1996 INDICATORS OF TECHNOLOGY-BASED COMPETITIVENESS OF NATIONS

SUMMARY REPORT

J. David Roessner
Alan L. Porter
Nils Newman

A report to the Science Indicators Unit, Science Resources Studies Division, National Science Foundation under Purchase Order D22588X-00-0

July 1997

TECHNOLOGY POLICY AND ASSESSMENT CENTER
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332
USA
APPENDIX: CURRENT INDICATOR FORMULATIONS

National Orientation (NO): Evidence that a nation is taking directed action to achieve technological competitiveness. Evidence of such action could be manifested at the business, government, or cultural levels, or any combination of the three.

Formula: \[ SNO = \frac{SQ1 + SQ2 + SQ3 + SQ4 + SF1V96}{4} \]

Q1 = To what extent does this country's government evidence a deliberate strategy to promote high technology-intensive production for export?
Q2 = To what extent do this country's basic cultural values associate technology and technological change with desirable social development?
Q3 = How closely do influential groups (e.g., unions, trade associations, religious organizations) in this country associate technology with desirable social development? For instance, one could imagine some groups not being favorably disposed toward introduction of more technologies. Or, some societies may emphasize redistributive measures, such as land reform, over technology-intensive industrial development?
Q4 = Please rate the presence of an "entrepreneurial spirit" in this country. That is, to what extent are its citizens, especially the business community, predisposed toward innovative action and economic risk-taking?
F1V96 = The Frost and Sullivan 5-year investment risk assessment index for 1996.

Socioeconomic Infrastructure (SE): The social and economic institutions that support and maintain the physical, human, organizational and economic resources essential to the functioning of a modern, technology-based industrial nation.

Formula: \[ SSE = \frac{SQ5 + SQ10 + SMH993}{3} \]

Q5 = Please give us your judgment of the mobility of capital in this country.
Q10 = To what extent are foreign-owned firms encouraged to do business in this country?
SMH993 = Harbison-Myers Human Skills Index for 1993. The formula for the index is W493+4*W693.
W493 = The percentage of students enrolled in secondary education in 1993. The percentage is based on the number of individuals in school vs. the total number of individuals who could be enrolled as defined by UNESCO.
W693 = The percentage of students enrolled in tertiary education in 1993. The percentage is based on the number of individuals in school vs. the total number of individuals who could be enrolled as defined by UNESCO.

---

1 Indicator formulae are written in "S-scores," which means that each indicator and its components are based on a 0 - 100 scale. Depending on the component, three classes of scaling are used:

- Absolute: for questionnaire items on a 1-5 scale, subtract 1 and multiply by 23 to obtain a 0-100 scale.
- Absolute 0; Relative 100: for other items there is a true 0 minimum (e.g., high tech exports cannot be negative) and a relative maximum (i.e., divide by the highest national value).
- Relative 0; Relative 100: for the remaining items, add the most negative country value to the raw scores, then divide by the highest national value to obtain 0-100 scaling.

2 Two digit numbers at the end of statistical variables (e.g., F1V96) represent the year from which the data are drawn.
**Technological Infrastructure (TI):** The institutions and resources that contribute to a nation's capacity to develop, produce, and market new technology.

**Formula:** STI = \[S(Q7+Q8)/2+SQ9+SQ11+SED98+S&E93)/5\]

Q7 = To what extent is this country capable of replenishing and increasing its supply of qualified, graduate-level (post-baccalaureate) scientists and engineers via local (indigenous) training and educational institutions?

Q8 = How would you characterize this country's contribution to the international pool of significant scientific and technical knowledge?

Q9 = Measures of research and development activity are available for most countries (see data table for example). To what extent do R&D activities in this country relate to industrial enterprise?

Q11 = The acquisition of "technological mastery" (the ability to make effective use of technological knowledge) is critical to development of technology-intensive products. To what degree has this country achieved technological mastery in high tech production?

