CIRJE-F-444

The U.S. Information Technology Revolution and Its Impact on U.S. Economy and Beyond

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October 2006

IT-2006Sept

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Abstract

Phenomenal advances, which many would call a "revolution," in U.S. information technology (IT) sectors of the 1990s gave rise to dramatic productivity gains. They had profound effects on economies of the U.S. and other nations. We begin with an overview of the IT industries of the nineties and examine their impact on U.S. economy, at large, and by industry. To see the development in perspective, we discuss the perceived catalysts to the revolution. Then we explore how the remarkable sequence of events of the decade affected the rest of the world, developed and developing, more focus placed on the latter. The paper ends with a review of Korea and Taiwan, with specific references to the impact on their industrial structures during and after the deepening U.S. IT revolution.

I am indebted to Irwin Feller, Edward Green, Chikara Komura, Chulhee Lee, Ray Lombra, Bee Roberts, Wil J. Smith, and James Tybout for their helpful comments and suggestions. On matters relating to technology, I have benefited from my discussions with L. Raymond Hattche, H. Thomas Hahn, Byung-Lip Lee, Forest Remick, Keith C. Riew, Yasuyuki Sawada, Donald P. Schneider, John Spychalski and others at selected U.S. research laboratories.

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1. Introduction

The fall of the Berlin Wall and collapse of the Soviet Union ushered in the extraordinary decade of the nineties, a decade that witnessed an era of Web browser and phenomenal advances in information technology (IT) in the U.S. These developments had profound effects on the U.S. economy and the economies of other nations.

We begin with an overview of the IT industries of the 1990s and examine their impact on the U.S. economy, at large, and by industry. To put the developments in perspective, we discuss the factors contributing to the explosive growth of the IT sector which many have called a "revolution." We then ask how the remarkable events of the 1990s affected the economies of other nations, both the developed and developing, especially the latter. The paper ends with a review of the economies of Korea and Taiwan, with specific reference to their changing industrial structures over the course of the deepening U.S. IT revolution.

2. Phenomenal Growth of U.S. Information Technologies (IT) Industries

The IT industries (defined to include computer hardware, computer software/services, and communications hardware/services) underwent rapid expansion during the nineties. Their value-added (see Table 1) rose from $371 billion in 1992 to $878 billion in 2000; the real growth rate (adjusted for inflation) was 92.8 percent over the eight years, while the corresponding GDP growth rate was 33.6 percent. The growth rate disparities became more pronounced in the latter part of 1990s. The IT sector share of GDP rose from 5.9 percent in 1992 to 8.8 percent by1999. Even after the recent "internet bust," the IT share of GDP still stood at an estimated 7.8 percent in 2004 (*Statistical Abstract* 2006, Table 1113).

Of the IT sector's total value-added, the *hardware* and *software/services* industries together accounted for $185 billion in 1992 and $561 billion in 2000, a real growth of 119 percent. Over the same 8-year period, growth in *software/services* alone was significantly higher - 165 percent, far exceeding the growth in the *hardware* or the *communications hardware/services*.

What we see in the IT sector development, impressive as it was, represented only a small part of the total changes in the nation's economy.[1] Rapidly developing IT industries and the resulting advances in productivity impacted a wide-range of other sectors of the economy.[2]

3. The IT Revolution and the U.S. Economy

a. Selective Macroeconomic Indicators

The GDP growth rate (Table 2) averaged nearly 3.7 (3.68) percent during 1992-1999 (the recession years of 1990-91 excluded). The record for 1997-1999 was higher at 4.4 percent, the level not seen since the end of the World War II. The corresponding average growth rate for the 1980s was just under 3.1 (3.08) percent. The difference in the growth data between the two decades, though substantial, does not fully reveal the significance of the developments of the 1990s.

The Reagan era's quantum rise in budget deficits (from the major tax cuts and the surging defense outlays of the 1980s) led to higher interest rates, both nominal and real. This, along with the then pervasive favorable foreign expectations of the U.S. economy in the 1980s (after the two major oil shocks and the recession-ridden decade of the 1970s), had induced the massive infusion of foreign capital to boost U.S. investment. It was during this decade that the U.S. became the foremost debtor nation in the world. Thus, what appeared to be the rosy growth performance of the 1980s was not one without some worrisome near- and long-term ramifications. By contrast, the economic growth of the 1990s was productivity-driven by rapid advances in the IT sector.

Important also, the growth rates for the1990s are understated to the extent that we overstate price increases. The problem here is far from trivial. First, the shifting trend in the industrial composition of the economy to service activities was more pronounced in the1990s - and we are not well adept at measuring service activities. Second, an increasing proportion of the goods we do measure have undergone rapid improvements in quality, making quality-adjusted price measurements more difficult. Traditionally conservative, the Census officials have not been keen to adequately account for quality improvement in their adjustments of the price index, thus overstating inflation. Furthermore, wide-ranging new products and services introduced by new technologies were not previously included in the U.S. national income accounts.   The combination of these factors would substantially overstate price increases and understate real-term growth rates.[3]

Rapid growth of the U.S. economy brought down the unemployment rate in the 1990's (1992-99) to an average of 5.7 percent, from the high of 7.3 percent for the1980s. The unemployment rate was even lower at 4.5 percent for 1997-1999, and lower still at 4.2 percent in 1999, reaching 4.0 percent in 2000.[4]

Despite the high growth and low unemployment, prices were relatively stable; rising productivity had inflation-suppressing effects.[5]   Inflation averaged only 2.6 percent during 1992-1999 and an even lower 2.0 percent during 1997-1999. These low inflation rates were in sharp contrast with the higher average rates of 5.3 percent in the1980s and 7.1 percent in the1970s.

With low inflation, interest rates stayed low, even in the late 1990s, helping to further fuel the frenzy in corporate investment, housing, and consumer demand for durables. Overinvestment in capital goods led to excess capacity and rising inventory and an eventual economic downturn that began in 2000 and accelerated since 2001.

b. The Relative Performance among the G-7 Nations

International comparisons highlights U.S. economy's performance of the 1990s. Table 3 shows that U.S. growth far exceeds that of other G-7 nations. Japan, with her continuing stagnation during the1990s, is seen as the worst performer. In employment also (not shown in our tables), the U.S. record in the 1990s was far better. The unemployment rates in Europe were at high single-digit or low double-digit levels, the disparities with the lower rates of the U.S. widening even further in late 1990s.

c. Differential Effects at Industry Level

Positive impacts of the IT sector advances are noted (Table 4) in wide-ranging segments of the U.S. economy, most notably in a) *services,* b) *finance/insurance/real estate,* c) *communications,* d) *construction,* and e) *trade (wholesale/retail).* The growth rates in these sectors (in current dollars) were much higher in the second half of the1990s, compared with the first half of the decade. When adjusted for inflation, the growth rate differences between the two halves of the 1990s are even larger, due to the more subdued inflation (from rising productivity) in the second half of the decade.[6] The records of the *finance/insurance/real estate* sector and the *services* sector are quite remarkable, both in their value added and growth rates. Within these categories, the greatest relative winner in growth rate, interestingly, is *security and commodity brokers*, with a growth rate of 259 percent in the 1990s.[7] The *insurance carriers* and the *financial institutions* also registered triple-digit percentage gains in their values added.

The phenomenal growth in *business services* (162 percent) largely reflect rising activities in *computer hardware* and *computer software,* with more and more firms and non-profit organizations opting for efficiency in production, distribution, product designs and innovations. With the advent of satellite technology came burgeoning communications industries (telephone, television broadcasting and related services). Productivity-driven rise in corporate profits and real wages, combined with IT-induced new products and product innovations, brought powerful impetus to surging demand for a wide-ranging array of consumer goods and services, thus raising wholesale and retail activities to very high levels.

