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International high tech competitiveness: Does China rank #1?

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Abstract

This paper compares three selected indicator series that address national, technology-based competitiveness. The "traditional" Georgia Tech High Tech Indicators (HTI) have been comparing 33 nations with respect to current and future prospects at exporting high tech products since the late 1980's. Those indicators blend expert opinion with statistical time series data. Second, we introduce "statistics only" HTI, a revised formulation that addresses knowledge-based service export capabilities as well as high tech products, biennially. Third, the World Economic Forum annually generates its Global Competitiveness Index (GCI), treating 125 countries.

The traditional HTI reported China supplanting the United States as the top-ranking economy as of 2007. That has generated some controversy. In striking contrast, the 2006-07 GCI reported China as #54. This paper explores the bases for these differences. To substantial degree, those derive from whether one normalizes based on a nation's size. We conclude that these indicator series provide multiple perspectives that complement each other. In the case of China, all of these indicators point to continuing dramatic increase in technology-based economic competitiveness. If not yet, then within not too many years, the United States will likely be supplanted by China as the leading technology-based economy.

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Introduction

Georgia Tech has been compiling national "High Tech Indicators" ("**HTI**"), with support from the U.S. National Science Foundation (NSF), since the late 1980s [see: //tpac.gatech.edu]. The primary purpose is to provide policy-makers and others with a means to gauge the present and likely future high technology competitiveness of rapidly industrializing countries. HTI cover 33 countries, including a number of highly developed nations for comparative interest. NSF incorporates selected HTI findings on future competitiveness ("INPUT indicators) in *Science & Engineering Indicators.* This paper keys on trends in "Technological Standing," our "output" indicator of present national competitiveness, with special focus on China.

HTI-2007 has sparked special attention because the #1 Technological Standing is now held not by the United States, but by China. In contrast, the 2006-2007 Global Competitiveness Index (GCI – World Economic Forum 2006) ranks China #54 among the 125 countries it treats. Differences of such magnitude should not spark controversy so much as stimulate consideration of what these indicators reflect. We are in the process of establishing a new statistics-only HTI(S) series. This tells a still different tale of competitiveness. We explore, herein, these three perspectives – Traditional "HTI(T)", HTI(S), and GCI -- on national capability to sell technology-based products and services in the global marketplace.

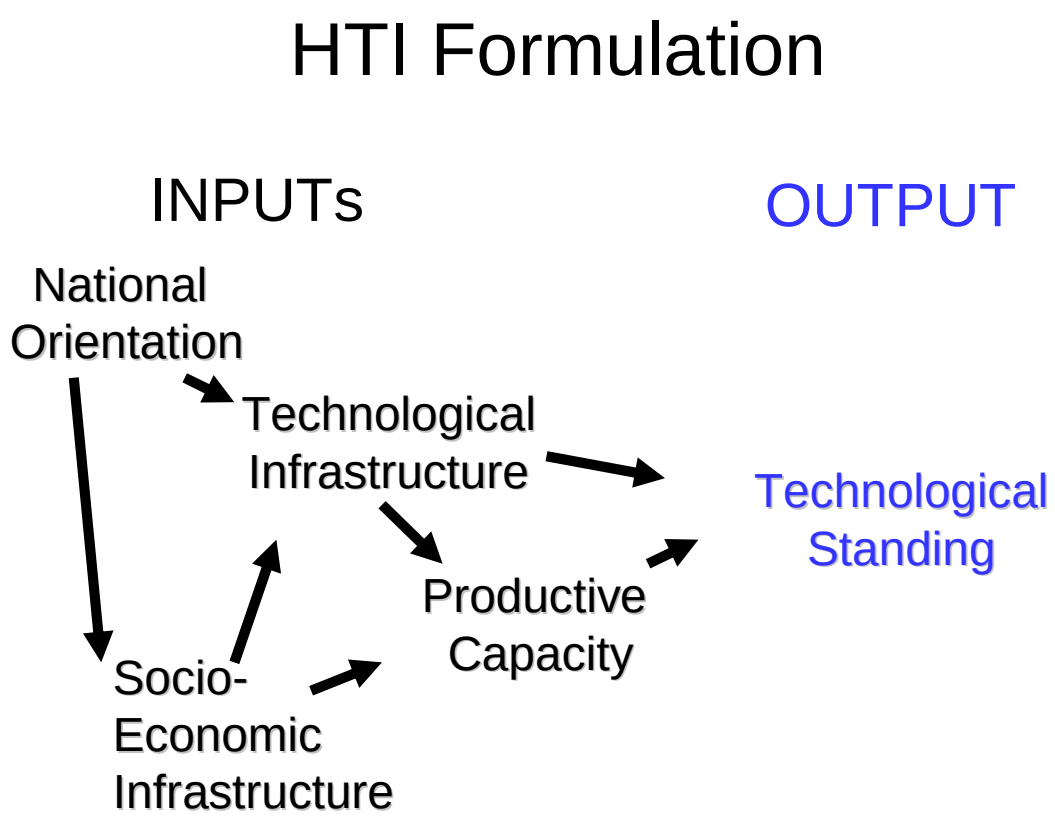
Background on the indicators

The HTI were developed as empirical manifestations of a conceptual model with four "input" factors (c.f., Roessner et al., 1992, for discussion of the conceptualization of these leading indicators). Our website offers a number of papers and reports from over the years, expounding on the indicators [//tpac.gatech.edu]. The HTI model posits that technology-based competitiveness depends long term (i.e., on the order of 15 years in the future) on the conjunction of:

1) National Orientation to so compete (**NO**)
2) Socio-Economic infrastructure **(SE**)
3) Technological Infrastructure (**TI**), and
4) Productive Capacity (**PC**)

Those four are sometimes averaged together as a composite "**INPUT**" indicator. Current Technological Standing ("**TS**") is tracked with a single "output" factor addressing current high technology export activity. Figure 1 sketches our current understanding of relationships among the factors. Experience in tracking them over two decades has led us to perceive TI and PC as more proximate influences on TS than are NO and SE.

Figure 1. Georgia Tech High Tech Indicators Conceptual Model



The indicators are defined as follows:

- **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.
- **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.
- **Technological Infrastructure (TI):** The institutions and resources that contribute to a nation's capacity to develop, produce, and market new technology.
- **Productive Capacity (PC)**: The physical and human resources devoted to manufacturing products, and the efficiency with which those resources are used.
- **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.

The traditional indicator set – **HTI(T)** -- combines statistical and expert opinion sources (Porter et al. 2008a). The HTI(T) statistical measures draw upon the United Nations Statistical Office, the World Bank, UNESCO, WIPO, Reed Yearbook of World Electronics, PRS Political Risk Letter, and the IMD World Competitiveness Report. The 2007 HTI(T) expert opinion consists of 392 assessments of technology-based capabilities for 33 target countries, an average of about 12 assessments per country.

Our new statistics-only version – **HTI(S)** – augments the statistical components of HTI(T) with additional series drawn from the World Development Indicators, Global Competitiveness Report, WIPO, and EI Compendex. Formulations are shown in the Appendix; these are elaborated for HTI(T) in the HTI-2007 Report and for HTI(S) in a corresponding report (Porter et al. 2008b) -- both available at //tpac.gatech.edu.

We here report on selected findings from both the traditional HTI(T), with the benefit of a consistent time series from 1993, and the new statistics-only HTI(S). Detailed operational definitions of the traditional indicators are provided in the full report, along with details on the statistical data sources.[2] The HTI-2007 Report covers the expert opinion survey questionnaire and methodology also. It and earlier reports, plus papers spotlighting interesting findings over the years, are available at //tpac.gatech.edu.

