lack of research publication activity portend lack of high tech economic competitiveness for nations? How does it fit in national and global systems of innovation (Archibugi et al., 1999). These are open questions. To illustrate the contrasts more specifically, consider the biotech area. For 1999, our tally for the class codes comprising this domain was 13,974 (*EI Compendex* abstract records). Of those our 33 countries account for 80%, led by the U.S. (33% itself – 4637 publications). In contrast, four of our countries had fewer than 10 biotech publications each, using this coding. That would seem to severely constrain their potential to commercialize this emerging technology.

The implications of this measure merit exploration. Our overall High Tech Indicators (HTI) point toward a dramatic broadening of high tech competitiveness across these 33 nations. This "emerging technology" measure points to a markedly different future in which relatively few of these nations dominate technological competitiveness over a 15-year or so horizon. In terms of relative (S) scores, six nations score 15 or higher; 27 score under 10 – and of those 27, a dozen score about 1 or under (publishing fewer than 400 papers per year in these areas). This disparity challenges those who would set national policy to foster technological competitiveness (Clark and Guy, 1998; Kim, 2000). Do the industrializing nations need to bolster their R&D in emerging technologies to enable them to compete economically in these areas in the future?

The leading countries based on our measures are: U.S., Japan, Germany, UK, China, and France (c.f., Table III-3 "sum," Table III-4 "average S-score," Figure III-1). The surprise to us is China. In the past few years China has moved up dramatically on Georgia Tech's High Tech Indicators. China's strength on emerging technologies suggests this nation may well power forward into a leadership role in next generation technologies.

References

Antonelli, G. and De Liso, N. (eds) (1997), *Economics of Structural And Technological Change*, London, New York, Routledge, 1997.

Archibugi, D., J. Howells and J. Michie (1999), "Innovation Systems In A Global Economy", *Technology Analysis & Strategic Management*, **11**(4), pages 527-539.

Archibugi, D. and Michie, J. (eds) (1998), *Trade, Growth And Technical Change*, Cambridge University Press, Cambridge, UK.

Clark, J. and K. Guy (1998), "Innovation And Competitiveness: A Review
& Strategic Management, **10**(3), pages 363-395.

Godin, B. (INRS/CIRST), "The State Of S&T Indicators In The OECD Countries", Reference Paper Submitted to Statistics Canada, August 1996.

Grupp, H. (1995), "Science, High Technology And The Competitiveness Of EU Countries", *Cambridge Journal of Economics*, **19**, pages 209-223.

Hansen, J. A. (1999), "Tech Innovation Indicators - A Survey of Historical Development & Current Practice", Working Paper, State University of New York College at Fredonia.

Kim, S. (2000), "Is Government Investment In R&D And Market Environment Needed For Indigenous Private R&D In Less Developed Countries?: Evidence From Korea", *Science and Public Policy* **26**(1), pages 13-22.

Lane, P. and Makri, M. (2000), "Responding To Diminishing Technological Opportunities: A Socio-Cognitive Model Of Science And Innovation", Arizona State University College of Business working paper.

Mani, S. (2000), "Exports Of High Technology Products From Developing Countries: Is It Real Or A Statistical Artifact?" Working Paper, UNU/INTECH, The Netherlands, March.

OECD 2000 Project Report: *A New Economy: The Changing Role Of Innovation And Information Technology In Growth*, in web: http://www.oecd.org/dsti/sti/stat-ana/prod/growth.htm.

OECD 1999 Project Report: *OECD Science, Technology And Industry Scoreboard, 1999 Benchmarking Knowledge-Based Economies*.

Popper, S.W., C.S. Wagner, and E.V. Larson (1998), *New Force at Work: Industry Views Critical Technologies*, The US Rand Corporation's Publication MR-1008-OSTP, in web: http://www.rand.org/publications/MR/MR1008/#contents.

Porter, A.L., J.D. Roessner, N. Newman and D.A. Cauffiel (1996), "Indicators Of High Tech Competitiveness Of 28 Countries", *International Journal of Technology Management*, **12**(1), pages 1-32.

Porter, A.L., J.D. Roessner, X-Y. Jin and N.C. Newman (to appear), "Changes In National Technological Competitiveness: 1990-93-96-99," *Technology Analysis & Strategic Management.*

Porter, M.E. and S. Stern (1999), *The New Challenge To America's Prosperity: Findings From The Innovation Index*, Council on Competitiveness, Washington, D.C. (http://www.compete.org/).

Roessner, J.D., A.L. Porter and H. Xu (1992), "National Capacity To Absorb And Institutionalize External Science And Technology", *Technology Analysis and Strategic Management*, **4**(2), pages 99-113.

Roessner, J.D., A.L. Porter, N.C. Newman and X-Y. Jin (to appear), "A Comparison Of Recent Assessments Of The High-Tech Competitiveness Of Nations", *International Journal of Technology Management.*

Sirilli, G. (1997). "Science And Technology Indicators: The State Of The Art And Prospects For The Future", in: G. Antonelli and N. De Liso (Eds), *Economics of Structural and Technological Change*, London, New York, Routledge, 1997.