Noteworthy also, construction industry saw bustling activities in the second half of the 1990s. The 59.9 percent increase in that period was a very large jump from the lesser 16.5 percent increase in the preceding five years of 1990-1995. The IT-based productivity increase, taming inflation and bringing sustained low interest rates, undoubtly contributed to this huge rise in construction activities during 1995-2000.[8]

Among the relative losers are agriculture, mining, and manufacturing. In manufacturing, the loss became more evident in the second half of the1990s. Continuing rise in U.S. wages led to outsourcing by U.S. firms, for parts and for the whole assembly of various final products as well, and to the retreat of the U.S. manufacturing sector during that period.

The combination of the high growth, high employment, and low inflation of the 1990s came as a surprise to many and was unanticipated by most economists. How the U.S. economy was able to achieve this record merits an inquiry. Such an inquiry will enable us to see the development of the decade in perspective and hopefully offer added insights into the future.

4. Catalysts of the IT Revolution

a. Changes in the U.S. Defense Posture

Disintegration of the USSR in 1991 and ending of the Cold War had a profound impact on defense postures of the U.S. The Department of Defense (DOD) budget, which had reached the historical high of $370 billion in 1989 (Appendix Table 1), fell dramatically to 262 billion in 1999 (all in 1996 dollars) - a real decline of 29.2 percent in defense expenditures. The DOD budget share of GDP, which had averaged 5.9 percent during 1982-1989, fell by about one half to just under 3.0 percent (2.97 percent) by 1999. The *peace dividend*, underappreciated by many, was of an immense proportion, even when we focus only on savings in the defense budget. Note that the saving in the DOD budget was not a one-shot event, but one that was to continue into the future.[9]

The large reduction in defense budgets, along with the 1993 tax legislation (the Federal individual income tax rate rose from the maximum 31 percent to 39.6 percent for the highest income bracket, in excess of about $270,000 for the joint filer), contributed significantly to the decline in budget deficits, paving the way to lower interest rates and the capital markets favorable to business investment and housing activities.

Concurrent with falling DOD budgets, there were rising calls for reprioritizing Federal R&D funding in support of the non-defense sector. Federal funds for defense-related R&D, which stood at about $46 billion during 1985-90 (twice the level for the decade of the 1970s, in real terms) had fallen to $37.9 billion by 1995 (Appendix Table 2). In the mid-1980s, Federal R&D appropriations for the defense sector were more than double the amount allocated to the non-defense sector. The differences in funding between the two sectors have narrowed rapidly during the1990s, moving them closer to parity by the end of the decade.[10]

b. Massive Shift of Defense Sector R&D Manpower

The **s**teep decline in the defense budget had coincided with major layoffs in defense industries, as reported in the media with increasing frequency, especially in the early to mid-1990s. Given the large magnitude of the budget contraction, the scale of the outflow of defense sector manpower would surely have been massive.[11] Absent official data, we can only attempt estimates of such manpower shifts, specifically of the scientists and engineers, based on reported data on changing defense-related R&D budgets. The latter, which reached the peak of $46.4 billion in 1990, as noted, had fallen to $37.9 billion in 1995 (both in 1996 dollars), an $8.5 billion decline over the first five years of the 1990s.

Assume that 50 percent of this amount ($8.5 billion) accounts for the R&D manpower reduction, with the remaining half for procurements (e.g., equipment, materials, and facilities), utilities, maintenance, clerical/custodial work, etc. Assume further that the average annual R&D personnel cost (salary, retirement, and other benefits) was $40,000.[12] The number of defense-related R&D staff laid off would have been 106,250 = ($8,500,000,000 x 0.5) / $40,000. During budget contractions, however, the R&D staff's share in the falling budget would likely be substantially higher, as physical assets and related maintenance costs are less amenable to immediate large adjustments. Thus, if we set the R&D manpower share in the budget contraction at a higher 75 percent, then the size of the manpower layoff rises to 160,000. Now, if we use a higher amount of $50,000 for the average costs, the estimate of layoffs falls to 127,500. Under our alternative assumptions, the number of R&D staff released from the defense sector would have been in the approximate range of 106,000 to 160,000.[13]

In discussing manpower shift out of the defense sector, we need also to consider a large contingent of production engineers and other professionals also laid off, with factory closures and production retrenchment in defense industries. Though not on the R&D team, their skills and know-how in process implementation and production in defense industries would certainly have played a positive role in the civilian sector, their new employer.

Scientists and engineers, now switching their "allegiance" in great numbers would have meant massive infusion of scientific and technological know-how to the non-defense sector. These professionals, many trained in high tech, cutting-edge R&D and production, would surely have contributed significantly to the rapid advances in the civilian sector economy in the 1990s.[14]

c. Declassification of Defense Sector Technology

Federal legislation enabling DOD technology transfers to civilian sector was debated extensively even during the Cold War years. Some in the Congress, Senators Evan Bayh (Indiana) and Robert Dole (Kansas) being most prominent among them, pointing to the perceived merits of the Japan, Inc. model, pressed for measures to facilitate “shared technologies.” This effort gained increasing Congressional support in the 1990s.

Economic growth models stress the role of human capital (education, R&D, knowledge, and skills) and its spillover effects. Wide-ranging DOD-supported R&D activities did add hugely to human capital, contributing to advances in cutting-edge technologies. Their impact on civilian sector productivity, however, was limited during the Cold War era, given the restrictions then in place. Subsequent easing of the restrictions in the 1990s would have meant another major channel of technology infusion into the civilian sector. Here, the transfer mechanism included announcements by the DOD-agencies, in periodicals and bulletins, of the lists of declassified technologies available for civilian sector purchases.

Also important, the Defense Advanced Research Project Agency (DARPA), the DOD’s umbrella organization that manages military R&D projects, was pressured by Congress to increase emphasis on “dual use” projects (to encourage civilian applications incorporated in the proposals) in its funding decisions. This applied also to NASA and other R&D support agencies operating directly under the control of the separate Armed Services of the United States.

d. The Apollo Project and the Reagan Defense Build-up

The stunning success of Sputnik by the USSR alarmed the U.S., prompting the incoming administration of John F. Kennedy to pursue an ambitious space program. Concurrently, America’s perceived “missile gap” led to a “catch up” campaign in the broad areas of science and technology. The U.S. success in landing a man on the moon in 1969 was a culmination of nearly a decade-long R&D effort of immense proportions.

A research campaign of this scale brought to the task an army of scientists and engineers trained in computer hardware/software, space technology, materials science, and an array of sophisticated instruments.[15]

Subsequently, the military build-up of 1980s led to another major R&D campaign. Ronald Reagan entered the 1980 presidential race with a commitment to counter the Soviet Union, which was believed to have greatly expanded its military capability in the 1970s. Defense expenditures, which had averaged $227 billion in the five years ending in 1981, jumped to an average of $334 billion during 1982-1989 (all in 1996 dollars), a 47-percent real increase. Defense-related R&D budgets rose sharply from $26.7 billion in 1980 to $45.9 billion in 1985, a real term increase of 72 percent, far exceeding the rise of the overall defense budget.