Note that the HTI indicators are relative. They are composed for the set of countries included in HTI, presently 33. Each HTI(T) component is scaled from 0-100, with 100 representing the highest national value for statistical components and the highest possible response for the scaled questions. HTI(S) values are presented as similarly rescaled standard scores (Z-scores) for the 33 countries on a given item.

We also compare with another indicators series. *The Global Competitiveness Report 2006-2007* is put out by the World Economic Forum (2006). Their Global Competitiveness Index (**GCI**) identifies nine pillars driving productivity and competitiveness:

- Institutions
- Infrastructure
- Macroeconomy
- Health and primary education
- Higher education and training
- Market efficiency
- Technological readiness
- Business sophistication
- innovation

The GCI conceptualization asserts that concerted effort and comprehensive policies make for competitive economies. GCI recognizes that suitable strategies will vary as a function of how developed an economy is. They report multiple indices, including subindexes for a) basic requirements (vital to those at a factor-driven stage – i.e., GDP per capita under US$2000), b) efficiency enhancers (vital to mid-stage development – i.e., GDP per capita of US$3000-9000), and c) innovation and sophistication factors (vital at the highest development stage – GDP per capita over US$17000). Transition stages fit between these. The GCI profiles 125 countries. Here's how our 33 countries fit the GCI stages:

[2] To give the flavor of these indicators that combine statistical and expert opinion measures, here is the formulation for TI, where "Q's" are question responses on a 1-5 scale:

TI = [(Q7 + Q8)/2 + Q9 + Q11 + EDP + S&E]/5.

- EDP = Electronic data processing equipment purchases for 2005 as obtained from the Reed Electronics Research
- S&E = The number of scientists and engineers engaged in research and experimental development as defined by UNESCO primarily from 2001.
- Q7 & Q8: output of indigenous academic S&E
- Q9: assessing linkages of R&D to industry
- Q11: ability to make effective use of technological knowledge

- Stage 1: China, India, Indonesia, Philippines
- Stage 1-2 Transition: Thailand
- Stage 2: Argentina, Brazil, Malaysia, Mexico, Poland, Russia, South Africa, Venezuela
- Stage 2-3 Transition: Czech Republic, Hungary, Korea, Taiwan
- Stage 3: All others

The GCI, as does HTI, blends statistical with expert opinion measures. They have a network of institutes (e.g., economics departments, independent research institutes, business organizations) around the world to provide the expert opinion (see World Economic Forum, 2006, p. 125 ff.). For 2006-2007, they obtained a total of 11,232 usable responses for 125 countries, an average of about 90 per country .

We draw upon the GCR 2006-2007 data selectively for our HTI(S)-07. We thus compare findings against this version. The GCR 2007-2008 is out now as well [http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm]. Notably, the rankings for China have escalated markedly in a year from #54 to #34.

Indicators, indicators

Today's competitive global economy and the growing awareness, even among economists, that technology is a prime driver of advanced economies, have led to a variety of attempts to gauge national technology-based competitiveness. Our early papers review extensive literature on the factors and influences affecting competitiveness in its various guises (c.f., Roessner, Porter, and Xu 1992, and others posted at //tpac.gatech.edu). We have updated treatment of the literature along the way (c.f., Porter et al. 2001; Roessner et al. 2002). Yglesias (2003) compared and synthesized our approach to technology-based competitiveness with that of Michael Porter and the US Council on Competitiveness.

Many issues harass those who set forth to provide definitive indicators. Recalling our own saga as we created the Georgia Tech HTI in the 1980's, issues include:

- Which "Bottom Line"? – HTI were formulated to address national economies' current and future abilities to compete in exporting high technology-based products. Related, yet different, national intelligence targets include: technology-based production for domestic use (and/or export), innovativeness (e.g., patenting), business climate (i.e., favorable to entrepreneurship), and information-based service sector for domestic use and/or export.
- Units of analysis -- Given the increasing influence of multinational corporations, does it even make sense to study nations as key units? We believe it does, but recognize that some trade and policy facets transcend national distinctions.
- Normalization – should we measure total national economies or per capita metrics? We chose to compare national economies as the key unit of policy interest. On a number of our component measures, this puts a huge premium on size. So, when Singapore scores highly on our indicators, that is quite astounding. On the other extreme, GCI keys on normalized (e.g., national savings rate as % of GDP) or size-independent metrics (e.g., quality of business schools on a 1-7 scale). Hence, smaller, highly advanced economies such as Switzerland, Finland, and Denmark score very highly in the 2006-2007 GCI, higher than the USA.
- Countries -- which nations to include? Our focus has remained on the rapidly industrializing nations. We include some of the highly developed OECD nations as comparisons, and as competitors of special interest to the USA. Limitations on statistical data coverage and quality intrude as one extends coverage beyond the OECD nations. Our coverage has expanded over these two decades from 17 to 33 economies.

- Scaling – Indicators come in many forms. Relative indicators with convenient scaling (e.g., top = 100) are appealing – as per our HTI(T). However, many options present themselves and the present paper touches on ranks, standard scores, and so forth. GCI and others receive considerable attention to their national "rankings" and how these shift from year to year.
- Topical inclusion – HTI's Technological Standing includes high tech exports, using a favored US definition from the 1980's (DOC3) with exclusion of expressly military oriented segments. Many other options present themselves. Of particular note, Technological Standing also incorporates electronics exports, thus showing especially well for nations active in that arena. Its third component, expert opinion on national high tech production capability counterbalances the statistical measures in being scaled 1-5.
- Time series comparisons – as noted, our country coverage has expanded. We have also revised our component measures and expert opinion questions slightly, more so prior to 1993. This leads us to limit temporal comparisons here to 1993-2007. This still provides one of the longer indicator series with which to track technology-based export competitiveness over time. That said, several of our countries added in the 1990's lack values for the earliest time series points.

Roessner et al. (2002) compared HTI with three other competitiveness indicators. These were the Competitiveness Innovation Index (US Council on Competitiveness), The World Competitiveness Yearbook (see recent version -- IMD 2007), and the competitiveness rankings generated by researchers at the United Nations University in Maastricht. The UN rankings have not been systematically updated. The Council on Competitiveness (2007) has updated their indexing, but they do not do so on a regular schedule. Others have picked up to compare "innovativeness" beyond the OECD, especially East Asia (Furman and Hayes 2004; Hu and Mathews 2005). Innovativeness is vital to high tech competitiveness, yet it is not the same thing.

IMD (2007) offers its World Competitiveness Scoreboard as a highlight of its *World Competitiveness Yearbook*. Table 1 presents a few selective comparisons between the 1997 and 2007 country rankings. Note that China climbs notably from the IMD country ranking of 27 in 1997 to 15 recently.