EDP96 = Electronic data processing equipment purchases for 1996 as obtained from the Elsevier Yearbook of World Electronics Data 1996.

S&E93 = The raw number of scientists and engineers engaged in research and experimental development as defined in the UN Statistical Yearbook, 1993.

**Productive Capacity (PC):** The physical and human resources devoted to manufacturing products, and the efficiency with which those resources are used.

**Formula:** SPC = \[S(Q6+Q12+Q13)+SA2696/2)/1.5\]

Q6 = Please rate the quantity and quality of skilled manufacturing labor available in this country.

Q12 = To what extent does a system of indigenous producers of components for technology-intensive products exist?

Q13 = Please rate indigenous industrial management capabilities to develop, produce, and market technology-intensive products.

A2696 = The value of total electronics production for 1996 as obtained from the Elsevier Yearbook of World Electronics Data 1996.

**Technological Standing (TS):** The current world market share in high technology products, reflecting not only current export market share statistics but also current manufacturing capability.

**Formula:** STS = \[SQ14i+sx95+SA294)/3\]

Q14i = Please characterize the present overall technology-intensive production in this country.

X95 = The value of high tech exports as drawn from the United Nations Statistical Office trade statistics for 1995. High tech exports were defined in accord with the U.S. Department of Commerce's DOC3 definition, excluding missiles and ordnance. X95 includes STIC Revision 2 codes 51, 52, 54, 58, 712, 713, 714, 716, 718, 75, 76, 772, 776, 792, 87, and 88.

A294 = The value of electronics exports in 1994 as obtained from the Elsevier Yearbook of World Electronics Data.
**Technological Emphasis (TE):** The extent to which a country emphasizes high tech products in its export mix.

**Formula:** \[ \text{STE} = \frac{\text{SRCP}95 + \text{SAIS}94}{2} \]

- \( \text{RCP}95 = \) The ratio of high tech exports for 1995 to total exports for 1995. The formula for \( \text{RCP}95 = \frac{X95}{XCT95} \).
- \( X95 = \) The value of high tech exports in 1995 as reported by the UN Statistical Office.
- \( \text{XCT}95 = \) The total exports of a country in 1995 as reported by the UN Statistical Office.
- \( \text{AIS}94 = \) The ratio of electronic exports for 1994 to total exports for 1994. The formula for \( \text{AIS}94 = \frac{A294}{XCT94} \), where \( XCT94 = \) total exports of a country in 1994.
- \( A294 = \) The value of electronics exports in 1994 as reported by Elsevier Yearbook of World Electronics Data.

**Rate of Technological Change (RTC):** An indicator that captures the speed with which a country is expanding its export market share in high tech products.

**Formula:** \[ \text{SRTC} = \frac{\text{SRDX} + \text{SDAEX} + \text{SQ14Delta}}{3} \]

- \( \text{RDX} = \frac{(X95-X94)/X94}{.510} + ((X94-X93)/X93)*.306 + ((X93-X92)/X92)*.184 \)
- \( \text{XY} = \) The value of high tech exports for the year YY specified as drawn from the UN statistical office.
- \( \text{DAEX} = \frac{(A294-A293)/A293}{.510} + ((A293-A292)/A292)*.306 + ((A291-A90)/A290)*.184 \)
- \( A2YY = \) The value of electronics exports for the year YY specified as drawn from Elsevier Yearbook of World Electronics Data.
- \( \text{Q14Delta} = (\text{Q14i96} - \text{Q114i93})/\text{Q14i93} \)
- \( \text{Q14i96} = \) *Please characterize the present overall technology-intensive production in this country.* The answers are drawn from the 1996 survey.
- \( \text{Q14i93} = \) *Please characterize the present overall technology-intensive production in this country.* The answers are drawn from the 1993 survey.
BACKGROUND

Indicator development work at Georgia Tech has proceeded in phases. The first phase, begun in 1987, developed a conceptual model of the processes by which industrializing nations gain access to external technology and technical information, absorb that technology/information effectively, and institutionalize a science-based development and manufacturing capability leading to export-led growth in high technology products. Four "input" or leading indicators of a nation's future capacity (15-year time horizon) to compete in international markets in high technology products were developed, as were three "output" indicators of a nation's current international competitiveness. During this first phase, the indicators were applied to data for twenty countries representing a range of regions and extent of industrialization.