The “Electric Age,” which had its debut in the 1880s, Paul A. David (1990) points out, did not generate real momentum for productivity gains in the U.S. economy until well into the 1920s. Gains from the major R&D campaigns of the1960s and of the 1980s, likewise, would have required a gestation period, and the post-Cold War easing of restraints on DOD technology transfers, to become a major force to usher in the phenomenal technology advances and the clusters of innovations of the 1990s. Appropriating hundreds of billions of dollars on military R&D may not have been a cost-effective way of promoting civilian sector productivity. This, after all, was not the primary goal of the programs. But these outlays, we might say, did provide some weighty technology feedback, beyond meeting the perceived erstwhile national security needs.

e. Japan’s Role; Other Factors

By the mid- to late-1970's, Japan had been known for its leading role in quality control and management/production efficiency. She excelled in high tech application in production of various high-end consumer goods and capital goods equipment, and was busy rolling out such high value-added and high-volume trade items as automobiles, televisions, optical/photographic equipment, wide-ranging electronic products, computer hardware and precision machinery. Computer-operated production of steel, shipbuilding, machinery and tools had long earned the respect of the world market. The high speed rail networks (the Shinkansen Tokyo-Kyoto route opened in 1964, extended to Fukuoka of the southern island of Kyushu in 1977) were put into operation well ahead of such rail networks in Europe.[16] In automobile, the well-known computer-controlled "Just in Time" model in production/logistics added serious further challenges to U.S. firms.

Japan, incorporating external technologies with its own to full advantage and with the ability of its R&D staffs to attend to minute details in product designs and innovations, established itself as a leader in technology and a super performer in world trade.[17] The case for U.S.-Japan joint projects in selected military research, geopolitical considerations aside, is to be seen in the context of such achievements on Japan's part.[18] In Japan, unlike in the U.S., industries have been ahead of universities in R&D activities.[19] Visits to Japan by U.S. firm representatives to their counterpart firms, and vice versa became continuing rituals in the 1970s and throughout the 1980s, a point stressed by Forest Remick, an emeritus professor at Penn State University and former director of the U.S. Nuclear Regulatory Agency. The cumulative effects of such interactions, undoubtedly, would have meant non-trivial mutual benefits.[20]

For the extraordinary U.S. economy of the 1990s, some would credit the role of the Federal Reserve. During the economic upswing of 1994 and early 1995, the Fed raised interest rates seven times, adding 1.75 percentage points to the discount rate. Monetary easing in 1998, in the midst of the Asian financial crisis and the subsequent Russian financial fiasco, has also been lauded. Then, in the ten months beginning in August 1999, there were six consecutive rate hikes, again totaling 1.75 percentage points, as the Fed attempted to preempt inflation and keep the economy from overheating.

The 1993 tax legislation, to note again, raised federal individual income tax rates significantly in the upper brackets. Declining budget deficits in the 1990s and the reversal to surplus during 1998-2001 may be attributed, in part, to this legislation. The changing federal budget balance would have allowed lower interest rates, positively impacting investment.

5. The IT Revolution: Its Global Impact

a. Impact on Industrialized Nations

The primary channel through which a nation's economy can affect other economies is trade. The theory would have us expect rising U.S. imports to result from its economic prosperity of the 1990s. The statistics indeed show unprecedented increases in U.S. imports and surging U.S. trade deficits that followed. The aggregate U.S. trade deficits rose from $111 billion in 1990 to $174 billion 1995, and to an incredible $452 billion in 2000 (Table 5). The rise in the deficits, we note, was much more pronounced in the second half of the 1990s; the increase in U.S. current account deficits during 1995-2000 were even greater, consistently (ERP, 2005, Table B-106). The stagnant economies of the rest of the world got a major boost in the 1990s.

The Japanese economy had been languishing since the crash of its equity and real estate markets in the early 1990s and the ensuing banking sector failure laden with massive nonperforming loans; the economy was headed for a possible meltdown.[21] Under the circumstances, the significant rise in exports to the U.S. during the 1990s was a welcome relief for Japan; the U.S. net imports from Japan increased from $42.6 billion in 1990 to $80.3 billion in 2000 (Table 5).[22]

Benefiting likewise from the booming U.S. economy was Western Europe. The U.S. had a trade surplus of $15.2 billion in 1995 with Western Europe. But the situation dramatically changed subsequently, with the U.S. reporting a trade deficit of $64.7 billion for 2000. The ailing economies of Europe (constrained by rigid labor markets, overarching entitlements, and excessive regulations) with their unemployment rates at high single-digit (Germany) or double-digit (France and Italy) during most of the 1990s, would have fared worse without their sizable net exports to the U.S.

b. Impact on Developing Countries

The high performing U.S. economy of the 1990s, meant even more for the developing countries, particularly those of East Asia. That the U.S. was able to absorb their large net exports (Table 5) was a critical relief for East Asia, as they were in the midst of the financial crisis and extreme liquidity crunch. Recall (Table 3) that even Japan and Germany, the vibrant economies not long ago, were vulnerable in the 1990s and not in a position to be of help to others. The strong U.S. economy undoubtedly shortened the duration of Asian financial crises; it did so indirectly too, by its being also a significant net importer from Japan and Europe.

During the latter part of the 1990s, rising labor costs in the U.S. and its production capacity shortage in the face of surging demand for IT products prompted U.S. firms turn to outsourcing, first for the components, then increasingly more for overseas assembly of wide-ranging final products. Benefiting the most in this process were the more advanced developing economies, such as Korea and Taiwan, which could offer the requisite infrastructure, educated manpower, the benefits of lower labor costs, and rising effective demand for IT products in the local markets.

6. The Impact on Industrial Structures of Korea and Taiwan

a. The Case of Korea

Note in Table 6 the high volumes of Korea's exports to the U.S. and their rapid growth during the 1990s, and more so during those critical years before and after Korea's 1998 financial crisis. Historically, the U.S. and Japan were the two principal destinations of Korean exports, the U.S. being the dominant of the two. Important to note, between 1996 and 1999, Korea's exports to the United States grew from $21.6 billion to $29.5 billion, a 37 percent increase in three years, while its exports to Japan remained virtually standstill ($15.8 billion to $15.9 billion). Exports to China, Hong Kong, and Singapore have either remained largely unchanged or declined between 1997 and 1999, alhough exports to Taiwan did increase by $1.7 billion, not an insignificant sum. Exports to five principal countries of Europe grew only moderately. Korea's rapid recovery from its financial crisis of 1998, it is apparent, owes much to the U.S. prosperity of the 1990s.

Important also, the U.S. economy of the 1990s impacted heavily on Korea's industrial structure. As seen in Table 7, Korea's total exports inceased by 79.3 percent between 1994 and 2000. During that period, exports of *food* and *light industry products* rose meager 7.3 percent and 13.5 percent, respectively, while those of high tech products all registered higher increases. In such areas as *semiconductors* and *information/communications equipment*, the exports rose by 145 percent and 284 percent, respectively, raising their combined IT sector share of all exports from 17.4 percent in 1994 to 28.7 percent in 2000. Most recently, in August 2006, the nation's IT exports reached $9.85 billion, raising the sector contribution to total exports to 35.6 percent for that month, surpassing the previous record of 32.5 percent set in March 2006 (*The Korea Herald*).[23]

Exports of *passenger cars, machinery/precision equipment*, and *chemicals/chemical products* rose by 192 percent, 85 percent, and 116 percent, respectively, from1994 to 2000. They together accounted for 20.4 percent of Korea's total exports in 2000 and for a higher 29.5 percent in 2005.