Van Raan, A.F.J. (Ed.) (1998), *Handbook Of Quantitative Studies Of Science & Technology*, North Holland, 1988.

The World Competitiveness Yearbook (WCY) 1998- 2000, Edited By WCY Research Team, International Institute For Management Development (IMD), Lausanne, Switzerland (Http://Www.Imd.Ch/Wcy.Html).

Chapter IV
Using Patent Data as Indicators for High Technology Industrial Competitiveness

by
Nils Newman

Introduction

Since the start of the High Technology Indicators (HTI) project in 1986, patents have always been considered a potential source for indicators. However, during past cycles, weaknesses in coverage and quality precluded the use of patent data. This trend is finally beginning to change. Patent data are finally beginning to appear on a regular basis in data sources that have the coverage necessary for the HTI project.

Patents have been of continuing interest to the HTI research team because they provide useful data on commercial intellectual activity. The presence of patent activity from sources both internal and external indicates that a nation is viewed as both a market worth protecting and a source of new ideas. Patent activity also provides insight into the technology transfer between the academic sector and the industrial sector as well as technology transfer from other countries. Finally, the mere presence of healthy patent activity suggests that a country has a functioning intellectual property system and is fostering an environment conducive to innovation.

For this study, we primarily focused on using patent data to improve the validity of the existing input indicators. The goal was to provide additional depth and stability to the input indicators by capturing additional aspects of a nation's capacity to develop, produce, and market new technology.

Literature

Although there are a significant number of valuable studies that use patent activity as an indicator of competitiveness, most view the competition as one region versus another.[8] Few sources address using patents in a universal measure of the kind needed for the HTI project.[9] The reason for the region-versus-region approach is due do the regional nature of most patent data. There are several different major patent systems and each works a little differently. Researchers usually adjust for these differences and thus limit the analysis to only a handful of regions.

[8] The works of H. Grupp, G. Munt and U. Schmoch and D. Archibugi and M. Planta in the 1996 OECD book entitled "Innovation, Patents, and Technological Strategies" provide a good summary of the various approaches to patent indicators.

[9] The HTI project requires coverage of 33 countries. The literature survey found numerous studies analyzing patent patterns within and between the major industrial powers and found studies assessing patent activity in developing countries but the survey found little literature addressing a comprehensive comparison between developed and developing countries.

The nuances of patent system comparability are addressed in the OECD Patent Manual which outlines how each of the major systems operate.[10] In addition to outlining the different patent systems, this document addresses the differences between using application data and patent issued data, the methodological issues associated with patents, and the usability of patent data in building science and technology indicators. The manual outlines three major approaches to patent indicators:

- Indicators based on Resident Applicant data
- Indicators based on non-Resident Applicant data
- Indicators based on applications filed in other countries

[10] OECD, 1994, *The Measurement of Scientific and Technological Activities Using Patent Data as Science and Technology Indicators Patent Manual 1994,* OECD, Paris, France. The OECD Patent Manual is part of the series of manuals that include the TBP Manual and the Oslo Manual. The series provides guidelines for the collection and analysis of data related to technological innovation.

Table IV-1 Patent Applications By Residents		
COUNTRY	Resident Applications (1997)	RA S-Score (1997)
ARGENTINA	824	0.23
AUSTRALIA	8,937	2.54
BRAZIL	36	0.01
CANADA	4,192	1.19
China (+ Hong Kong)	12,812	3.65
CZECH REPUBLIC	601	0.17
FRANCE	18,669	5.31
GERMANY	62,052	17.65
HUNGARY	774	0.22
INDIA	N/A	N/A
INDONESIA	N/A	N/A
IRELAND	946	0.27
ISRAEL	1,796	0.51
ITALY	2,574	0.73
JAPAN	351,487	100.00
MALAYSIA	179	0.05
MEXICO	429	0.12
NETHERLANDS	5,227	1.49
NEW ZEALAND	1,735	0.49
PHILIPPINES	125	0.04
POLAND	2,401	0.68
RUSSIA	15,277	4.35
SINGAPORE	N/A	N/A
SOUTH AFRICA	N/A	N/A
SOUTH KOREA	64	0.02
SPAIN	2,856	0.81
SWEDEN	7,893	2.25
SWITZERLAND	5,814	1.65
TAIWAN	N/A	N/A
THAILAND	238	0.07
UNITED KINGDOM	26,591	7.57
USA	125,808	35.79
VENEZUELA	201	0.06

1) Resident Applicant

According to the OECD patent manual, “the number of resident applications (RA) can be regarded as reflecting the country’s invention output.” (OECD, 1994) Theoretically, an indicator based on resident application data would provide a direct indicator of inventor output. Unfortunately, the variations in national patent systems make it very difficult to compare one country to another. In Table IV-1, one can see that in addition to capturing the relative patent activity in each country, raw counts of resident applications also captures the differences in the systems.[11] Note the unusually high number of resident applications in Japan. The Japanese system has a two-tiered review structure. Therefore an application in Japan is not technically the same as an application in France. The variations between patent systems would mean that any final cross-country indicator would require some form of calibration.