Table 1. Changes in IMD World Competitiveness Country Rankings

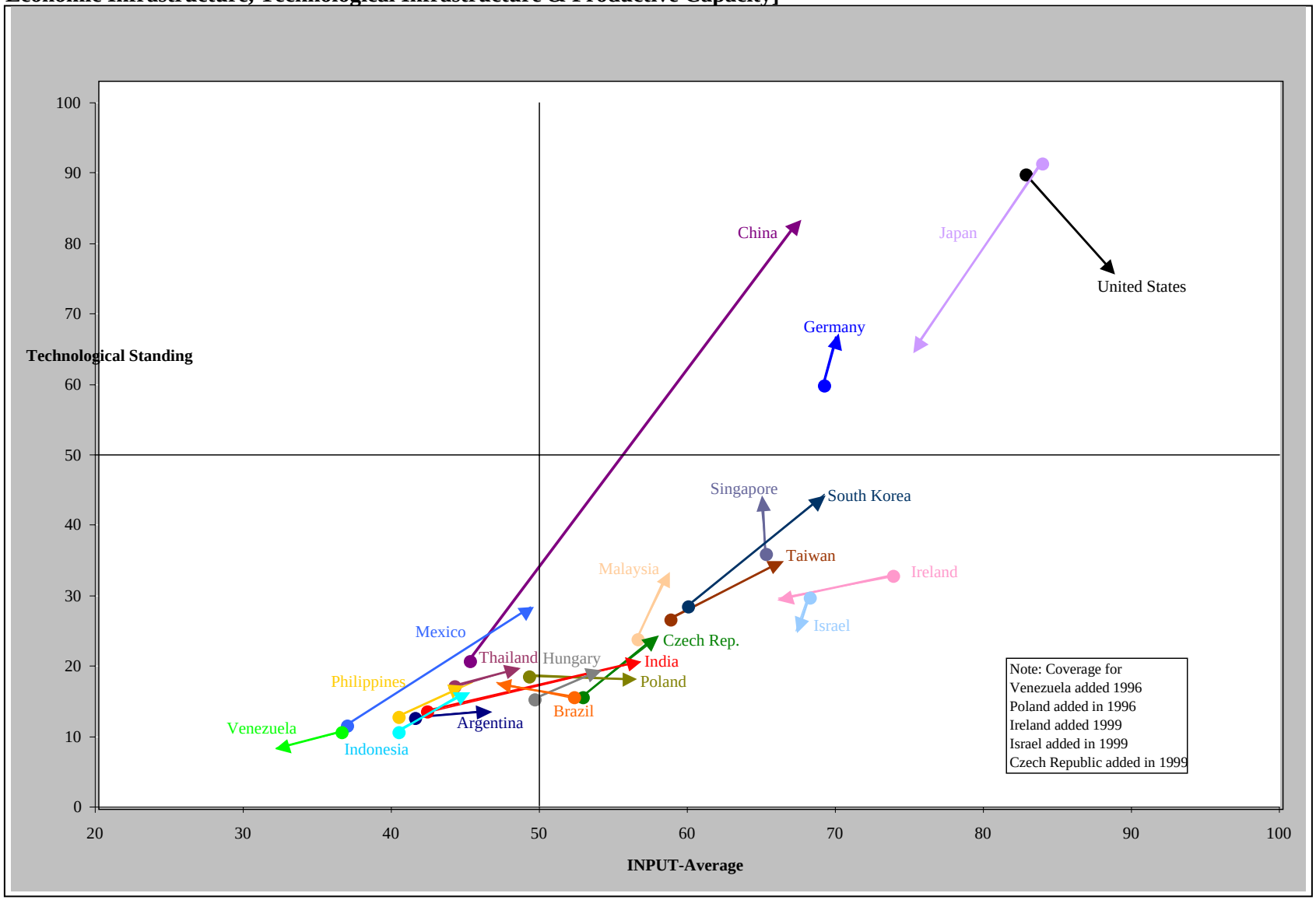
Country	1997 Ranking	2007 Ranking
USA	1	1
Japan	9	24
Singapore	2	2
China	27	15

This paper does not attempt to compare all such national indicators. For our present purposes, the three indicator sets we are analyzing [HTI(T), HTI(S), and GCI] are sufficient. These cover all of our 33 countries (GCI covers 125 nations). Unlike many other indicator sets, these also are intended to appear regularly (GCI annually; HTI bi-annually). And they focus on national economic competitiveness, with special attention directed to technological capabilities as a key component.

HTI – Traditional (T) findings

Figure 2 presents the compelling portrait of change in the traditional High Tech Indicators for a number of our target countries. This scattergram connects a country's 1993 and 2007 datapoints. The vertical axis shows Technological Standing (**TS**). The horizontal axis shows the change in **INPUT** (the average of National Orientation, Socio-Economic Infrastructure, Technological Infrastructure, and Productive Capacity). As indicated in the legend, a few countries span shorter times as they were incorporated into HTI after 1993. If one focuses on the circular nodes (1993), two countries had a substantial lead on all others by these metrics – Japan and the USA. On these relative scales, both have reverted toward the group mean on TS. This does not indicate absolute decline, just that other nations are becoming relatively more competitive. Other countries have moved various modest distances. Of the Asian Tigers, South Korea and Taiwan have increased quite sharply on both INPUT and TS; Singapore has increased on TS.

Figure 2. Change in Technological Standing and INPUT: 1993-2007 [Note: INPUT is the average of National Orientation, Socio-Economic Infrastructure, Technological Infrastructure & Productive Capacity]



And then there is China. Over this 15-year period, China has advanced enormously on both INPUT and TS. In our conceptual model, strong and increasing INPUT presages longer term gains in TS. In 1993, China's INPUT score was in the lower region, neighboring Thailand, just beneath Hungary, Poland, and Brazil. In 2007, China's INPUT score of 67.2 scales just above Taiwan (66.1) and Ireland (66.1), and just below Canada (67.3) and Israel (67.3). Others do score higher, including some not shown to keep the figure from being too busy (Sweden at 68.1 and the UK at 69.5). On TS, China leads all at 82.8, trailed by the US at 76.1. [See Table 2 for details.]

As one considers the makeup of the HTI indicators, arguments could certainly be posed. In particular, TS includes both general high-tech exports and electronics exports. That reflects somewhat of a double-counting of electronics, which are less prominent as markers of "high tech" today than they were in the 1980's and 1990's. For instance, today one could point toward biotech and nanotech as possibly more important emerging high tech domains. That said, Figure 2 proclaims astounding change for China over 15 years. The increasing strength on INPUT suggests that China will continue to advance strongly in the coming decades. Knowledge external to the HTI project per se reinforces Chinese prospects. For instance, some analyses of nanotechnology research publication in international journals now show China challenging, or even edging ahead of, the USA as of 2007 (Kostoff, Koytcheff and Lau 2007; Youtie, Shapira and Porter, to appear).

Figure 2 leaves out some of the 33 countries to enhance clarity. Table 2 provides Technological Standing and INPUT values for all of the countries, for all available years from 1993-2007. In scanning the table, one sees that most countries remain relatively stable across this 15-year period. Recognize that this is largely a reflection of the relative nature of the indicators. As described in the Appendix, values for a given component for all 33 countries for any data series are "S-scored." That is, they are scaled so that the highest nation's score equals 100. The INPUT and TS indicators are averages of such 0-100 scaled components.

Some general observations of the HTI(T) trends:

- The highly developed OECD nations show general stability from 1993 to 2007
- Asian countries generally increase their Technological Standing from 1993 to 2007, and their INPUT scores less clearly.
- On this measure of national competitiveness (TS), the Asian countries have risen to be strongly competitive to OECD nations, such as those of Western Europe.
- Competitiveness is broadening globally.
- The only countries showing notable slippage on TS from 1993 to 2007 are Japan, Italy, South Africa, and Venezuela (from 1996).
- Slippage on the INPUT composite indicator is most notable for South Africa. Japan and Ireland have dipped somewhat as well.