Rapid increase in the global demand for U.S. IT products in the late 1990s provided added momentum for Korea to move up to a more technology- and skill-based industrial structure. The U.S. IT sector outsourcing, as noted, initially involved component procurements, but gradually extended into a more inclusive range of production processes. Korean firms, deeper into the 1990s, were rapidly moving up on their learning curve, developing their own credible R&D manpower, and churning out quality products including those in numerous high value-added IT sector products.[24] That Korea's exports to China increased three fold over the five years ending in 2005 (reaching $61.9 billion in 2005, far surpassing its U.S.-bound exports of $41.3 billion) could occur due, in large part, to its upgraded industrial structure, along with its expanded productive capacity. Korea benefited much from the challenges of China's rapidly rising consumer demand, huge needs of intermediate goods for its expanding industrial production (including those of multinational firms), and demands for materials and equipment for wide ranging infrastructure, in urgent want for the 2008 Olympic.

b. The Case of Taiwan

Taiwan survived the Asian financial crisis relatively unscathed. While Korea experienced a 6.7 percent fall in GDP between 1997 and 1998, Taiwan achieved a positive growth of 4.6 percent (the preceding three years' average was 5.9 percent). Taiwan's economy, which depends much on trade (more so than does Korea – Taiwan's 2004 exports comprised 54.4 percent of the GDP as against Korea's 35.7 percent), did suffer a fall in exports (by $11.5 billion or 9.4 percent), before regaining most of the loss in 1999. Much of this loss, Table 8 shows, came from falling shipments to Asian countries. The exports to the U.S., the largest single market for Taiwan, however, remained virtually unchanged at around a strong $30 billion level between 1997 and 1998, followed by a significant rise of $5.4 billion in the next two years. The robust trade relationship with the U.S. helped Taiwan withstand the stresses of the Asian crisis.[25]

Important also, the changing character of U.S. demand markets, as in the Korean case, had profound effects on the structure of the island economy. Taiwan's world-wide total exports rose by 43.2 percent between 1994 and 2000 (Table 9). Exports of such traditional low-tech products as *garments*, *footwear*, and *toys/games/sports products* all lost grounds during the 1990s, with the negative growth becoming even more conspicuous during 2000-2005. Increase in exports of high-tech products, on the other hand, was phenomenal. During the six year, 1994-2000, Taiwan witnessed surging exports of *electronic goods* and *information/communications products*, by 158 percent and 188 percent, respectively. Note also the large increases in *chemicals/plastic products* and *precision instruments*. Clearly, during the 1990s, Taiwan's overall industrial structure became more technology- and knowledge-based. The year 2001, when the U.S. economy was in recession, witnessed a general retreat in Taiwan's exports. Soon, however, a forceful recovery began in 2003, continuing into 2005. Looking back, Taiwan's rapid economic progresses during the 1990s and thereafter (both in growth and in elevated industrial structure), as with Korea, were closely linked to the U.S. IT sector developments of the 1990s.[26]

The dynamics involving Taiwan's China-bound exports (via Hong Kong) is, again, similar (though to a lesser extent) to the one involving Korea. The U.S. and China were the two principal destinations for Taiwan's exports during the 1990s, the U.S. being the dominant. The situation, however, changed beginning in 2002, and by 2005, the China-bound exports reached $30.7, exceeding the $28.6 billion exports to the U.S. Only a decade and half ago, in 1990, Taiwan's exports to China were a mere $8.6 billion, compared with the far larger U.S.-bound exports of $21.7 billion. Rapid industrialization in China and its continuing rise in per capita GDP at the annual average of 8.2 percent in the 1980s and 9.5 percent in the 1990s (Compendium of Statistics, p.11) were prompting China's unbridled demand for industrial machinery and materials (such as basic metals) and for consumer goods ranging from air conditioners and other electric appliances to electronic products and cars.[27] Among the Taiwan's China-bound exports in 2005, *machinery and electrical equipment* ($16.8 billion) and *semiconductor, micro-assemblies, & others* ($10.2 billion) comprised the two major categories, accounting for 87.8 percent of the total exports, with *basic metals and articles thereof* ($2.76 billion) making a distant third (*TSDB, 2006*, Table 11-12 b, c, d, pp. 233-236). Taiwan, with its technology and expanded productive capacity, was ready to partake in the share of China's rapidly rising import demands of consumers, industrial firms, and of the government attending to urgent infrastructure needs for the Olympic.

7. Concluding Remarks

In explaining the IT revolution and remarkable U.S. productivity growth of the 1990s, we cited, as their main catalysts, massive outflow of the defense sector R&D manpower to the civilian sector that followed the end of the Cold War, the concurrent easing of restraints on DOD technology transfers, and the delayed productivity effects of the mammoth federal R&D campaigns of the 1960s (the Kennedy era Apollo project) and 1980s (the Reagan defense build-up).[28]

The IT revolution had other players also, private industries and higher education institutions. Jorgenson's remark (2001), "The introduction of the Personal Computer (PC) by IBM in 1981 was a watershed event in the information technology development," aptly describes the private sector role, although it was not without feedback from technologies of military origin.[29] There are other indications that the surge in private sector technology predated the 1990s. Kortum and Lerner (1998) note that the rapid upturn in U.S. patenting (over the ten years ending in 1996) began in the second half of the 1980s. The civilian sector, on its own, is capable of bringing the information technology and the productivity to ever higher levels. It is unlikely, however, without the Cold War's end and the ensuing developments described, that the explosive IT sector advances of the 1990s would have occurred as early as it did in the nineties and proceeded with such speed and intensity.

Future growth of the U.S. economy will continue to be technology driven. On the supply side of technology, we observed that the "big bang" of the 1990s originated from the aforementioned unique set of forces. Will future progress in technology be largely incremental in nature, built upon what we have already achieved? Or could a potential synergy of the vast array of new technologies spur further clusters of new innovations - possibly leading to quantum breakthroughs (for a revolutionary new energy source, for instance)? Absent the latter scenario, what we witnessed in the 1990s (the phenomenal advances in technology and surging productivity on broad fronts of the economy) most probably was a one-time event not likely to recur anytime soon.

On the demand side, the IT revolution had induced strong demand of the firms for high-tech infrastructure. The resulting growth in productivity, profits, and bulging corporate capitalization values provided the firms with ever more funds for capacity expansion, while rising income and the wealth effects from booming equity markets pushed consumer demand into overdrive. Ironically, the productivity growth, which tamed inflation (despite strong demand), keeping interest rates low, helped sustain high-level investments through the very end of the 1990s, which led to widespread overcapacity and cumulating inventory, and, inevitably, to a prolonged economic stagnation beginning in 2000. The U.S. IT sector had become a victim of its own success.

A rebound in the IT sector in 2003 was short-lived (lasting barely a year ending in fall 2003), remaining stagnant overall since, in spite of the healthy GDP growth (that averaged 3.5 percent during 2003-2005).[30] The IT sector's past achievements apparently continue to bear positive impacts on productivity of the overall economy, even while the IT sector itself is at a pause. Sustained IT sector advances would require a steady and more forceful macroeconomic rebound. Current uncertainties, however, with U.S. involvement in Afghanistan, Iraq, the Middle East, international nuclear disputes (Iran and North Korea), high U.S. consumer debts, and surging oil prices all restrain firms in their major investment decisions.

Externally, Europe's economies seem to continue on a stagnant course with their structural problems largely unresolved. Recent developments in Germany (its attempts at lessening labor market rigidities and regulatory excesses)[31] and Japan (its reported progress in financial sector reform, dramatic contraction of nonperforming loans, respectable growth rates, and so on) are welcome news.[32] China's rapid and spectacular rise as a world's economic player and India, a newly emerging giant, with their high single digit growth rates, exert positive global influence, as do the smaller, yet still vibrant, "four tigers" of East Asia.[33]

Even with a more potent macroeconomic rebound in the U.S. and elsewhere, how soon, or even whether, the IT sector of the U.S. can achieve its potential is unclear. But one thing seems certain. For the U.S. IT firms, the "glory" of the 1990s, when they were the unrivalled presence in the world of information technology, is over. Today, many nations, including the more advanced developing economies, compete fiercely and successfully for their shares of the global market for wide ranging I.T. products.