[11] All patent data are drawn from the World Intellectual Property Organization (WIPO), Industrial Property Statistics CD.

Table IV-2
Patent Applications By Non-Residents

Reporting Country	Non-Resident Applications (1997)	NRAS (1997)
Argentina	5 035	4.14
Australia	39 274	32.29
Brazil	31 947	26.27
Canada	50 254	41.32
China (+ Hong Kong)	50 955	41.90
Czech Republic	29 976	24.65
France	93 962	77.26
Germany	113 543	93.36
Hungary	29 331	24.12
India	N/A	N/A
Indonesia	4 517	3.71
Ireland	82 484	67.82
Israel	308	0.25
Italy	88 836	73.05
Japan	66 487	54.67
Malaysia	6 272	5.16
Mexico	35 503	29.19
Netherlands	85 402	70.22
New Zealand	33 402	27.46
Philippines	3 440	2.83
Poland	30 137	24.78
Russia	32 943	27.09
Singapore	29 467	24.23
South Africa	N/A	N/A
South Korea	37 184	30.57
Spain	110 911	91.20
Sweden	107 107	88.07
Switzerland	107 038	88.01
Taiwan	N/A	N/A
Thailand	5 205	4.28
United Kingdom	121 618	100.00
USA	110 884	91.17
Venezuela	2 323	1.91

2) Non-Resident Applicant

According to the OECD patent manual, "the number of non-resident applications (NRA) provides information on the extent to which the country is considered a worthwhile market for the introduction of foreign inventions, or a serious competitor in technological activity…" (OECD, 1994) An indicator based on Non-Resident Application data is shown in Table IV-2. Although the indicator does not directly speak to the native capacity to innovate, it does capture the world's perception of both the sophistication of the internal market and the perceived quality of intellectual property system.[12] Nations would not go through the expense of registering patents in other nations unless the other nation was viewed as a threat and an adherent to the principles of intellectual property.

[12] Although the research team found no comprehensive studies using this type of indicator, some regional studies do use this approach. Of particular interest was a 2000 study released by the Ministry of Finance in Denmark that looked at what countries were patenting in Denmark in relationship to indigenous patenting.

Table IV-3 Patent Applications Filed in Other Countries		
COUNTRY	Total Applications Submited To All Patent Offices (1997)	TASAS (1997)
ARGENTINA	576	0.04
AUSTRALIA	73,125	4.85
BRAZIL	5,064	0.34
CANADA	83,925	5.56
CHINA	12,653	0.84
CZECH REPUBLIC	2,570	0.17
FRANCE	161,402	10.70
GERMANY	378,650	25.10
HUNGARY	6,367	0.42
INDIA	798	0.05
INDONESIA	N/A	N/A
IRELAND	8,720	0.58
ISRAEL	37,446	2.48
ITALY	76,381	5.06
JAPAN	321,963	21.34
MALAYSIA	N/A	N/A
MEXICO	1,662	0.11
NETHERLANDS	96,310	6.38
NEW ZEALAND	15,566	1.03
PHILIPPINES	N/A	N/A
POLAND	1,051	0.07
RUSSIA	19,453	1.29
SINGAPORE	N/A	N/A
SOUTH AFRICA	1,815	0.12
SOUTH KOREA	29,647	1.97
SPAIN	20,106	1.33
SWEDEN	147,973	9.81
SWITZERLAND	91,964	6.10
TAIWAN	N/A	N/A
THAILAND	N/A	N/A
UNITED KINGDOM	299,676	19.86
USA	1,508,656	100.00
VENEZUELA	N/A	N/A

3) Applications filed in other countries

According to the OECD patent manual, “the number of external applications (EA) may be regarded as an indicator of the interest of a country’s firms in safeguarding the return from their inventive activity in foreign market." (OECD, 1994) An indicator based on Application Filed in other Countries is shown in Table IV-3. This indicator captures an intriguing aspect of both the internal capacity to innovate and the desire to compete in the world market. Unfortunately, the total dominance by the United States means that it would be difficult to use this indicator without some type of modification.

Recommendations

Based on the information in the tables above, Non-Resident Applicant data appears to provide the most effective solution in terms of coverage, ease of use, and availability. Although this indicator is the least capable of speaking directly to a nation's ability to innovate it does provide insight into other nations perceptions of a nation's capacity to develop, produce, and market new technology. As such, it is appropriate to add this indicator as a component of Technological Infrastructure (TI).

Table IV-4 shows the results of adding Non-Resident Application (NRA) data as an equally weighted component of TI. Non-Resident Application data from 1997 are used in the construction. Data for 1997 were the latest available at the time of this analysis. Note that the results are not radically different but show some significant differences. Countries in the European Patent Office System all appear to benefit from the addition of NRA. This is reasonable considering the potential efficiencies that may develop as the European Union consolidates. Note too that countries with weak or externally hostile patent systems such as Japan, Korea, and the Philippines are all weakened by the addition of NRA. This too seems reasonable. Overall the addition of Non-Resident Application data appears to benefit the formulation of Technological Infrastructure and should be included in future cycles of the HTI project.