Table 2. Traditional HTI(T) INPUT and Technological Standing (TS) Indicators: 1993-2007
[Countries are grouped by region: North America; South America; Europe; Asia; Other]

	INPUT = (NO + SE + TI +PC)/4						Technological Standing					
Country/economy	INPUT-93	INPUT-96	INPUT-99	INPUT-03	INPUT-05	INPUT-07	TS-93	TS-96	TS-99	TS-03	TS-05	TS-07
United States	82.8	86.2	87.4	85.4	86	88.7	90	91.4	95.4	93.9	82.9	76.1
Canada	59	59.8	69.1	67.2	64.2	67.3	24	28.1	35.4	32.6	27.6	29.4
Mexico	37	40.6	32.2	42	45	49.4	11.6	20.1	19.8	27.3	26.3	28.4
Argentina	41.5	37.3	38.3	40.2	43.4	46.3	12.7	9.6	11.3	12.7	12.7	13.7
Brazil	52.1	47.2	47.6	43.5	49.3	47.1	15.5	19.1	18.2	15.4	18.7	17.6
Venezuela	-	36.4	33.9	30.7	37.5	32.2	-	10.5	7.7	7.5	14.3	8.4
Czech Republic	-	-	53.3	52.1	58.1	57.7	-	-	16.4	18.5	21.1	23.6
France	63.5	66.5	68.1	64.8	63.6	65	45.6	45.7	48	44	45	45.3
Germany	69.2	65.9	68.8	70.9	71.6	70	60.5	59.2	58.7	61.4	65.4	66.8
Hungary	49.7	47.7	55.6	54.2	54.9	53.4	15.4	17.1	20.9	20.3	22.4	18.8
Ireland	-	-	73.6	65.5	61.5	66.1	-	-	32.7	34.3	35.9	29.6
Italy	53.8	56.4	54.6	59.9	58.5	56.7	31.5	29.5	26.2	31.4	29.3	25.5
Netherlands	60.3	67	63	68.4	64.3	64.3	35.1	40.3	38.7	45.3	40.3	43
Poland	-	49.4	50.6	52.8	54	56	-	18.8	18.4	14.9	14.9	18.1
Spain	52.2	51.5	55.3	48.2	51.3	52.3	18.3	16	18.4	20.3	20	18.2
Sweden	64.5	59.6	57.7	65.2	69.3	68.1	28	32.2	30.2	34.6	31.9	31.1
Switzerland	60.6	55.3	59.2	62	59.3	63.6	32.5	30.5	32.8	31.9	31.8	32.2
United Kingdom	58.8	62	65.9	69.2	69.7	69.5	49.3	48.6	53.8	54.1	47.7	43.6
China	45.1	45.5	51.4	55.7	68	67.2	20.7	22.5	44.2	49.3	73.9	82.8
India	42.6	48	54.8	49.2	54.4	56.8	13.5	18.3	20.8	17.9	20	20.7
Indonesia	40.5	31.8	34.7	33.1	37.6	45.1	11	11.2	14	14	14.2	16.1
Japan	83.6	78.1	76.1	74.4	74	75.7	90.8	93.9	82.7	81.6	73.1	66
Malaysia	56.6	54.7	50.7	51.5	57.2	58.5	24.3	28.2	30.8	32.8	35.8	32.2
Philippines	40.2	55.1	44.5	45.8	47.4	45.5	12.6	14.9	15	19.6	23.2	17.7
Singapore	65.3	64.9	62.3	68.1	66.9	65	35.8	46.7	51.5	52.4	47.7	43.4
South Korea	60.1	59.6	60.4	64.7	64.8	69.2	28.7	32.6	32.7	40.1	45.2	44.4
Taiwan	59	64.8	65.5	68.1	63.7	66.1	27	31.5	35.2	39.3	37.9	34.5
Thailand	44.7	43.4	37.1	39.2	44.9	48.5	17.2	18.1	16.6	20	21.1	19.8
Australia	54.4	56.4	66.5	59.2	66.4	60.1	15.6	20.6	19.5	19.6	23.3	22.3
Israel	-	-	68.1	66.5	68.7	67.3	-	-	29.5	26.7	25.1	25.1
New Zealand	50.9	58.7	55.9	61.4	60	64.6	16.8	13.5	16.8	21	19.3	20.6
Russia	40.6	49.4	46.8	51.6	47.5	55.2	14.7	19	15.2	17.5	16.5	15.8
South Africa	52.5	42.6	43.2	42.3	45.3	46.9	22.1	15.4	14.3	12.5	15.4	17.7

Notes: Missing values appear for countries for years prior to their inclusion in the HTI series.

HTI – Statistics-only (S) findings

Porter et al (2008b) report in detail on the new HTI(S) indicators. In particular, that report (available at //tpac.gatech.edu) offers extensive comparisons with HTI(T). It also focuses on changes in the indicators from 2005 to 2007. Two main factors drive our effort to devise a reformulated HTI:

- Desire to base HTI completely on data generated by others
- Intent to expand treatment of information economy (service sector) elements and other "emerging technology" oriented capabilities.

As detailed in the Appendix, the HTI(S) formulation still incorporates expert opinion, especially several components provided by GCI. Those are rather more robust samplings of knowledgeable persons as *GCI 2006-2007* incorporated 11,232 responses, in contrast to HTI(T)'s 392.

HTI(S) differ in composition considerably from HTI(T). The numbers of shared components are:

- Technological Standing (TS) – 2 of 4
- National Orientation (NO) – 1 of 3 components
- Socio-economic Infrastructure (SE) – 1 of 3
- Technological Infrastructure (TI) – 2 of 9
- Productive Capacity (PC) – 1 of 6

So overall, INPUT(S) shares only 5 of 21 components with INPUT(T).

One of the opportunities provided by reformulating an indicator set is the possibility of alternative scaling options. Porter et al. (2008b) discuss and compare various alternatives considered. Most notably, HTI results – primarily on the INPUT group (NO, SE, TI, and PC) – as presented in *Science & Engineering Indicators* (National Science Board 2008), scale the US = 100. That did not work well for HTI(S). First, because of the wide variation in component range, we determined that normalization was needed to avoid overwhelming the influence of scaled items (e.g., several GCI measures on 7-point scales). We settled on standard (Z) scores to do that:

$$\mathbf{Z(X_i) = (X_i - Mean\ X) / Std\ Dev\ of\ X}$$

Z scores range about zero. However, because the US scores very near the mean (by definition, zero) on several components, normalizing against it explodes the resulting score range – defeating a key purpose of such transformation.

Thus, we chose to use a second transformation – normalizing against the maximum country score (not necessarily the US). This is much the same as the S-scores used in HTI(T), except that we first are converting the raw data into standard scores (Z scores):

$$\mathbf{S(Z_i) = (Z_i - Minimum\ Z) * 100 / Range\ of\ Z}$$

[As the Minimum is a negative value, this effectively adds the minimum so that the lowest S(Z) becomes 0; when divided by the Range (Max – Min), the Maximum S(Z) becomes 1.]

Table 3 presents the resulting HTI(S) "INPUT" and TS values for 2005 and 2007. As some of the component data are not available for earlier years, it was not possible to go back further. One of the 21 components of INPUT uses the same data for both years (a GCI measure, "administrative burden of startups"). Many statistical compilations provide the "most recent available" data, not data reflecting the compilation date per se. Also some metrics may include widely varying years that different countries have provided -- for instance, "scientists and engineers in R&D" to UNESCO vary widely in what year is given for particular countries.