Such challenges, of course, were to have been expected in the dynamic setting of today's open economy. Still, the nation aspires for advances in technology, as its survival and the destiny of the mankind would depend on it. Technology is a public good that entails externalities. Policies aimed at human capital development, attuned to changing global economic environments, and public programs for sustained high-level

R&D activities in broad fronts of strategic sectors (which the U.S. can afford, with her rich resources) will positively affect the path ahead for the nation's technology and productivity.

Table 1
Gross Domestic Income in Information Technologies Industries:
1990 – 2001

Industry	1990	1992	1995	1998	1999	2000	2001	Growth 90-95	Growth 95-00	Growth 90-00
	(Billion dollars)							(%)		
Total (all IT Industries) (% share of the economy)	330 (5.8)	371 (5.9)	482 (6.4)	647 (7.3)	821 (8.8)	878 (8.8)	829 (8.1)	46.1	65.1	141.2
Hardware[1]	103	110	155	211	252	244	189	50.5	62.6	144.7
Software/Computer Services[2]	60	75.0	111	186	278	317	320	85.0	121.6	310.0
Communications Hardware[3]	21	24	31	47	61	67	55	47.6	100.0	195.0
Communications Services[4]	147	162	173	203	231	250	264	17.6	37.6	61.9

Notes: 1, Computer & equipment, C&E wholesale/retail, semiconductor, passive electronic components, etc.
2, Computer programming services, prepackaged software, computer integrated system design, computer processing & data preparations, computer-related services, etc.
3, Telephone/telegraph equipment, radio/TV & communication equipments.
4, Telephone/telegraph communications, cable & other TV services, etc.

Sources: U.S. Bureau of Census, *Statistical Abstract of the United States: 2004-2005*, Washington D.C., Government Printing Office, (Table 1116).

Table 2
U.S. Economic Indicators, Annual Averages for Selected Periods
1980-2004

	Growth Rate*	Unemployment Rate	CPI (yr to yr)	Corp. Bonds Moody's Aaa	Fed. Res. (N.Y.) Disc. Rate
			(In percent)		
1980-89	3.1 (3.08)	7.3	5.3	11.43	8.63
1990-91	.9	6.2	4.8	9.03	6.21
1992-99	3.7 (3.68)	5.7	2.6	7.39	4.32
1997-99	4.4	4.5	2.0	6.94	4.85
1999	4.5	4.2	2.2	7.04	4.62
2000	3.7	4.0	3.4	7.62	5.73
2001-02	1.4	5.3	2.2	6.79	2.78
2003-2004	3.7	5.8	2.5	5.65	1.24

*Average annual growth rates.

Sources: Calculated from the data presented in *Economic Report of the President*, 2005 Edition, (Tables B-2, B-35, B-60, B-73).

Table 3
Growth Rates in Real GDP among G-7 Nations
1980-2005

Year	US	Japan	Germany[1]	France	Italy	UK	Canada
			(In percent)				
1980-89	3.1	3.8	1.8	2.3	2.4	2.4	2.9
1990-91	.9	4.5	5.4	1.7	1.8	-.6	-.8
1992-99	3.7	1.0	1.4	1.8	1.2	2.4	2.8
1997-99	4.4	.2	1.8	2.9	1.5	2.9	4.6
1999	4.5	.1	1.9	3.2	1.7	3.0	5.5
2000	3.7	2.4	3.1	4.1	3.0	4.0	5.2
2001	.8	.2	1.2	2.1	1.8	2.2	1.8
2002	2.4	-.3	.1	1.3	.4	2.0	3.1
2003	2.6	1.4	-.2	.9	.3	2.5	2.0
2004	4.4	2.7	1.6	2.0	1.2	3.2	2.9
2005[2]	3.5	2.0	.8	1.5	[3]	1.9	2.9

[1]Data through 1991 are for West Germany only.
[2]Forecasts as published by the International Monetary Fund.
[3]Figure is zero or negligible.

Sources: Average figures were calculated from *Economic Report of the President (ERP)*, *2000* (Table B-110) and *ERP*, *2006* (Table B-112). The U.S. data are in the national income and product account, presented in *ERP*, *2006* (Table B-2).

Table 4 - Gross Domestic Product by Industry 1990-2001
(In billions of current dollars)

Industry	1990	1995	2000	2001	Growth* (%) '90-'95	'95-'00	'90-'00
GDP (Total)	5,803	7,401	9,824	10,082	27.5 (12.5*)	32.9 (21.9*)	69.3 (37.1*)
Agriculture, forestry, fisheries	108	110	134	141	1.8	21.9	24.1
Mining	112	96	133	139	-0.9	38.5	18.8
Construction	249	290	461	480	16.5	59.0	85.1
Manufacturing	1,041	1,289	1,520	1,483	23.8	17.9	46.1
Industrial machinery	118	133	173	148	12.7	30.1	46.1
Electronics & elec. equipm't	106	147	162	143	38.7	10.2	52.8
Motor vehicles & equipment	47	98	120	111	108.5	22.4	155.3
Chemicals & allied products	110	151	169	164	46.3	11.9	53.6
Apparel & textile products	47	52	49	45	10.6	-5.8	4.3
Primary metal industries	43	53	50	45	23.2	-5.7	16.3
Paper & allied products	45	59	60	56	31.1	1.7	24.4
Printing & publishing	73	81	107	100	11.0	32.1	46.6
Transport. & pub. utilities	491	643	809	819	30.9	25.8	69.8
Transportation	177	233	313	306	31.6	34.3	76.8
Communications	148	202	279	292	36.5	38.1	88.5
Wholesale	376	500	696	681	33.0	39.2	85.1
Retail	500	647	887	932	29.4	37.1	77.4
Finance, insurance, real estate	1,012	1,347	1,977	2,027	33.1	46.8	95.4
Financial institutions (Depository & non-depository)	194	262	431	449	35.0	64.5	121.6
Security/commodity brokers	42	78	151	175	85.7	93.6	259.5
Insurance carriers	65	120	182	170	84.6	51.7	180.0
Services	1,072	1,462	2,116	2,227	36.4	44.7	97.4
Business services	204	302	534	544	48.0	76.8	161.8
Health services	314	433	549	590	37.9	39.9	74.8

* Growth rates in constant dollars.

Sources: U.S. Bureau of Census, *Statistical Abstract of the United States: 2003,* Washington, D.C., Government Printing Office, Table 660. Growth rates were calculated from the same table. The *SAUS, 2004-2005 editions* was not used because its definitions of industry subgroups and its composition of the subgroups are different from those of earlier editions, thus making meaningful comparisons dating back to the early nineties difficult.