References

Ministry of Finance, *Structural Monitoring – International Benchmarking of Denmark*, (Denmark, The Danish Government, August 2000).

Organization for Economic Co-operation and Development, *Innovation, Patents, and Technological Strategies*, (Paris, France: Organization for Economic Co-operation and Development, 1996).

Organization for Economic Co-operation and Development, *The Measurement of Scientific and Technological Activities Using Patent Data as Science and Technology Indicators Patent Manual 1994*, (Paris, France: Organization for Economic Co-Operation and Development, 1994).

World Intellectual Property Organization, *Industrial Property Statistics 1997*, (Compact Disc, World Intellectual Property Organization, 1997).

Table IV-4 Comparison of Technological Infrastructure 1999 With and Without Non-Resident Application Data						
Reporting Country	Non-Resident Applications (1997)	NRAS (1997)		STI99 with NRAS	STI99 Original	Reporting Country
USA	110 884	91.17		95.28	96.10	USA
Japan	66 487	54.67		74.34	78.28	Japan
Germany	113 543	93.36		68.97	64.09	Germany
United Kingdom	121 618	100.00		66.48	59.77	United Kingdom
France	93 962	77.26		61.20	57.99	France
Netherlands	85 402	70.22		55.97	53.11	Netherlands
Italy	88 836	73.05		52.48	48.37	Italy
Switzerland	107 038	88.01		60.37	54.85	Switzerland
Canada	50 254	41.32		51.51	53.54	Canada
Sweden	107 107	88.07		60.95	55.52	Sweden
Spain	110 911	91.20		48.60	40.08	Spain
Australia	39 274	32.29		49.56	53.02	Australia
New Zealand	33 402	27.46		42.81	45.88	New Zealand
Hungary	29 331	24.12		39.82	42.96	Hungary
Russia	32 943	27.09		48.56	52.86	Russia
Singapore	29 467	24.23		36.47	38.92	Singapore
South Korea	37 184	30.57		42.25	44.59	South Korea
Taiwan	N/A	N/A		N/A	43.59	Taiwan
South Africa	N/A	N/A		N/A	40.46	South Africa
Malaysia	6 272	5.16		27.44	31.90	Malaysia
China (+ Hong Kong)	50 955	41.90		45.66	46.41	China (+ Hong Kong)
Philippines	3 440	2.83		20.79	24.38	Philippines
Thailand	5 205	4.28		17.77	20.47	Thailand
India	N/A	N/A		N/A	46.80	India
Indonesia	4 517	3.71		16.61	19.19	Indonesia
Mexico	35 503	29.19		23.01	21.77	Mexico
Brazil	31 947	26.27		38.05	40.40	Brazil
Argentina	5 035	4.14		23.63	27.53	Argentina
Venezuela	2 323	1.91		18.09	21.33	Venezuela
Poland	30 137	24.78		35.98	38.22	Poland
Czech Republic	29 976	24.65		38.67	41.47	Czech Republic
Ireland	82 484	67.82		51.29	47.99	Ireland
Israel	308	0.25		48.52	58.17	Israel

References

Chapter V
Assessing the Effect and Sensitivity of Expert Opinion in HTI Indicators

by
Elmer Yglesias

Validity, reliability and sensitivity tests were performed on HTI 1999 data to study the effectiveness of the model suggested by its present formulation. Accordingly, the model was statistically analyzed with the benefit of time-lagged indicators collected during the past decade. Analysis of the collected data served two purposes: (1) to examine the relative ability of expert opinion vs. statistical data to assess a country's present and future high technology production capacity, and (2) to evaluate whether the computation of output indicators using this expert opinion is proper and effective. Based on the statistical tests-- the model holds, but problems with opinion bias, indicator formulation, and relative scoring were apparent. This brief reports on several of these details and provides guidelines for later survey collections.

Statistical Analysis Background

This brief assumes the reader's familiarity with HTI and published studies; references can be found at http://www.tpac.gatech.edu/hti99.html.

Statistical computations were performed on HTI 1999 data to test (a) the validity and reliability of the sample via a series of correlation runs, and (b) the predictive validity of the model itself. Validity, reliability, and sensitivity of HTI 1999 data were tested by performing the following statistical calculations and/or formulations:

a. Correlation matrices were computed for the individual components of each of the four input indicators and TS.
b. In order to observe how closely related are the opinion-based components and the statistical-based components, each input indicator and TS were reorganized accordingly into two 'sub-indicators' (one opinion-based and one statistical-based) and then their correlation matrices were closely compared.
c. Correlation matrices were computed for each input sub-indicator vs. its corresponding indicator, in order to assess sensitivity.
d. The variance within each country's expert opinion responses was computed and high values/outliers were identified.
e. Survey questions that yielded high variance were identified.

The predictive validity of the model was tested by performing a series of multiple regressions. TS indicator for 1999 was regressed against the corresponding four input indicators for 1999, 1996, 1993, and 1990 (partial). Optimization was then explored by testing various alternative weights on the components of TS, which yielded at least one new balanced formulation.