The second phase used data on an expanded set of 29 countries to examine in detail the indicators' reliability and validity. The conceptual model and the results of this phase are summarized in J.D. Roessner, A.L. Porter, and H. Xu, "National Capacities to Absorb and Institutionalize External Science and Technology," Technology Analysis & Strategic Management, Vol. 4, No. 2 (1992).

In the third phase of indicators work (1992-1995), we developed recommended formulae for seven indicators whose definitions followed the recommendations specified in the previous phase, applied them to generate a set of indicators using these recommended formulations, tested the value of the indicators for policy and scholarly purposes, and tested further the processes of data collection and verification. The results of this phase were published in two articles: David Roessner, 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; and Alan Porter, 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.

After nearly ten years of research and testing of a set of High Tech indicators at Georgia Tech, a reporting of results in Science and Engineering Indicators 1993, and completion of the phase three final report, it was timely and appropriate to move from indicator development and testing to routine data collection and reporting. This summary report describes the major results obtained during the first of the "routine" data collection and analysis phases of indicator research.

COUNTRIES INCLUDED

Several changes were made in the countries covered in the 1996 study compared with those included in 1993. Because of the absorption of Hong Kong into China in 1997, it was omitted as a separate country in the 1996 study. Three additional countries, Poland, Venezuela, and South Africa, were added in the 1996 study, so the total number of countries studied came to 30. As in previous reports, the countries are clustered roughly by region, aside from the "big three" -- United States, Japan, and Germany.

INDICATOR DEFINITIONS

The conceptual definitions of the seven indicators follow. They are the same as those used in the 1993 study. With the exception of Technological Emphasis, each indicator is comprised of both statistical data (S) and data from a survey of experts (E). Questionnaire data were obtained from a 1996 mail survey of the International Technology Indicators Panel, a group of 207 experts who collectively provided 265 responses; the average number of responses per country was 8.9, ranging from 5 to 18. Full operational definitions of the indicators and sources of data for statistical components and the numerical values of the indicators appear in the appendix to this Summary.

Raw data were transformed into scales of 0 to 100 for each indicator component and then averaged to generate comparable indicators with a 0 to 100 range. For survey items, 100 represents the highest response category for a question; for statistical data, 100 typically represents the value attained by the country with the largest value among the 30 countries. Thus, this is a relative scaling so that an apparent "decline" over time or low score is only relative to the other countries in that data set for a particular year.

National Orientation (NO): Evidence that a nation is undertaking directed action to achieve technological competitiveness. Such action can be manifested at the business, government, or cultural levels, or any combination of the three.
S: investment risk index (constructed from Frost and Sullivan data series)
E: questions addressing national strategy, implementation, entrepreneurship, attitudes toward technology.

Socioeconomic Infrastructure (SE): The social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to the functioning of a modern, technology-based industrial nation.
RESULTS: INPUT INDICATORS

Figure 1 shows National Orientation (NO), which indicates a country's commitment to technology-based development along a number of dimensions: government policy, political stability, entrepreneurial spirit, and acceptance of the idea that development should be technology-based. The 30 countries are presented in seven groupings that will be maintained throughout the presentation of data. Compared with 1993, there is a flattening of the profile overall, with the outstanding feature characterized by a few countries that exhibit relatively low levels of planning for technology-based development: South Africa, Russia, and Argentina. Notably, however, Russia's score has improved considerably since 1993. Taiwan and Singapore are standouts, although not by large margins. It appears that differences among countries' commitment to technology-based development are diminishing, a development worth attention.