Table 3. Statistics-only HTI(S) INPUT and Technological Standing (TS) Indicators: 2005-2007

Country/economy	S-Z(S) INPUT-05	S-Z(S) INPUT-07	Change in INPUT	S-Z(S) TS-05	S-Z(S) TS-07	Change in TS
North America						
United States	91.37	87.16	-4.21	92.96	88.30	-4.66
Canada	54.18	53.05	-1.12	11.06	12.49	1.43
Mexico	22.51	24.57	2.06	9.13	7.24	-1.88
South America						
Argentina	15.77	16.28	0.51	0.31	0.56	0.26
Brazil	24.85	24.28	-0.57	2.87	2.66	-0.21
Venezuela	5.79	5.67	-0.12	0.16	0.04	-0.12
Europe						
Czech Republic	31.32	34.88	3.55	1.48	1.64	0.16
France	48.60	52.25	3.65	20.02	19.69	-0.33
Germany	60.64	59.07	-1.57	35.40	37.94	2.54
Hungary	34.99	38.18	3.19	3.31	4.08	0.77
Ireland	46.99	48.50	1.51	20.56	24.93	4.37
Italy	33.84	35.44	1.60	9.72	10.37	0.65
Netherlands	54.05	54.22	0.17	18.77	21.35	2.58
Poland	23.07	26.93	3.86	1.53	1.86	0.33
Spain	39.11	39.52	0.40	7.11	8.13	1.02
Sweden	61.35	60.54	-0.80	6.53	8.19	1.66
Switzerland	53.48	53.45	-0.03	8.04	13.71	5.67
United Kingdom	60.93	62.40	1.47	32.19	33.77	1.58
Asia						
China	31.76	33.12	1.36	36.96	47.05	10.08
India	22.46	25.86	3.40	3.88	5.97	2.10
Indonesia	18.56	19.00	0.45	1.24	2.40	1.16
Japan	62.95	62.87	-0.07	47.08	44.34	-2.75
Malaysia	35.08	38.23	3.14	11.72	9.57	-2.15
Philippines	14.52	16.72	2.19	3.64	2.61	-1.03
Singapore	54.21	53.38	-0.83	18.39	20.57	2.17
South Korea	40.14	42.40	2.26	17.75	18.18	0.43
Taiwan	47.47	48.65	1.18	13.19	9.10	-4.09
Thailand	27.50	29.24	1.74	6.00	5.61	-0.40
Others						
Australia	52.34	49.17	-3.16	2.32	2.45	0.13
Israel	45.90	44.42	-1.48	3.03	2.50	-0.53
New Zealand	51.87	46.52	-5.35	0.49	0.50	0.01
Russia	19.79	18.96	-0.83	1.59	2.33	0.74
South Africa	28.81	28.13	-0.68	0.27	0.87	0.60

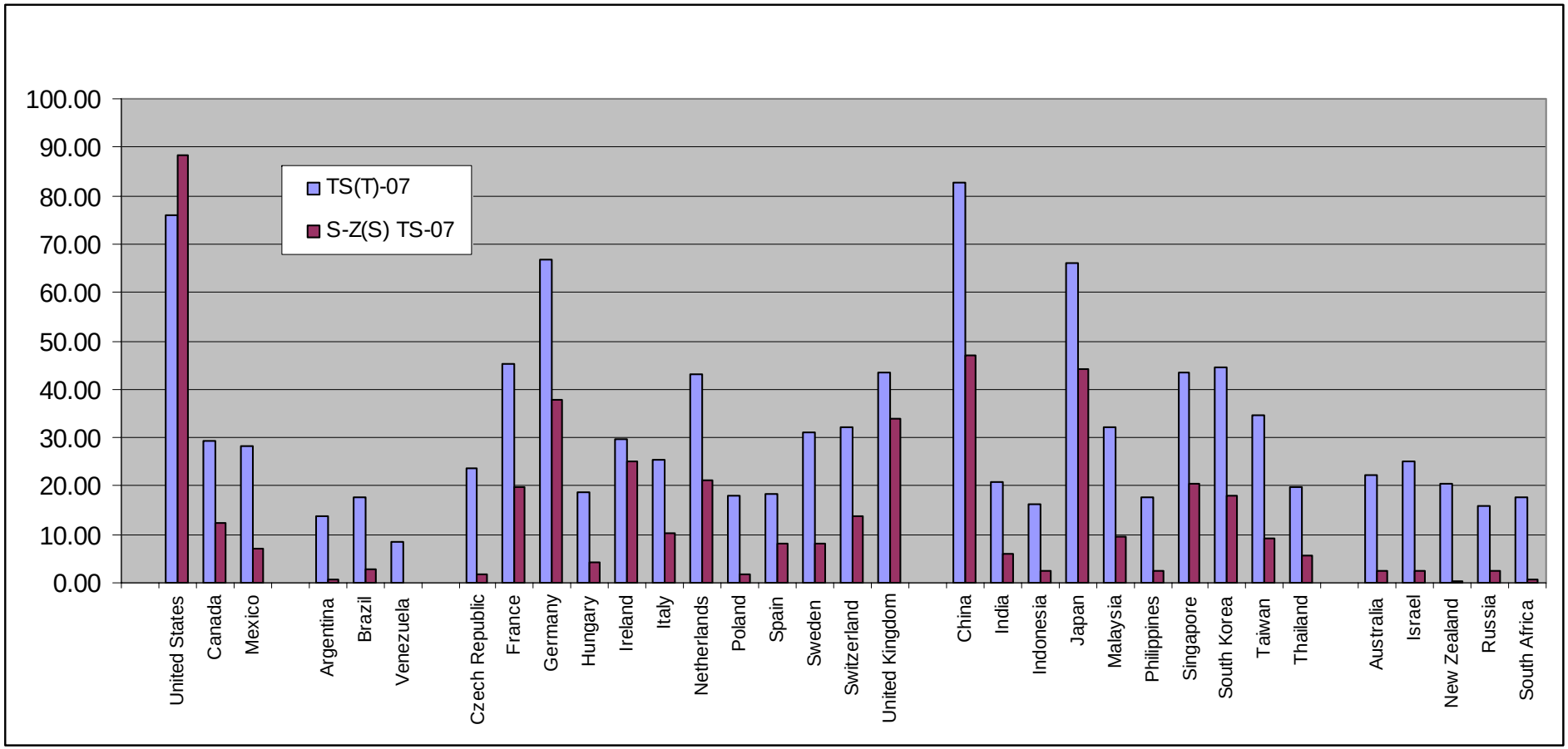
Again, interpret these data as "indicators" – relative, comparative measures – not absolutes. That said, it's interesting to examine the changes over this recent two-year period as shown in Table 3:

- INPUT – notable decreases for New Zealand, US, and Australia
  notable increases for Poland, France, Czech Republic, India, Hungary, Malaysia
- Technological Standing (TS) – notable decreases for the US and Taiwan
  notable increases for China, Switzerland, and Ireland

Figure 3 compares HTI(T) and HTI(S) Technological Standing values for 2007. The more statistically based and updated (broader spectrum) HTI(S) values refine the message. Key points:

- In general, using HTI(S), the US considerably extends its lead over the others.
- China, which had nudged ahead of the US as #1 on HTI(T), is well back by HTI(S). However China is still #2 using HTI(S), just ahead of Japan, who is trailed by Germany and the UK. No other nation tops the 30 level, while Japan and China exceed 40, and the US shows at nearly 90.