General Findings and Recommendations from the Statistical Tests

Formulation

Indicator formulation should be reconsidered to include a different balance between its expert-based components and statistical-based ones. For example, PC has a formulation that uses three expert-based components while only one statistical-based one is incorporated with them. This may explain why the expert-based sub-indicator [PCEXPERT] highly correlates with PC, while the statistical-based one is not equally/similarly as strong [PCSTATIS], and the correlation between the two sub-indicators is so low.

		SPC	PCEXPERT	PCSTATIS
SPC	Pearson Correlation	1.000	.909**	.724**
	Sig. (2-tailed)	.	.000	.000
	N	33	33	33
PCEXPERT	Pearson Correlation	.909**	1.000	.372*
	Sig. (2-tailed)	.	.	.033
	N	33	33	33
PCSTATIS	Pearson Correlation	.724**	.372*	1.000
	Sig. (2-tailed)	.000	.033	.
	N	33	33	33

** Significant at the 0.01 level (2-tailed)
* Significant at the 0.05 level (2-tailed)

Nevertheless, a more appropriate balance can be formulated, as for example, TS, where data from 1990-99 indicates that an optimized formulation appears to follow the weighting:

$$TS = 2/3*SQ14I + 1/6*SX + 1/6*SA2$$

The results of using the reformulated TS raised the model's R square and improved TI significance with $t^*>2.04$ and Sig. $T<0.05$ (R square=0.882; minor significance loss in PC (SPC99); the model was then verified using stepwise regression).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.939	.882	.865	6.7300

a Predictors: (Constant), SPC99, SSE99, SNO99, STI99

Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	-12.357	6.522		-1.895	.069
	SNO99	.106	.149	.081	.711	.483
	SSE99	-6.116E-02	.154	-.043	-.397	.694
	STI99	.372	.171	.333	2.179	.038
	SPC99	.755	.215	.603	3.513	.002

a Dependent Variable: NSTS99

Furthermore, formulation of indicators should avoid using the same survey items. For example, PC and TS both make use survey item Q14i. Therefore, when tested, their correlation was very high, and any regression analysis performed of input indicators on output indicators is likely to be skewed in its significance.

Redundancy of Reed Electronic Research (Elsevier Yearbook of World Electronics) Data

The present formulation's use of the Reed Electronic Research data as a component for several indicators should be reviewed. Testing the model may result in higher R squared in part because indicators TS, PC, TE, and RTC all either share A2YY or A26YY (autocorrelation). Furthermore, when indicators are added for an average, A2YY (or A26YY) is compounded. As the formulation intends, the components A26YY and A2YY as used in PC and TS, respectively, may not be sufficiently different: correlation between electronic production (A26YY) and electronic exports (A2YY) is likely to be high intrinsically. The introduction of a patent indicator, as suggested by Nils Newman, could compensate for the over-reliance on Reed Electronic Research data that currently is skewing some of the correlations between indicators.

Two survey questions should be reviewed for wording.

Using a variance greater or equal to one as a criterion, Q1 and Q7 have high variance and should be reviewed for wording. This finding is consistent in all surveyed years. In particular, Q7 historically exhibits very high variance, which in turn may have an impact on TI via its current formulation.

Question Number	Total 1999 Countries with Var>=1	Total 1996 Countries with Var>=1	Total 1993 Countries with Var>=1
Q1	11	7	9
Q7	11	10	9
Q14c F	11	7	4
Q14g F	12	5	2
Q14h F	7	2	1

Q14#F future prediction survey items do indicate some significant variance, but this may be attributed to differing opinion about the course of each country in the future of high technology competitiveness. Q14iF asks experts to predict what will be the technological production capability for a given country 15 years in the future (scale 1-5). In fact, a comparison of 1993 and 1999 expert opinion data of production capabilities indicated that their opinion (that is, their ability to predict) has been over-optimistic (also true for intervals from 1993-96 and 1996-99). Fortunately, since the formulation of TS and RTC rely solely on 'present' data, it avoids this overestimation (and greater error) of the predictions in the 'future' data. Nevertheless, it appears that expert

Doctorales (Paris: 1998); Germany—Statistisches Bundesamt, Prüfungen an Hochschulen (Wiesbaden: 1998); United Kingdom—Higher Education Statistical Agency, Students in Higher Education Institutions, 97/98 (Cheltenham: 1999); United States—National Science Foundation, Science Resources Studies Division, Science and Engineering Doctorate Awards: 1997, NSF 99-323 (Arlington, VA: 1999).

Survey questions can benefit from having a country as a benchmark for relative comparison

Currently, survey questions are designed to collect opinion on a given country without providing a country of comparison (for exception in a 1987 prototype survey instrument, which used the U.S. as the benchmark). Not having an anchor may result in expert opinion that may be locally, regionally, or internationally based; the survey offers no reference on what basis the expert is responding, and in turn--the formulations should not simply assume the highest ranking country is the benchmark that the user has in mind. The problem is particularly acute in competitive regions such as Asia, where expert opinion might be strongly influenced by regional competition.