Figure 2 displays country values of SE, which indicates the strength of each nation's educational system, its mobility of capital, and its encouragement of foreign investment. Socioeconomic infrastructure is more evenly distributed among the 30 countries than is National Orientation. As in the 1993 study, on this key measure of future capability, the remaining three Tigers (Singapore, South Korea, Taiwan) are striking in their parity with the strongest of the industrialized nations. Indonesia's apparent decline in commitment to this element of infrastructure warrants exploration.

Technological infrastructure (TI) captures the strength and contributions of a nation's scientific and engineering manpower, its EDP purchases, the relationship of its R&D to industrial application, and its ability to make effective use of technical knowledge. There continues to be much greater variation in TI among the 30 nations than was the case for either NO or SE (Figure 3). The U.S. and Japan are standouts, and Russia's defense-based technological infrastructure, apparent in the 1993 study, has declined only slightly. Indonesia's drop and the increases in infrastructure by India and the Philippines may be worth watching. Overall, however, there are no major changes in this indicator relative to 1993.

PC uses the value of electronics production and a set of survey items related to manufacturing and managerial capabilities to measure the amount and efficiency of resources devoted to manufacturing technology-intensive products. Productive Capacity clearly separates Japan and the U.S. from the rest of the countries in our sample (Figure 4). France has apparently overtaken Germany on this indicator, possibly a function of the continuing drain that German unification has placed on the economy. Russia, the
Philippines, and India increased since 1993, while Spain and Brazil dropped somewhat, on a relative basis.

The pattern of these four "leading" indicators shows more of a mixed picture than was the case in the 1993 study. In the earlier study, the Four Tigers had emerged as obvious challengers to the developed nations of the West, with several of the "Asian Cubs," notably Malaysia, the Philippines, and Indonesia following not far behind. The 1996 results show some consistency but also show, pending further investigation, how social instability and the narrowness of these nations' industrial base, among other factors, can lead to plateaus or even temporary setbacks in their pursuit of technology-based competitiveness.

RESULTS: OUTPUT INDICATORS

Figure 5 shows High Tech Standing (TS), a measure of current high tech production and export standing. As in 1993, Japan and the US remain well ahead of all others in high tech competitiveness. The relative positions of other OECD nations in our sample have not changed substantially. The nations of the Pacific Rim continue to show steady increases in their competitiveness, but no nation stands out in terms of its position relative to 1993. Russia shows a significant increase, although this may not be a fully robust finding due to the small number of responses for Russia in both 1993 and 1996.

Figure 6 profiles the 30 countries on the degree to which they emphasize high tech products in their export mix. Singapore again sets the standard, with its extreme emphasis on electronics. Malaysia follows, but the remaining countries show more diversification in their exports. Only Mexico seems to have substantially increased its emphasis on high tech exports.

RTC is intended to be a rate of change measure. As such, countries beginning with lower High Tech Standing can more easily show high rates of change. Mexico is the standout for 1996, possibly reflecting NAFTA, whereas Indonesia was in 1993. Australia and New Zealand have switched positions, with Australia now showing more rapid change. The remaining three Asian Tigers all continue to show high rates of change, even higher than in 1993. Malaysia, China, Thailand and the other nations of southeast Asia are increasing their market share of high tech products internationally at rates that equal those of the Three Tigers, suggesting that they are advancing notably.

Figures 9 through 15 compare the indicator values for the 27 countries studied in both 1993 and 1996. The most striking differences have been noted in the previous paragraphs.

As in 1993, we asked our expert panel to estimate high tech production capability at present and in 15 years for each of eight sectors and overall. Figure 8 compares present and future overall estimates provided by the 1996 panel. Not surprisingly, the flattening of the profile that appeared in the 1993 predictions is retained. The three new countries added to the sample, South Africa, Venezuela, and Poland, show the same optimistic predictions as other emerging nations.