Figure 3. Technological Standing (TS) – Comparing HTI(T) and HTI(S) Versions for 2007



GCI – Global Competitiveness Index comparisons

Table 4 presents indicator values for our 33 countries for the Global Competitiveness Index (World Economic Forum 2007), together with our HTI(T) and HTI(S) Technological Standing (TS) values. While the GCI 2007-08 values are available as this is written, we use the 2006-07 values for more temporally aligned comparison. HTI Technological Standing-2007 values are composed of:

- X2007 – high tech exports from the UN Statistical Division as of 2007; data are for 2005
- A2-2007 – electronics exports forecast for 2007 from Reed's *Yearbook of World Electronic Data*
- Royalty/license fees – from World Development Indicators, 2007
- OCSE -- Export of Computer, communications and other services, from World Development Indicators, 2007

And as mentioned, HTI(S) incorporates several GCI components in its INPUT indicators, using the 2006-07 values.

Table 4. GCI (Global Competitiveness Index) 2006 compared with HTI(T) and HTI(S) Technological Standing (TS) Indicators: 2007

Country/economy	HTI(T) TS(T) 2007	HTI(S) S-Z(S) 2007	GCI 2006 Score
North America			
United States	76.10	88.30	5.61
Canada	29.40	12.49	5.37
Mexico	28.40	7.24	4.18
South America			
Argentina	13.70	0.56	4.01
Brazil	17.60	2.66	4.03
Venezuela	8.40	0.04	3.69
Europe			
Czech Republic	23.60	1.64	4.74
France	45.30	19.69	5.31
Germany	66.80	37.94	5.58
Hungary	18.80	4.08	4.52
Ireland	29.60	24.93	5.21
Italy	25.50	10.37	4.46
Netherlands	43.00	21.35	5.56
Poland	18.10	1.86	4.3
Spain	18.20	8.13	4.77
Sweden	31.10	8.19	5.74
Switzerland	32.20	13.71	5.81
United Kingdom	43.60	33.77	5.54
Asia			
China	82.80	47.05	4.24
India	20.70	5.97	4.44
Indonesia	16.10	2.40	4.26
Japan	66.00	44.34	5.6
Malaysia	32.20	9.57	5.11
Philippines	17.70	2.61	4
Singapore	43.40	20.57	5.63
South Korea	44.40	18.18	5.13
Taiwan	34.50	9.10	5.41
Thailand	19.80	5.61	4.58
Others			
Australia	22.30	2.45	5.29
Israel	25.10	2.50	5.38
New Zealand	20.60	0.50	5.15
Russia	15.80	2.33	4.08
South Africa	17.70	0.87	4.36

The GCI range is quite narrow – from 3.69 to 5.81 for our 33 countries. In contrast, HTI is scaled on a 0-100 range. Hence, directly plotting the values side-by-side does not work. Statistically, correlations between HTI(T) and HTI(S) are high (0.90), while those between HTI(T) and GCI (0.53) and HTI(S) and GCI (0.46) are moderate.

We would not expect the indicators to tell the same story. In our "indicators issues" discussion, we particularly noted that HTI generally seek to measure national capability, not adjusted for size, whereas GCI generally does the opposite. That said, Figure 4 shows a transformed GCI as "GCI-rescaled" to facilitate comparison. This takes the scaled GCI and sets the lowest value for the 33 country set at 0 and the highest at 100 – i.e., similar to the S-scoring applied to HTI.

Scanning Figure 4, we see technologically advanced economies – e.g., setting a threshold of those scoring above 65 (by region):

- USA* and Canada
- France*, Germany*, Ireland, Netherlands*, Sweden, Switzerland and the UK*;
- Japan*, Malaysia, Singapore*, South Korea*, Taiwan
- Australia, Israel, and New Zealand

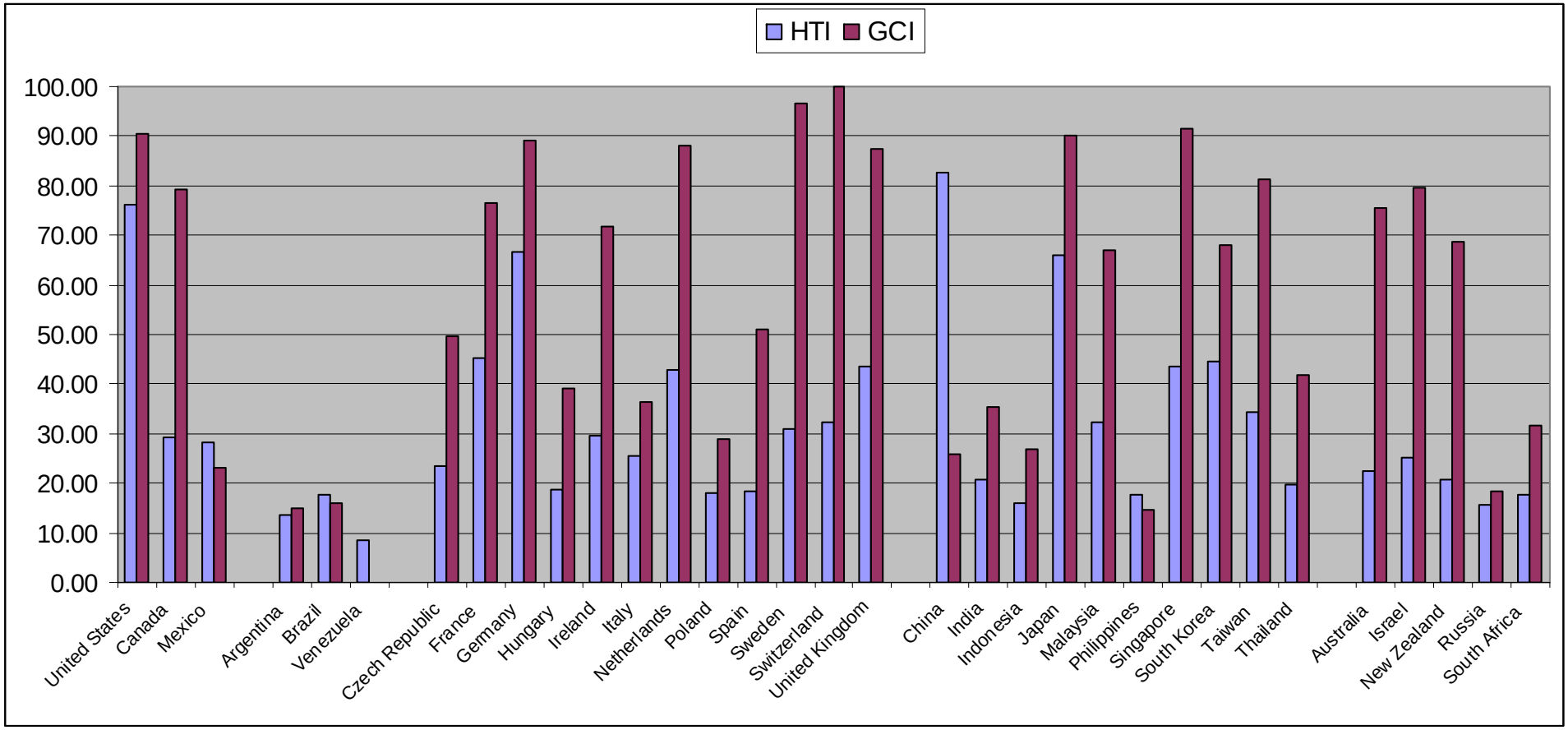
The ones with an asterisk (*) also score above 40 on HTI(T) Technological Standing. The striking anomaly is China. It stands at 26 on the rescaled GCI and 83 on HTI(T) TS.

As noted, the Global Competitiveness Index (GCI) is built of nine pillars, each including a number of component measures. Table 5 compares China with the USA on those. With the exception of macroeconomy, the US is notably stronger. The GCI reflects a weighted average of these pillars. They are grouped into Basic Requirements (Averaging Pillars 1-4), Efficiency Enhancers (5-7), and Innovation Factors (8-9). As a Stage One economy, China's GCI is composed of 50% weight on Basic Requirements, 40% on Efficiency Enhancers, and 10% on Innovation Factors – yielding its overall 4.24. The USA, as a Stage Three economy, uses respective weights of 30%, 40%, and 30% to net a GCI of 5.61.