Recommendations

Indicator formulation should be reconsidered to include a different balance between its expert-based and statistical-based components. A different balance for TS can be formulated, for example, where data from 1990-99 indicates that an optimized formulation appears to follow the weighting: TS = 2/3*SQ14I + 1/6*SX + 1/6*SA2. This formulation increases R squared in the model and improves the significance level of TI.

The present HTI formulation's use of the Reed Electronic Research data as a component for several indicators should be reviewed. Testing the predictive value of the model results in high R squared in part because indicators TS, PC, TE, and RTC all share either A2YY or A26YY (autocorrelation). The introduction of a patent indicator could compensate for the over-reliance on Reed Electronic Research data that currently is skewing some of the correlations between indicators.

Using a variance greater or equal to one as a criterion, survey questions Q1 and Q7 have excessively high variance and should be reviewed for wording. In particular, Q7 historically exhibits very high variance, which in turn may have an impact on TI via its current formulation.

An education indicator (ED) should be considered, reformulated mainly from SE. This would bring greater stability to SE, which appears to be overly sensitive because of its somewhat unrelated components. A possible formulation for ED could be [(HMHS99 from SE) + (Q2 from NO) + (Q8 from TI)]/ 3. Also, the UNESCO data HMHS99 could be enhanced with NSF *Science and Engineering Indicators* data on S&E education.

Survey questions can benefit from having a country such as the U.S. as a benchmark for relative comparison. Currently, survey questions are designed to collect opinion on a given country without providing a country of comparison.

Chapter VI
Incorporating Measures of Social Capital in HTI Model

by
David Roessner

In a series of articles and a book, Kash and Rycroft have argued that the economic success of nations, industries, and firms requires the commercialization of "complex technologies" that can be developed and produced by complex, self-organizing networks (Kash and Rycroft, 1998; Rycroft and Kash, 1999a, 1999b). They define these concepts as follows (Kash and Rycroft, 2000):

> "Complex technologies are those products or processes that cannot be understood in full detail by an individual expert sufficiently to communicate the details across time and space."
>
> "Complex networks are those linked organizations that crate, acquire and integrate the diverse knowledge and skills required to innovate complex technologies. Self-organization refers to the capacity these networks have for reordering themselves into more complex structures and for using more complex processes without centralized management guidance."

Examples of complex, self-organizing networks directed toward technological innovation include horizontal, inter-firm corporate alliances that sometimes involve competitors, vertical alliances between manufacturers and suppliers, and formal research collaboration among industrial firms, government agencies, and universities. These networks, according to Kash and Rycroft, have three sets of resources: core capabilities (the knowledge and skills that give the network the ability to innovate technologies uniquely well), complementary assets (supplementary bodies of knowledge and skills that have been accessed to take full advantage of core capabilities), and the capacity to learn (learning that occurs in the process of solving problems). Learning is both social and technological, and a key element of successful social learning involves trust. Trust, together with other ways of behaving appropriately such as reciprocity and nonopportunism, facilitate learning. "Trust and reciprocity lead to cooperative patterns of behavior that, in turn, increase the productivity of knowledge. . . . Trust allows network members to interact in ways that generate a form of social capital (e.g., a 'stock' of collective learning that only can be created when a group of organizations develops the ability to work together for mutual gain. . . ." (Kash and Rycroft, 2000: 820-821).

To the extent that complex technologies represent the forefront of innovation in high-tech industries, the level of a nation's social capital will, in part, determine the extent to which that nation can compete internationally at the cutting edge of technology. Indeed, Fountain (1998) observes that the concept of social capital is drawn from research that relates the nature of institutional and social arrangements on economic development. Branscomb (199_) extends this idea to explain differences in innovation rates among countries with similar capital, labor, and national differences. Powell, Koput, and Smith-Doerr (1996) studied learning networks in the U.S. biotechnology industry. They note that "when the knowledge base of an industry is both complex and expanding and the sources of expertise are widely dispersed, the locus of innovation will be found in networks of learning, rather than in individual firms. The large-scale reliance on interorganizational collaborations in the biotech industry reflects a fundamental and pervasive concern with access to knowledge."

The possible relationship between social capital and economic growth has been investigated empirically by Knack and Keefer (1997), who correlated measures of trust and civic norms as indicators of social capital with economic performance (average annual growth in per capita income, 1980-92) for 29 market-based countries. Knack and Keefer found that trust and civic cooperation are associated with economic performance, and that trust and norms of civic cooperation are stronger in countries with formal institutions that effectively protect property and contract rights, and in countries that are less polarized along lines of class or ethnicity (Knack and Keefer, 1997: 1251).