Table 5
U.S. International Trade Balance in Goods by Area/Country, 1990-2002

	1990	1995	1997	1998	1999	2000	2001	2002
	(In billions of dollars)							
Total (Excess of Imports)	-111.0	-174.2	-198.1	-246.7	-346.0	-452.4	-427.2	-482.9
Industrial Countries	-46.1	-86.7	-91.3	-112.3	-155.7	-198.0	-193.2	-223.1
Japan	-42.6	-59.9	-57.3	-65.4	-74.8	-83.0	-70.6	-71.8
W. Europe	2.2	15.2	-23.6	-34.9	-52.1	-64.7	-69.6	-92.5
Eastern Europe	2.1	-1.3	-.6	-3.5	-6.3	-10.2	-7.5	-8.5
Asia & Latin America *	-49.3	-61.4	-78.2	-113.2	-154.6	-190.3	-183.7	-223.8

*Excludes Japan and OPEC nations while including Africa except South Africa.
Sources: *Economic Report of the President (ERP), 2000* edition (Table B-103) and *ERP, 2004-5* edition (Table B-105).

Table 6
Korea's Exports by Country of Destination, 1994-2005

Country	1994	1996	1997	1998	1999	**2000**	2001	2003	2005	Increase '94-'00
	(In billions of dollars)									
U.S.	20.6	21.7	21.6	22.8	29.5	**37.6**	31.2	34.2	41.3	17.0
Japan	13.5	15.8	14.8	12.2	15.9	**20.5**	16.5	17.3	24.0	7.0
China	6.2	11.4	13.6	11.9	13.7	**18.5**	18.2	36.1	61.9	12.3
Hong Kong	8.0	11.1	11.7	9.3	9.0	**10.7**	9.4	14.6	15.6	3.7
Taiwan	2.7	4.0	4.6	5.1	6.3	**8.0**	5.8	7.0	10.9	5.3
Singapore	4.2	6.4	5.8	4.1	4.9	**5.6**	4.1	4.6	7.4	1.4
U.K.	1.8	3.2	4.0	4.2	4.8	**5.4**	3.5	4.1	5.3	3.6
Germany	4.3	4.7	4.8	4.0	4.2	**5.2**	4.3	5.6	10.3	.9
Netherlands	1.1	1.7	1.5	1.9	2.1	**2.7**	2.5	2.5	3.6	1.6
Italy	.8	.9	1.2	1.7	1.7	**1.9**	2.1	2.5	4.3	1.1
France	1.0	1.2	1.3	1.4	1.7	**1.7**	1.5	1.8	3.2	.7

Sources: Bank of Korea, *Monthly Statistical Bulletin*, *June 2000* edition (pp. 110-111), *March 2004* (pp. 104-105), and *June 2006* (Table 43).

Table 7
Korea's Exports by Principal Commodity, 1994-2005
(In billions of dollars, excepted as noted)

Type of Export	1994	1996	1997	1998	1999	**2000**	2001	2003	2005	Increase 1994-2005	**(%)**
Total exports	96.1	129.7	136.2	132.3	143.7	**172.3**	150.4	193.8	284.4	188.3	**195.9**
Food items	2.6	3.1	3.0	2.7	3.0	**2.8**	2.7	2.8	3.2	0.6	**23.1**
Light industry products	26.7	32.7	33.8	32.5	29.7	**30.3**	26.3	27.3	26.3	- 0.3	**-1.1**
Semiconductor	10.6	15.2	17.4	17.0	18.9	**26.0**	14.3	19.5	30.0	19.4	**183.0**
Information & comm. equip.	6.1	8.6	9.7	8.9	16.7	**23.4**	21.9	34.8	44.8	38.7	**634.4**
Passenger cars	3.8	8.3	8.6	8.2	9.4	**11.1**	11.5	17.5	27.2	22.4	**615.8**
Machinery & precision equipment	6.5	9.4	10.2	10.1	11.6	**12.0**	11.6	16.0	32.0	25.5	**392.3**
Chemicals	5.6	7.9	9.3	9.0	9.4	**12.1**	10.8	14.8	24.8	19.2	**342.9**

Sources: Bank of Korea, *Monthly Statistical Bulletin*, *June 2000* (p.108), *March 2004* (pp. 102-103), and *June 2006* (p. 104).

Table 8
Taiwan's Exports to Selected Countries of Destination, 1990-2005

Country	1990	1994	1996	1997	1998	1999	**2000**	2001	2003	2005	**Increase 94-'00**
					(U.S. dollars in billions)						
U.S.	21.7	24.3	26.9	29.6	29.4	30.9	**34.8**	27.7	25.9	28.6	**10.5**
Hong Kong	8.6	21.3	26.8	28.7	24.8	26.0	**31.3**	27.0	28.4	30.7	**10.0**
Japan	8.3	10.2	13.7	11.7	9.3	11.9	**16.6**	12.8	11.9	14.5	**6.4**
Singapore	2.2	3.4	4.6	4.9	3.3	3.8	**5.5**	4.1	5.0	7.6	**2.1**
Malaysia	1.1	2.2	3.0	3.0	2.3	2.9	**3.6**	3.1	3.0	4.1	**1.4**
Korea	1.2	1.7	2.7	2.4	1.5	2.6	**3.9**	3.3	4.6	5.6	**2.2**
Philippines	.8	1.2	1.9	2.2	1.9	2.6	**3.0**	2.1	1.3	4.2	**1.8**
Australia	1.3	1.6	1.8	1.9	1.6	1.8	**1.8**	1.4	1.9	2.4	**.2**
Canada	1.6	1.5	1.4	1.6	1.6	1.8	**1.9**	1.6	1.5	1.7	**.4**
Germany	3.2	3.2	3.6	3.7	4.1	4.1	**4.9**	4.5	4.2	4.4	**1.7**
Netherlands	1.9	2.4	3.8	4.3	4.4	4.2	**4.9**	4.2	4.1	4.3	**2.5**
U.K.	2.0	2.2	2.8	3.3	3.3	3.8	**4.5**	3.3	2.9	3.2	**2.3**
France	1.1	1.0	1.3	1.4	1.4	1.6	**1.6**	1.2	1.3	1.3	**.6**

Sources: Council of Economic Planning and Development, Republic of China, *Taiwan Statistical Data Book, 2006* (pp. 218-222).

Table 9
Taiwan's Exports by Principal Commodity, 1990-2005
(U.S. dollars in billions, except as noted)

Type of Export	1990	1994	1995	1996	1997	1998	1999	**2000**	2001	2003	2005	**Increase '94-'05 (%)**
Total Exports	67.2	93.0	111.7	115.9	122.1	110.6	121.6	**148.3**	122.9	144.2	189.4	**103.7**
Textile products	7.1	11.5	13.3	13.4	14.2	12.2	12.1	**13.0**	10.9	10.4	10.9	**-5.2**
Garments	3.2	2.5	2.4	2.3	2.5	2.3	2.1	**2.2**	1.8	1.5	.9	**-63.0**
Footwear	3.5	1.7	1.4	1.2	1.0	.7	.7	**.6**	.5	.4	.4	**-76.5**
Toys, games, sports	2.9	2.7	2.7	2.7	2.4	1.9	1.8	**2.2**	1.7	1.7	1.8	**-33.3**
Electronic products	7.7	12.3	16.3	16.6	18.0	16.9	21.8	**31.7**	23.6	31.2	45.7	**271.5**
Info/communication products	5.0	6.8	9.9	12.5	14.4	13.8	15.1	**19.6**	15.7	14.1	10.5	**54.4**
Precision instruments	1.5	2.1	2.3	2.3	2.5	2.2	2.7	**3.8**	3.1	7.2	13.4	**538.1**
Machinery	5.8	7.2	8.3	9.5	9.7	7.8	7.9	**9.7**	8.3	9.9	12.8	**77.8**
Chemicals/plastic products	5.1	8.1	10.3	10.0	9.9	8.8	9.8	**12.0**	11.1	14.3	22.6	**179.0**
Electric machinery	2.2	3.4	4.0	4.2	4.8	4.4	4.6	**5.4**	4.7	6.0	9.1	**167.6**

Sources: Council of Economic Planning and Development, Republic of China, *Taiwan Statistical Data Book*, *2006* (pp. 230-231).