Table 5. GCI (Global Competitiveness Index) 2006 – China and USA

#	Pillar	China	USA
1	Institutions	3.51	4.84
2	Infrastructure	3.54	5.82
3	Macroeconomy	5.72	4.37
4	Health and primary education	6.44	6.6
5	Higher education and training	3.68	5.82
6	Market efficiency	4.22	5.67
7	Technological readiness	3.07	5.49
8	Business sophistication	4.05	5.78
9	innovation	3.44	5.72

Figure 4. Comparing GCI-rescaled and HTI(T) Technological Standing (TS) for 2007



Discussion

How can we gauge worldwide technological competitiveness? We compare three indicator sets – two versions of the Georgia Tech High Tech Indicators [traditional HTI(T) and new statistics-only HTI(S)] and the Global Competitiveness Index (GCI) from the World Economic Forum. As illustrated plentifully, the indicators offer complementary perspectives. HTI are oriented toward national comparisons, lending heavier weight to the mass of an economy. GCI lean toward a "per capita" view, so that smaller size nations are not penalized in the comparisons. Figure 4 vividly contrasts the different pictures that result from HTI and GCI.

Figure 3 shows how HTI(S) and HTI(T) differ in their representations of current high tech-based economic competitiveness. While both blend wide-ranging statistical components with limited-range (scaled item) components, we believe that HTI(S) provides a better balanced treatment for today's emerging technologies and how they are used economically. It incorporates components intending to get at information-economy services as well as manufactured products. Technological Standing in HTI(S), as compared to Technological Standing in HTI(T), better characterizes a nation's competitive power in a knowledge-based global marketplace.

Consequently, we anticipate the Georgia Tech High Tech Indicators adopting the HTI(S) formulation as its standard in the future. However, HTI(T) provides a sound time series enabling us to see better what has been changing – and, via extrapolation, to anticipate upcoming changes as well. Figure 2 shows this.

Beginning in the 1980's, the HTI activity has been guided by a conceptual model (Figure 1). That model points to four major contributors to future export competitiveness ("Technological Standing") of nations – National Orientation, Socio-Economic Infrastructure, Technological Infrastructure, and Productive Capacity. Within each, we identified factors deemed important conceptually, then sought empirical manifestations. In the mid-1980's, relatively few statistical time series covered the industrializing countries robustly. Hence, we devised a tightly focused expert opinion instrument to address those important factors for which we could not locate regular statistical sources. Two decades later, the statistical series resources are enriched, though still incomplete in coverage of those important contributing factors. So for our new "statistics-only" HTI(S) series, we still include expert opinion metrics. In this case, we find those compiled in the Global Competitiveness Report (World Economic Forum 2006) especially attractive because they are regularly collected and comprised of a very large number of knowledgeable opinions.

Why do we look toward the Global Competitiveness Report's GCI, rather than other national competitiveness indicators? As mentioned, one consideration is regularity – some very rich endeavors are not systematically continued year after year -- e.g., the Council on Competitiveness indicators (c.f., Furman and Hayes 2004), UN University indicators (c.f., Mani 2000). Lots of appealing components likewise do not continue regularly.[3] Other indicators are extremely empirical. For instance, the *World Competitiveness Yearbook* (IMD 2007) "measures 55 countries on the basis of 323 criteria." We find more in common with GCI and its model-driven compilation of data. As noted, the GCI model builds on nine pillars that could map to the four HTI INPUT indicators (not trivially). They selectively compile statistical data and enrich with their robust expert opinion process. Results enable one to spotlight strengths and weaknesses of a given national economy.

[3] As an illustration, we include "ICTCON" in our new Technological Infrastructure indicator, based on UNCTAD (United Nations Conference on Trade and Development) who developed, but did not continue, this statistical composite measure. But, UNCTAD did explicitly report their sources – primarily ITU (International Telecommunication Union) data that are regularly reported.

Turning to China, what do the multiple indicator perspectives offer?

- On all of these technology-based competitiveness indicator series, China shows tremendous gains over time (Figure 2 "says it all")
- HTI Technological Standing shows China rivaling the USA for global leadership (Figure 3)
- GCI and the HTI INPUT indicators show that China has extensive issues to overcome.

So, is China #1 or #54 or ?? The issue of technology-derived national competitiveness is too multi-dimensional to yield meaningfully to a singular ranking. In terms of overall national competitiveness, we assert that China is much closer to #1 than #54. The *GCI 2006-2007* #54 has already increased for *GCI 2007-2008* to #34. As discussed, the GCI ranking downplays the size of the Chinese economy. It is more like a "per capita" metric (though not in a simple way). The degree of increase on GCI in one year says much. The huge and steady HTI(T) gains over the past fifteen years (Figure 2) tell us not to overemphasize China's considerable issues in projecting its future competitiveness. All told, the signs inexorably point to China's increasing technological competitiveness.

Were we pressed to pick a single valued response as to China's current technological competitiveness, we would point to our HTI(S) Technological Standing. As Figure 3 shows, China is #2. Overall, the USA stands well above, as a strong #1. By this metric, China now noses ahead of Japan, Germany, and the UK as #2. [Smaller economies are somewhat suppressed by their size in this metric. But, one might note with a degree of amazement that tiny Singapore, nonetheless, nudges just ahead of France as a potent national high tech competitor.]

Both our Technological Standing (TS) and the GCI are composite indicators. Should one like to consider a simple statistical measure by itself, our most recent (2005) value of technology products exported (a component of TS) puts China behind the United States by the amount of "a rounding error" -- about $100 million. But, yes, such statistics may cover a variety of considerations. When China exports an Apple iPod, it may well have assembled components that were largely imported to implement an American design. On the other hand, one might argue that American contributions to USA high tech exports are relatively soft (systems configuration and marketing), so liable for rising economies to usurp.

All this suggests that China is rapidly heading to rival the United States as the principal driver of the world's economy – a position the USA has held since the end of World War II. Japan, which jockeyed with the USA for top spot in our HTI(T) Technological Standing in the early 1990's, now seems to be slipping behind China (with a resurgent Germany pushing it as well). [Do recall that the HTI indicators are relative, so Japan's drop in Figure 2 is not an absolute decline.]

Moving beyond the indicators, what do we foresee? One might well predict that China will surpass the United States in technology-based competitive capabilities within a decade or two. The image of China as just a low-cost producer of manufactured goods is plain wrong. Other data reflect China's expanding research and development activities. For instance, in the emerging nanotechnology domain, depending on which databases one scours, China is either #1 or #2 in publishing in the international literature (the USA is still well ahead in accruing citations to its publications, an indicator of importance – c.f., Kostoff, Koytcheff and Lau 2007; Youtie, Shapira and Porter, to appear). As China becomes more proficient at innovation processes (GCI Stage 3 emphasis) linking its burgeoning R&D to commercial enterprise, watch out. And China is increasing attention to management of technology (c.f., Li et al. 2007) to do just that.

China is drawing more talented students to careers as scientists and engineers. With a huge pool of people upon which to draw, a forceful government able to set and implement policy, and increasing salaries for technical careers, this human resource will almost surely continue to grow. One can contrast the situation in the USA and other highly developed economies.