CONCLUDING OBSERVATIONS

The projections of dramatically broadening, international high tech competition have critical implications for corporate planning and government policy making. The profiles vary importantly by sector but, as in 1993, the overall pattern is compelling: National high tech competition will shift from a steep slope to a broad plateau. High tech production will diffuse dramatically over the coming 15 years. No longer will a few leading nations dominate. Japan and the US are projected to maintain their lead, but the gap will close across the board as nations continue to invest in the factors that enhance their ability to compete in high tech products internationally.
Figure 7
Rate of Technical Change 1996
National Orientation (NO): Evidence that a nation is taking directed action to achieve technological competitiveness. Evidence of such action could be manifested at the business, government, or cultural levels, or any combination of the three.

Formula: \[ SNO = \frac{SQ1 + S(Q2+Q3)/2 + SQ4 + SF1V96}{4} \]

Q1 = To what extent does this country's government evidence a deliberate strategy to promote high technology-intensive production for export?
Q2 = To what extent do this country's basic cultural values associate technology and technological change with desirable social development?
Q3 = How closely do influential groups (e.g., unions, trade associations, religious organizations) in this country associate technology with desirable social development? For instance, one could imagine some groups not being favorably disposed toward introduction of more technologies. Or, some societies may emphasize redistributive measures, such as land reform, over technology-intensive industrial development?
Q4 = Please rate the presence of an "entrepreneurial spirit" in this country. That is, to what extent are its citizens, especially the business community, predisposed toward innovative action and economic risk-taking?
F1V96 = The Frost and Sullivan 5-year investment risk assessment index for 1996.

Socioeconomic Infrastructure (SE): The social and economic institutions that support and maintain the physical, human, organizational and economic resources essential to the functioning of a modern, technology-based industrial nation.

Formula: \[ SSE = \frac{SQ5 + SQ10 + SHMHS93}{3} \]

Q5 = Please give us your judgment of the mobility of capital in this country.
Q10 = To what extent are foreign-owned firms encouraged to do business in this country?
HMHS93 = Harbison-Myers Human Skills Index for 1993. The formula for the index is W493+4*W693.
W493 = The percentage of students enrolled in secondary education in 1993. The percentage is based on the number of individuals in school vs. the total number of individuals who could be enrolled as defined by UNESCO.
W693 = The percentage of students enrolled in tertiary education in 1993. The percentage is based on the number of individuals in school vs. the total number of individuals who could be enrolled as defined by UNESCO.

Technological Infrastructure (TI): The institutions and resources that contribute to a nation's capacity to develop, produce, and market new technology.

Formula: \[ STI = \frac{S(Q7+Q8)/2 + SQ9 + SQ11 + SEDP96 + SS&E93}{5} \]

Q7 = To what extent is this country capable of replenishing and increasing its supply of qualified, graduate-level (post-baccalaureate) scientists and engineers via local (indigenous) training and educational institutions?
Q8 = How would you characterize this country's contribution to the international pool of significant scientific and technical knowledge?
Q9 = Measures of research and development activity are available for most countries (see data table for example). To what extent do R&D activities in this country relate to industrial enterprise?

Q11 = The acquisition of "technological mastery" (the ability to make effective use of technological knowledge) is critical to development of technology-intensive products. To what degree has this country achieved technological mastery in high tech production?

EDP96 = Electronic data processing equipment purchases for 1996 as obtained from the Elsevier Yearbook of World Electronics Data 1996.

S&E93 = The raw number of scientists and engineers engaged in research and experimental development as defined in the UN Statistical Yearbook, 1993.

**Productive Capacity (PC):** The physical and human resources devoted to manufacturing products, and the efficiency with which those resources are used.