Appendix Table 1
U.S. Defense Expenditures, 1962-2003
(In billions of dollars)

	Defense Expenditures		GDP	Def. Exp./GDP
	Cur. Dollar	1996 Dollar	Cur. Dollar	(Percent)
1962	52.3	283.6	586	8.92
65	50.6	252.9	720	7.03
68	81.9	364.0	911	8.99
1971	78.9	284.9	1,127	6.99
74	79.3	221.4	1,500	5.28
77	97.2	215.3	2,031	4.79
1980	134.0	231.3	2,790	4.79
81	157.5	247.2	3,128	5.03
82	185.3	270.7	3,255	5.69
83	229.9	324.4	3,537	6.50
84	227.4	299.4	3,933	5.78
85	252.7	327.2	4,220	6.00
86	273.3	353.7	4,463	6.14
87	282.0	361.5	4,740	5.95
88	290.3	364.5	5,104	5.68
89	303.5	370.5	5,484	5.53
1990	299.3	353.9	5,803	5.28
91	273.3	312.1	5,996	4.55
92	298.4	328.8	6,338	4.71
93	291.1	314.9	6,657	4.37
94	281.6	298.1	7,072	3.98
95	272.1	280.9	7,398	3.68
96	265.7	265.7	7,816	3.40
97	270.5	269.4	8,304	3.26
98	268.5	263.2	8,747	3.07
99	274.9	262.4	9,268	2.97
2000	294.5	272.1	9,817	3.00
01	304.9	276.2	10,128	3.01
02	348.6	305.3	10,487	3.33
03	404.9	342.3	11,004	3.68

Source: *Economic Report of the President*, *(ERP)* 2005, Tables B-1, and B-80. In calculating the 1996 dollars figures (col. 2), we used the deflator (chain-type price index) specific to national defense expenditures, available in *ERP* 2005, Table B-7).

Appendix Table 2
Federal Funding for R&D, Defense and Non-Defense
1985-2002

	Defense R&D	Non-Defense R&D
	(In 1996 constant dollars in billions)	
1985	45.9	22.0
1990	46.4	25.7
1995	37.9	32.2
1999	38.7	34.9
2000	39.9	33.8
2001	41.6	37.5
2002	47.8	40.3

Sources: *Statistical Abstract of the United States*, *2004-2005*, Table 770.

Endnotes

[1] The definition of IT industries becomes more inclusive in more recent editions of the Statistical Abstract of the United States (SAUS) from which our data are extracted (see the preface to Section 24, SAUS, 2004-2005). Given the expanding IT-based production and services, our use of the data based on increasingly more inclusive definitions seems to be in order.

[2] Firms (first the larger ones with more resources, then the medium and smaller firms) adopting information technology to their operation led to the great leap in productivity. For an illustration close at hand, we may note the widespread implementation of integrated logistics management systems to achieve greater efficiency in supply chains. For example, point of sale data captured at the cash register provides instantaneous recording of changes in a firm's inventory. Inter-firm links for such data enable suppliers to adjust production plans on a demand-pull rather than a production push basis. This helps minimize inventory excesses for the suppliers and the distributors, reducing their inventory holding costs, and secure timely delivery, benefiting all parties involved (see, for instance, Lewis, 2001). Many such revolutionary changes have occurred across the broad spectrum of industries, from manufacturing, communications, and transportation, to financial and other business services.

[3] For further discussions, see Paul A. David (1990): Council of Economic Advisors (2001); and Leonard Nakamura (1997). In the case of computers (for the purpose of U.S. national accounts), the prices since 1986 have been measured by "hedonic" regression techniques. The prices are explained by combination of attributes, e.g., the level of speed, memory, disk drive access speed, and so on (see Gordon, 2000b). This technique (and Grimm's matched model approach (1998) with hedonic methods for price-indexing semiconductors) may be ideal as applied to a limited range of products, but it falls short of addressing the big picture – namely overstated general price increase, hence understated growth rates.

[4] Edward Green cautions that we not attribute this fall in unemployment rates entirely to the IT sector boom. We had sustained federal job training programs in the 1990s. Also, there was a significant increase in prison population (from rising drug-related and other crimes) during the 1990s that reduced the unemployment rate of the decade by an estimated 0.3 percent (unemployed persons are withdrawn from the statistics while being incarcerated).

[5] The "China effects" may also have played a role in mitigating inflation pressures. Multinational companies moving their plants to China in large numbers in the 1990s would certainly have meant lower global commodity prices.

[6] Based on current dollars, the GDP growth of the second half of the 1990s exceeded that of the first half by 19.6 percent, but, when compared in real term growth, the former

exceeded the latter by 75.6 percent. The data in Table 4 are all in current dollars, as our focus here is on relativity of growth among different sectors of the economy.

[7] It is interesting to note that the brokerage firms stayed on course with their continuing high incomes even when much of the rest of the economy, in 2001, had begun their rapid downturn from their ascent of the 1990s.

[8] Gordon observes (2000b, 50) that "recent productivity revival appears to have occurred primarily within the production of computer hardware, peripherals, and telecommunications equipment, with substantial spillover to the 12 percent of the economy involved in manufacturing durable goods." Given our data presented, his remark, "… in the remaining 88 percent of the economy, the New Economy's effects on productivity are surprisingly absent," is at odd with reality.

[9] The DOD budget has risen significantly since the 9/11 and the subsequent U.S. involvement in Afghanistan and, further and more importantly, in Iraq. Unless the latter are endogenous to (i.e., the necessary events that must follow) the end of the Cold War, we could regard the budget contraction in continuing terms.

[10] Important also, the declining defense R&D funds suggest that the civilian sector now faces a less formidable rival in its search for young scientists and engineers. One can only surmise the intense DOD bidding for the top Ph.D graduates in science and engineering in the 1980s, when its R&D budgets, as noted, were nearly double that of the 1970s.

[11] Manpower shift out of the defense-related R&D does not necessarily involve workers changing their place of employment. It can occur when firms switch their businesses from defense-related to civilian sector activities.

[12] This figure, which may seem somewhat low, approximates the average personnel costs of the R&D staff that include the entry-level and other younger professionals, such as postdoctoral associates and Ph D. candidates in academia and junior-level (post-baccalaureate) research staff in industry working on defense-related R&D projects.

[13] In determining the R&D staff share in the budget and the average staff compensation, the author consulted scientists and engineers in academia and those in industry. They were in agreement that, given similar educational backgrounds, compensations for industry-affiliated R&D staff were, in general, considerably higher than those in academic institutions. The layoffs, when they occur at universities and affiliated research institutes, are assumed to first affect the younger, untenured members. In industries, likewise, the initial layoffs presumably affected the younger staff. However, where early retirement incentives were offered, as happened among many firms (Du Pont Corporation being one better known case), more able, valued individuals were often the first to take such offers and then seek new jobs which would have been readily available.

[14] The growth of' the 1990s was technology shock-driven, with delayed productivity payoffs from decades of massive government-sponsored R&D activities. The endogenous growth models, especially the ones that include 1990s in the sample period, would run into severe technical problems in adequate accounting for the effects of human capital. Tallman and Wang (1994), seeing shortcomings of cross-country analyses (difficulty to capture the effects of country-specific characteristics, the difference in the data samples, and so on) undertakes a time series

analysis specific to Taiwan. In this work, the perceived relationship between their human capital variable (weighted indices representing educational achievements) and economic growth is contemporaneous, because "these educated individuals are available for current labor input." When portions (fairly significant) of educated individuals of high caliber are ushered into the activities not relevant to civilian sector productivity, the empirical studies that perceive immediacy of the effect of human capital, as measured, would be missing a great deal.