Knack and Keefer's data on trust and civic norms were obtained from the World Values Survey (http://wvs.isr.umich.edu/index.html), which has carried out national surveys of basic values and beliefs of citizens in more than 65 societies on all six continents. At the global level, surveys were conducted in 1990-91, 1995-96, and 1999-2000. The 1990-93 survey covered 42 independent countries; the 1995-97 survey covered 54 countries. Sixty-six countries have been surveyed in at least one wave of the investigation. The following table shows country coverage for HTI countries as of the 1995 surveys:

COUNTRY	WVS coverage
USA	x
JAPAN	x
GERMANY	x
UNITED KINGDOM	x
FRANCE	x
NETHERLANDS	x
ITALY	x
SWITZERLAND	x
SWEDEN	x
SPAIN	x
IRELAND	x
CANADA	x
AUSTRALIA	x
SOUTH AFRICA	x
NEW ZEALAND	x
RUSSIA	x
POLAND	x
HUNGARY	x
CZECH REPUBLIC	x
SINGAPORE	
SOUTH KOREA	x
TAIWAN	x
MALAYSIA	
CHINA	x
THAILAND	
INDONESIA	
PHILIPPINES	x
INDIA	x
MEXICO	x
BRAZIL	x
ARGENTINA	x
VENEZUELA	x
ISRAEL	

Incorporating Measures of Social Capital in Lead Indicators

There is substantial theoretical and some empirical basis for including a measure of social capital in the HTI model. If the data are based on broad measures of civic cooperation and trust, as are those using the World Values Survey, then the most appropriate lead indicator would be socioeconomic infrastructure. If the data are based on measures more specific to business alliances such as formal R&D collaborations, data on co-authorship of technical articles across institutions, etc., then the most appropriate indicators would be technological infrastructure. At present, only the WVS offers data that spans any significant proportion of the HTI countries, and so presents a possible opportunity. Additional investigation, however, would be necessary to check country coverage for the 1999-2000 survey, examine reliability and validity of the WVS data for our purposes, and conduct sensitivity analyses for various ways of incorporating the data into HTI.

Research Policy, **29**, 7-8 (August 2000): 819-831,

Knack, Stephen and Keefer, Philip. "Does Social Capital Have an Economic Payoff? A Cross-Country Investigation," *The Quarterly Journal of Economics*, November 1997: 1251-1288.

Powell, W.W., Koput, K.W., and Smith-Doerr, L. "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology," *Administrative Science Quarterly*, **41** (1996): 116-145.

Rycroft, R.W., and Kash, D.E. "Managing Complex networks Key to 21st Century Innovation Success,"*Research-Technology Management*, **41**, 3 (May/June 1999a).

Rycroft, R.W., and Kash, D.E. *The Complexity Challenge: Technological Innovation for the 21st Century*. London: Pinter, 1999b.

World Values Survey http://wvs.isr.umich.edu/index.html.

Chapter VII
Web Basis for 1999 HTI Survey

by
Xiao-Yin Jin

In our earlier studies, the "soft data" collections from HTI experts were mainly conducted by the traditional method – surface mail or faxes. With the revolution of information technology on a global scale, it becomes possible to conduct the survey on the World Wide Web. We used 'Microsoft FrontPage' software to design our HTI 1999 web survey. In doing so, we made the following minor changes from our 1996 questionnaire, answer sheets, and cover letter (the expert opinion questionnaire has remained essentially the same from 1990 on):

- Added 3 new target countries (Ireland, Israel, and Czech Republic)
- Added 'software' as one of nine sectors inquired about in the last question
- Adapted for web-based surveying
- Made minor format changes.

We published our questionnaire on the web (http://tpac.gatech.edu/hti99/) with background materials and followed up by e-mail to invite experts to participate in this HTI Panel. The web-based approach considerably facilitates collection internationally. This is vital, since we seek persons familiar with technology-based economic development in specific countries. The advantages of web survey are:

- Compared with the traditional method, it is more efficient. We included our web address for the 1999 HTI Survey with the e-mail cover letter to more than 1200 experts without any mail charges.
- Quick responses can be obtained. In the following few days after publishing the web address for our survey, we received many answers from experts throughout many countries in the world. We could complete the web survey within a few weeks, given a good network of contacts with the HTI International Panel.
- Communications between HTI staff and HTI experts in any part in the world for discussion on any issues related to the survey were much easier than before.
- The web-based survey makes it possible to get more experts involved even without initially knowing their names and addresses. Theoretically, nearly all HTI experts in the world have the opportunity to participate in our web survey if they are interested in this area and can access the Internet.

One problem is that some experts, especially those from developing countries, are unable to access the Internet. So, as an alternative we also provided an e-mail version of the survey as well as hard copy (this combined all three parts – cover invitation letter, questionnaire, and answer sheet, together as one document). This problem should lessen in the future. Another problem is that we have no capacity to compensate panelists for their responses. Instead, we offered all respondents the chance to win one of five $50 gift certifications to amazon.com, the Internet bookstore. Although this was successful, we probably need additional incentives to increase the size of the panel.