Formula:  \[ SPC = \frac{[S(Q6+Q12+Q13)+SA2696/2]}{1.5} \]

Q6 = Please rate the quantity and quality of skilled manufacturing labor available in this country.

Q12 = To what extent does a system of indigenous producers of components for technology-intensive products exist?

Q13 = Please rate indigenous industrial management capabilities to develop, produce, and market technology-intensive products.

A2696 = The value of total electronics production for 1996 as obtained from the Elsevier Yearbook of World Electronics Data 1996.

**Technological Standing (TS):** The current world market share in high technology products, reflecting not only current export market share statistics but also current manufacturing capability.

Formula:  \[ STS = \frac{[SQ14i+SX95+SA294]}{3} \]

Q14i = Please characterize the present overall technology-intensive production in this country.

X95 = The value of high tech exports as drawn from the United Nations Statistical Office trade statistics for 1995. High tech exports were defined in accord with the U.S. Department of Commerce's DOC3 definition, excluding missiles and ordinance. It includes STIC Revision 2 codes 51, 52, 54, 58, 712, 713, 714, 716, 718, 75, 76, 772, 776, 792, 796, 87, and 88.

A294 = The value of electronics exports in 1994 as obtained from the Elsevier Yearbook of World Electronics Data.

**Technological Emphasis (TE):** The extent to which a country emphasizes high tech products in its export mix.

Formula:  \[ STE = \frac{[SRCP95+SAIS94]}{2} \]

RCP95 = The ratio of high tech exports for 1995 to total exports for 1995. The formula for RCP95 = \( \frac{X95}{XCT95} \).

X95 = The value of high tech exports in 1995 as reported by the UN Statistical Office.

XCT95 = The total exports of a country in 1995 as reported by the UN Statistical Office.

AIS94 = The ratio of electronic exports for 1994 to total exports for 1994. The formula for AIS94 = \( \frac{(A294/(XCT94))}{\text{where } XCT94 = \text{total exports of a country in 1994}} \).

A294 = The value of electronics exports in 1994 as reported by Elsevier Yearbook of World Electronics Data.
Rate of Technological Change (RTC): An indicator that captures the speed with which a country is expanding its export market share in high tech products.

Formula: \( \text{SRTC} = \frac{[\text{SRDX} + \text{SDAEX} + \text{SQ14Delta}]}{3} \)

\( \text{RDX} = ((X95-X94)/X94)*.510+((X94-X93)/X93)*.306+((X93-X92)/X92)*.184 \)

\( \text{XYY} = \text{The value of high tech exports for the year YY specified as drawn from the UN statistical office.} \)

\( \text{DAEX} = ((A294-A293)/A293)*.510+((A293-A292)/A292)*.306+((A291-A90)/A290)*.184 \)

\( \text{A2YY} = \text{The value of electronics exports for the year YY specified as drawn from Elsevier Yearbook of World Electronics Data.} \)

\( \text{Q14Delta} = (\text{Q14i96-Q114i93})/\text{Q14i93} \)

\( \text{Q14i96} = \text{Please characterize the present overall technology-intensive production in this country. The answers are drawn from the 1996 survey.} \)

\( \text{Q14i93} = \text{Please characterize the present overall technology-intensive production in this country. The answers are drawn from the 1993 survey.} \)

1. Indicator formulae are written in "S-scores," which means that each indicator and its components are based on a 0 - 100 scale. Depending on the component, three classes of scaling are used:

- Absolute: for questionnaire items on a 1-5 scale, subtract 1 and multiply by 25 to obtain a 0-100 scale.
- Absolute 0; Relative 100: for other items there is a true 0 minimum (e.g., high tech exports cannot be negative) and a relative maximum (i.e., divide by the highest national value).
- Relative 0; Relative 100: for the remaining items, add the most negative country value to the raw scores, then divide by the highest national value to obtain 0-100 scaling.

2. Two digit numbers at the end of statistical variables (e.g., F1V96) represent the year from which the data are drawn.