Figure 2 shows that China has transformed itself into a high tech exporting powerhouse in just 15 years. The figure also shows major Chinese gains in the INPUT factors that portend continuing strong gains in technology-based competitiveness. INPUT factors (socio-economic infrastructure, etc.) affect innovative capability (Furman and Hayes 2004), and are evolving themselves (Suarez-Villa and Hasnath 1993).

In addition to China, other East Asian countries are making up for their relatively late start in impressive fashion (Hu and Mathews 2005). Inspecting Figure 2 further, note that many of the large gainers are Asian economies – South Korea, Singapore, Taiwan, Malaysia, and India. The expanded message is that global high tech competition will likely see not just China, but Asian economies more broadly, supplant Western leadership.

How about the shift from manufacturing to services? In today's Information Economy, high value services may be even more amenable to internationalization. Our engagement in competitive technical intelligence ("CTI")[4] capability development finds serious competition from abroad, especially India, in software development. But that's not all. Multinational companies who have been buying our software to perform analyses are now outsourcing those analyses, especially to India. The barriers to Asian countries participating strongly in innovative product development and in information-based services are crumbling.

We close by wondering what the future holds. Fifty years from now, what would an HTI profile of the 33 nations treated here look like? For those in the West who have enjoyed the fruits of high tech economic dominance, what can they do to retain competitive positions? We point toward the HTI INPUT indicators in closing:

- National Orientation – Can short-term oriented economies and democracies assert strategic leadership?
- Socio-Economic Infrastructure – Can we revitalize and incentivize science and engineering education?
- Technological Infrastructure – How to bolster technical skills and innovative capacity?
- Productive Capacity – Can this discarded pillar be rebuilt?

[4] Georgia Tech and Search Technology, Inc., have developed and market "VantagePoint" software [//theVantagePoint.com].

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Appendix

The HTI Indicators are formulated as follows:
Traditional – **HTI(T)** -- [Survey questions + statistics components]
New Statistics-only -- **HTI(S)** -- [more inclusive statistics components without survey data]

Raw data are transformed to **"S-scores"**. Each indicator component is scaled from 0 to 100 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 (nearly all items are scaled 1-5, so 1 transforms to S = 0; 5 transforms to S = 100).[5] For statistical data, 100 typically represents the value attained by the country with the largest value among the 33-country set. Thus, this is a relative scaling so that an apparent "decline" over time or low score is only relative to the other countries in the set of 33. Depending on the component, two classes of scaling are used:

- Absolute 0; Relative 100: for some items there is a true zero 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.

Traditional (T): All are S scores of the indicated components.

- TS (T) = (X + A2 + Q14a)/3
- NO (T) = [Q1 + (Q2 + Q3)/2 + Q4 + F1V]/4.
- SE (T) = (Q5 + Q10 + HMHS)/3.
- TI (T) = [(Q7 + Q8)/2 + Q9 + Q11 + EDP + S&E]/5
- PC (T) = [(Q6 + Q12 + Q13) + A26/2]/1.5
- IN (T) = [NO (T) + SE (T) + TI (T) + PC (T)]/4

Here are brief descriptions of the components; fuller details and source information is available in the HTI-2007 Report (Porter et al. 2008a) at //tpac.gatech.edu. We pose the questions ("Q#" – condensed versions here) to our International Technology Indicators Panel primarily via e-mail. We seek at least 10 responses per country; for 2007, the 392 well-qualified responses attained this for all countries except

[5] Note that *Science & Engineering Indicators-2008* rescales the INPUT indicators so that the USA equals 100 to facilitate comparisons.

Russia, addressed by 9 knowledgeable individuals. Nearly all questions are 5-point scale opinion items. We have used this approach since the late 1980's to get at elements that we felt contributed essentially to the indicators, but were not available via uniform statistical sources.

Technological Standing:

Q14a: present technology-intensive production capability
X: high tech exports [from the United Nations Statistical Division (UNSD) COMTRADE trade statistics for 2005. High tech exports were defined in accord with the U.S. Department of Commerce's DOC3 definition, excluding missiles and ordinance.
A2: electronics exports, forecasted for 2007, from Reed's *Yearbook of World Electronics Data 2006/2007*

National Orientation:

Q1: government evidences deliberate strategy to promote technology-intensive production for export
Q2: country's basic culturual values associate technology with desirable social development
Q3: influential groups associate technology with desirable social development
Q4: presence of an entrepreneurial spirit
F1V: 5-year investment risk assessment index for January 1, 2007, from The *Political Risk Letter* by the PRS Group

Socio-Economic Infrastructure

Q5: mobility of capital
Q10: extent to which foreign-owned firms are encouraged to do business in the country
HMHS: Harbison-Myers Human Skills Index. The formula for the index is W42007+4*W62007. W4 is the net % in secondary education, while W6 is the gross % in tertiary education, from UNESCO

Technological Infrastructure

Q7: capability of training graduate-level scientists and engineers
Q8: country's contribution to international scientific and technological knowledge
Q9: extent that R&D activities relate to industrial enterprise
Q11: degree of achieving technological mastery
EDP: electronic data processing equipment purchases for 2007, from Reed
S&E: scientists & engineers in R&D, from UNESCO

Productive Capacity

Q6: available skilled manufacturing labor
Q12: extent that a system of indigenous component producers exists
Q13: industrial management capabilities
A26: electronics production for 2007, from Reed

Here are the newly expanded, statistics-only indicators –

HTI (S)

- TS (S) = [X + A2 + ROYLR + OCSE]/4
- NO (S) = v7 + v8 (data-based) + F1V07
- SE(S) = v17 + v23 + HMHS + FDI (5-yr unweighted moving average-flow)
- PC (S) = v36 + v37 + v51-imports data + labor productivity + A26-2005 + MVA + SVA, where MVA and SVA are 3-year weighted moving averages
- TI (S) = v33 + v44 + EDP-2005+S&E+ RATIOROYL + ICTCON + PatApRes + BIBLIO + R&DEXP
- INPUT(S) = Average (NO, SE, PC, TI)

Technological Standing [X and A2 described above]
ROYLPR: Royalty/license fees, from World Development Indicators
OCSE: export of Computer, communications and other services, from World Development Indicators

National Orientation: [F1V described above]
v7 intellectual property protection effectiveness [GCR-9.07]
v8 ease of starting a business [GCR-6.05]

Socio-Economic Infrastructure [HMHS described above]
v17 financial market sophistication [GCR-6.19]
v23 impact of rules on foreign direct investment [GCR-7.14]

Technological Infrastructure [EDP and S&E described above]
v33 firm-level technology absorption [GCR-7.02]
v44 capacity for innovation [GCR-9.08]
RATIOROYL: Ratio of royalty and license receipts /royalty and receipts payments, from World Development Indicators
ICTCON: "Connectivity" measure defined as the minimum set of measures necessary for ICT access, comprising Internet hosts per capita, PCs per capita, telephone mainlines per capita, and mobile subscribers per capita, from UNCTD
PatApRes**:** Patent applications by residents, from WIPO
Biblio**:** research publication pertaining to six emerging technologies tabulated from EI Compendex
R&DExp**:** R&D Expenditures, from World Development Index

Productive Capacity [A26 described above]
v36 local supplier quality [GCR-8.02]
v37 production process sophistication [GCR-8.03]
v51: national market attractiveness to outsiders – multiply together: imports of goods and services as % of GDP X total GDP [GCR]
MVA**:** Manufacturing Value Added, from World Development Indicators
SVA: Services Value Added, from World Development Indicators

Full details on the GCI are available in the *Global Competitiveness Report 2006-2007* (World Economic Forum 2006).