We plan to make some improvements for our web survey in the future (scheduled in 2002):

- Review the questionnaire and indicators for minor revision to reflect the emergence of knowledge-based economy, and explore the feasibility of including patent data and services/non-manufacturing products.
- Update and expand the International High Tech Indicators Panel, moving toward establishing a large, reliable, and reasonably stable network of experts. There were 303 members of the Panel in the 1999 HTI survey (207 members in 1996); collectively they provided 336 responses (257 responses in 1996). The addresses and affiliations of these panelists need to be updated and new members need to be added to the panel to increase the average number of respondents for selected countries that had relatively low respondents in the 1999 survey. Our goal continues to be to achieve a minimum of ten respondents per country (the range of responses was 6 to 22 in the 1999 survey).
- Make efforts to promote the HTI web survey and let more HTI experts have the chance to access our web site.

Chapter VIII
Summary of Major Results and Recommendations

Incorporating Non-manufacturing Industries in the Definition of "High-Tech" and in Lead Industries.

Based on an assessment of the nature of knowledge-intensive services and available data that seek to measure imports and exports of these services, it would appear that the most relevant category of World Bank data on trade in commercial services is "other commercial services," since it includes most of those services mentioned as particularly knowledge-intensive. World Bank data on total commercial service exports, other commercial exports as a percentage of total commercial exports, and dollar value of other commercial exports was examined for HTI countries. The face validity of these export data, indicated by the ranking of HTI countries, seems sufficiently high to warrant further investigation of inclusion of these exports in the definition of high tech exports used for TS, TE, and RTC.

In addition, OECD's 1999 Scoreboard provides data on real value added in knowledge-intensive industries, 1987 through 1996, for the OECD member countries, Mexico, and South Korea. If such data were available for all HTI countries they would offer a promising additional or substitute component of a lead indicator such as PC. Also, national exports in these ISIC code classifications could be added to existing manufacturing exports in ISIC classifications used in current HTI high tech output indicators.

WEFA, formerly Wharton Econometric Forecasting Associates, has assembled industry and trade data for 68 countries over the period 1980-1997. WEFA provides national production and trade data (measured in millions of 1997 U.S. dollars) for five knowledge-based (high-tech) service industries: communication services, financial institutions, business services, educational services, and health services. The WEFA data that we could obtain from S&E Indicators 2000 and from staff at NSF, which has a subscription to WEFA data, suggest both strengths and weaknesses. WEFA is a potentially promising source, though, and should be explored in greater depth in the future.

Production of knowledge-based services, as measured by WEFA, could serve as the non-manufacturing analog of EDP production, an industry whose output enhances innovation and productivity in many other key industries in the economy. If WEFA data were the only source of production information for knowledge-based services for HTI countries, for purposes of consistency it might be desirable to use the same source for export data used to enhance HTI output indicators.

Incorporating Emerging or Leading-Edge Technologies

INSPEC and *EI Compendex* class codes were used to measure research activity of nations related to the Rand Corporation's leading "emerging technology" categories. These classes were screened to identify those that show strong recent and increasing publication rates. The resulting measures show strong convergence; indeed their lack of divergence is unsettling. Our measures suggest that China now stands forth as an "emerging technology" research power comparable to

Germany, UK, and France. A number of other nations evidence a striking lack of R&D activity using these measures, posing questions about their longer range high-tech competitiveness.

Patents

Non-Resident Applicant patent data appears to provide the most promising patent-based indicator in terms of coverage, ease of use, and availability. Although this indicator is the least capable of speaking directly to a nation's ability to innovate, it does provide insight into other nations' perceptions of national capacity to develop, produce, and market new technology. As such, it is appropriate to add this measure as a component of Technological Infrastructure (TI). Overall, the addition of Non-Resident Application data appears to benefit the formulation of Technological Infrastructure and should be included in future cycles of the HTI project.

Assessing the Effect and Sensitivity of expert Opinion in HTI Indicators

Indicator formulation should be reconsidered to include a different balance between its expert-based and statistical-based components. A different balance for TS can be formulated, for example, where data from 1990-99 indicates that an optimized formulation appears to follow the weighting: TS = 2/3*SQ14I + 1/6*SX + 1/6*SA2. This formulation increases R squared in the model and improves the significance level of TI.

The present HTI formulation's use of the Reed Electronic Research data as a component for several indicators should be reviewed. Testing the predictive value of the model results in high R squared in part because indicators TS, PC, TE, and RTC all share either A2YY or A26YY (autocorrelation). The introduction of a patent indicator could compensate for the over-reliance on Reed Electronic Research data that currently is skewing some of the correlations between indicators.

Using a variance greater or equal to one as a criterion, survey questions Q1 and Q7 have excessively high variance and should be reviewed for wording. In particular, Q7 historically exhibits very high variance, which in turn may have an impact on TI via its current formulation.

An education indicator (ED) should be considered, reformulated mainly from SE. This would bring greater stability to SE, which appears to be overly sensitive because of its somewhat unrelated components. A possible formulation for ED could be [(HMHS99 from SE) + (Q2 from NO) + (Q8 from TI)]/ 3. Also, the UNESCO data HMHS99 could be enhanced with NSF *Science and Engineering Indicators* data on S&E education.

Survey questions can benefit from having a country such as the U.S. as a benchmark for relative comparison. Currently, survey questions are designed to collect opinion on a given country without providing a country of comparison.

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