[15] During this period, according to Donald Schneider (a Cal Tech astrophysics Ph D. and now deputy chair at Penn State University Department of Astronomy), many able young mathematicians, scientists, and engineers completing their advanced degrees were drawn into high-paying government (defense related) research projects.

[16] France which was in vanguard of high speed passenger rail travel in Europe had its TGV (Train a Grade Vitesse) operating between Paris and Lyon built in 1981.

[17] In 1980, Japan's population was 116.8 million, same as the combined population of West Germany and France combined (116.7 million). That this large population had to live in a small land mass (the size of California) perhaps was a disguised blessing; the nation benefited from of economies of scale and of clusters. Most of its major industrial centers (including the three largest, Tokyo/Yokohama, Osaka, and Nagoya) are all port cities and in close proximity (within reach of two and half hours on the Shinkansen rapid train). This allowed cost advantages in production, logistics, and shipping, as well as positive externalities from efficient intra- and inter-industry interactions. Important also, Japan's post-War Constitution, which limits defense expenditures (to one percent of GDP), meant lower taxes with their attedent benefits and, no less important, fuller utilization of highly educated manpower in the civilian economy and the government sector. This was a huge benefit, when compared with other industrialized nations, especially the U.S., and to lesser extent, France and West Germany, during the Cold War era, in particular.

[18]Japan's more recent achievements in technology includes the first commercially viable high brightness blue LED, invented in 1993 by Shuji Nakamura, an employee of the Japan-based Nichia Chemical Corp. and now at University of California, Santa Barbara. His white LED (Light Emitting Diode, semiconductor-based devices), likely to lead to replacing the traditional incandescent light bulbs (the lighting method invented by Thomas Edition in 1878) is seen as an epoch-making breakthrough or described as "holy grail of semiconductor optoelectronic engineers." In 2006, Nakamura won the Millenium Technology Prize (of Finland). Winipedia, Free Encyclopedia, http://en.wihipedia.org./wiki/Millenium_Tchnology_prize; http://www.engineering.ucsb.edu/Announce/nakamura/html; Taiwan Journal, p. 8.

[19] Professor Chikara Komura of Seikei University, Tokyo called my attention to this point. It is to be expected, given the well-documented fact that wide ranging industrial R&D activities of the private sector benefited greatly from active support of the government (of the MITI, in particular, and the state-controlled financial institutions).

[20] The U.S.-Japan R&D collaboration also extended to the academic sector. Don Schneider recalls the joint astronomy research project of the late 1980s and early 1990s in which Japan, apart from its financial contribution, provided top talents (from University of Tokyo and the Yugawa Center for Advanced Studies, Kyoto) who joined the staffs on the U.S. side (from Institute of Advanced Studies at Princeton and of University of Chicago). Schneider, who had

participated in the joint work, notes also that the specialized computer hardware and software developed in Japan were critical inputs to the project.

[21] For discussion of the severity of the financial sector dysfunction and associated problems, see Hoshi and Kashyap (2004).

[22] It is interesting to note that recent resurgence of the Japanese economy (2.3 and 2.6 percent real GDP growth registered, respectively, for 2004 and 2005 – *Japan Statistical Year Book 2006* Table 3-3; Cabinet Ministry, Japan homepage release) was export-driven and further that it followed closely the uplifting of the U.S. economy that began in 2003 (2.9 percent real growth and 4.2 percent and 3.5 percent growth, respectively, in 2004 and 2005 – U.S. Department of Commerce, Bureau of Economic Research, *News Release*, June 19, 2006).

[23] Increasing demands for chips, mobile handsets, flat panel, and digital TVs in emerging markets of China, Eastern Europe, Mexico, and others are adding to the brisk rise in Korea's IT exports (*The Korea Herald*, September 6, 2006).

[24]Semiconductors stand prominently among such products. Samsung Electronics Co., one of Asia's principal semiconductor makers, moving brusquely in the race for advanced chip technology, just unveiled the world's first 32-gigabit NAND flash memory chip (Korea Herald, September 10, 2006).

[25] The relative success of Taiwan, vis-à-vis Korea, in overcoming the challenges of the Asian financial crisis owes in part to its development policy designs. Whereas Korea relied heavily on internal (state-owned banks') subsidized loans and government guarantees of external loans that favored large firms, long since the early 1960s, Taiwan resorted to elaborate schemes of tax incentives for "strategic industries" which affect firms of all sizes (see Riew, 1988; Chang and Riew, 1994). Taiwan's small/medium firms and their success stories can be explained, to large extent, to this policy choice for development. These firms, unlike Korea's debt-riddled large firms, were relatively debt-free and less vulnerable to the ill effects of speculative flows of external capital.

[26] Taiwan's exports of Information/Communications products show (Table 9) steep fall from $19.6 billion in 2000 to $10.5 billion in 2005. The main contributing factor, as explained by economists in Taiwan, was the rising labor costs, particularly in Taiwan's IT sector, forcing local firms and plants to relocate, to mainland China. Interestingly, this was precisely the way the U.S. IT firms found their reason for outsourcing parts and component procurements as the starter during the nineties. An interesting question we need to address here is why Korea's exports of IT products kept rising at phenomenal paces.

[27] China, according a recent IMF report, China has consumed more than half of the world's metal output over the past four years (Korea Herald, September 10, 2006).

[28] What we see here around the turn of the 20th century, it seems, is consistent with Douglas North' observation (1981, ch.12) that "population and military technology and organization" are "the two major forces for change in the millennium" (the millennium that followed the disappearance of the Roman Empire in the fifth century A.D.).

[29] The path-breaking development of the transistor in 1947 was the work of the Bell Telephone Laboratory scientists (the three co-inventors won the Nobel prize in physics in 1956).

[30] While the DOW index, currently in the vicinity of 11,000 (at this writing in the early fall of 2006), nearly returned to the June 2000 peak of about 11,700, the NASDAK, still hovers in the 2,100- 2,300 range (following the trough experienced at below 1,200 in the fall of 2002) falling well short of one half of the peak (of over 5,000) in March 2,000.

[31] In Germany, under the new rule, effective February 2006, an unemployed person (single, childless, 40 year old) gets *60 percent* of *net* wages (up to a ceiling of $2,018 per month) for *12 months*. This compares with Denmark's *90 percent* of *gross* (before-tax) wages (up to $1,994 per month) for *four years* and France' *57.4 percent* of *gross* salary (up to $7,015 per month) for *23 months*. The corresponding rules in the U.S. vary among states, with Pennsylvania, for instance, providing up to $486 a week, higher than Louisiana's $258, for up to 26 weeks (6 months) in both states. (*New York Times*, October 8, 2005) Such differences in entitlements (and, also, perhaps, "expensing," for tax purposes, of capital acquisition under Europe's value added taxes) would probably go a long way explaining large cross-Atlantic unemployment rate disparities.

[32] Japan also had to resort, eventually, to taxpayer bailout of the massive nonperforming loans, as was done in the U.S.during its S&L Crisis of the late 1980s, except that the magnitude of the problem facing Japan was far greater. For Japan's achievements and ongoing efforts to expand the scope of financial sector structural reforms, see Hubbard (2005).

[33] Recent banking reform in China, we might note also, deserves a mention, as the nation plays an increasingly important role in our open world economy today.

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