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by Amar Bhidé*

1. Introduction

The "techno-fetishism and techno-nationalism" described by Ostry and Nelson in 1995 has apparently drawn strength over the last decade from concerns in the West about globalization. The mindset incorporates two related tendencies. One is the focus on the upstream development of new products and technologies while glossing over their downstream consumption and use. The other is the belief that national prosperity requires upstream international *leadership* in upstream activities – "our" scientists, engineers, entrepreneurs, and firms have to better than everyone else's – they must write more papers, file more patents and successfully launch more products. Otherwise, competition from low-wage countries like China and India will erode living standards in the West especially as they upgrade their economies to engage in more innovative activities.

In this paper I claim that the two tendencies misapprehend the nature and role of innovation as well as the implications of globalization. I argue that the willingness and ability of individuals to acquire and use new products and technologies is as important as – and in small countries more important than – the development of such products and technologies. Moreover nations – unlike many individuals and organizations – don't have to outperform 'competitors' in order to prosper. Notwithstanding the rhetoric about the competitive advantages of nations – a transplant from the domain of inter-firm rivalry that has displaced references to old-fashioned comparative advantages – countries are not locked into zero-sum trade. An innovation originating in one country does not impoverish other countries. Rather it tends to improve standards of living in all countries that have the downstream capacity to acquire and implement the innovation.

My concern with the neglect of the consumption and use of innovation, and the policy implication thereof) dates back to 1982. As an employee of the consulting firm, McKinsey & Co., I was working on a study to help the European Union promote the Information Technology industry. The focus of the study was entirely on what the EU could do to help the producers of IT equipment through grants, subsidies and tax breaks. My efforts to broaden the scope to include the behavior and needs of the users of IT were

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futile. I was the lowest ranking consultant on the team, and the clients on the EU side had no interest. A *Harvard Business Review* article (Bhidé 1983) about the importance of the nature of the demand for innovative products that I then wrote had similarly negligible impact.

My perspective has subsequently been informed by my studies over the last 18 years of new and emerging businesses that for convenience we may call "entrepreneurial" firms. Numerous research associates, students and I have examined, in varying depth and detail, more than five hundred such firms. These studies, including notably, an on-going study of U.S.-based venture-capital backed firms[*], suggest that very few of entrepreneurial firms, including those in the high-tech sector undertake cutting edge "upstream" R&D activities. Rather, they combine (often not in particularly revolutionary ways) and distribute innovations generated by upstream individuals and firms; to borrow terminology from the computer industry, they play the role of "system integrators" or "value-added resellers." Accordingly their success – and their much vaunted contribution to productivity – requires not just an amply supply of innovative inputs; entrepreneurial firms also require venturesome and resourceful customers – many of whom are not in the high tech sector, who are willing to take a chance on their products and services. Moreover, entrepreneurial firms do not combine and "add value" just to domestic innovations; in an era of growing cross-border flows of ideas and knowledge, the sources of their innovative inputs are increasingly global. Therefore an increased supply of innovative inputs from abroad is a boon, to the entrepreneurial firms, their customers and to the broader economy.

Although I have derived my perspective mainly through an inductive process, my field observations and a review of the literature show that many of the components are not novel. I will report the linkages as I go along. Here I will mention the especially noteworthy items of prior art that my perspective integrates with or has unwittingly re-discovered.

A close relationship between technology adoption and economic development has been examined by several economic historians. These include Morrison (1966), Rosenberg and Birdzell (1986) – who argue that the West grew rich first because the resistance to adopting new technologies was weaker there – and Mokyr (1990). I use contemporary examples to argue that technology adoption continues to play a critical role.

This paper also repeats Carter and Williams's (1964) caution, of more than four decades ago, that "it is easy to *impede* growth by excessive research, by having too high a percentage of scientific manpower engaged in adding to the stock of knowledge and too small a percentage engaged in using it. This is the position in Britain today." Similarly, in 1986, Paul David wrote that innovation had become a "cherished child, doted upon by all concerned with maintaining competitiveness… whereas diffusion has fallen into the

[*] As of this writing, Liz Gordon and I have interviewed the CEOs of 72 such firms out of a target of 100.

woeful role of Cinderella, a drudge like creature who tends to be overlooked when the summons arrives to attend the Technology Policy Ball."*

My argument incorporates country and firm level differences in "absorptive capacity" for innovations. The term "absorptive capacity" has been used in the economic development literature since at least the early 1960s to refer to the limited capacity of backward countries to put new investments and by extension the innovations they may embody into productive use. Cohen and Levinthal (1989) applied the term "absorptive capacity" to refer to the ability of individual firms to effectively absorb new technologies, and their usage has now become commonplace. But, although their definition is broad, Cohen and Levinthal and subsequent researchers focus on high tech firms, examining for instance how their internal R&D efforts help firms use research produced in university labs.

In examining how absorptive capacities matter, I pay more attention to organizations that don't have any formal R&D efforts and to final consumers. I also suggest that the absorption of innovations, like their generation, has disorderly entrepreneurial facets, such as the willingness to confront Knightian certainty. This venturesome consumption of innovations, like their venturesome production falls outside neo-classical models and (unlike R&D spending) eludes objective measurement.

Lastly, the construct of an "innovation system", comprising many related but different components (instead of a single innovator or a swarm of similar innovators) provides me with a useful expositional device. The idea of a system popularized by Richard Nelson and other scholars accurately reflects how modern innovation really works. Researchers however tend to focus on the upstream elements of the system and their linkages, for instance between university researchers and commercial R&D labs. I will include in the system, the role of intermediate and final consumers of innovations, who are far removed from university labs and have no internal research programs.

Structure. The next section provides exemplars of the techno-nationalistic view that prosperity requires leadership in innovative activity and suggests that such views are incongruent with the failure of per capita incomes in Europe and Japan to catch up with per capita incomes in the U.S. The subsequent three sections provide an alternative to the techno-nationalist view: Section 3 covers some salient general features of modern innovation systems, Section 4 focuses on the roles and rewards of mid- and down-stream consumers and Section 5 explores the implications of globalization. Section 6 argues that this alternative view of innovation helps explain why in spite of the erosion its upstream technological leadership the U.S. continues to enjoy higher per capita incomes than Europe and Japan. Section 7 explores hypotheses about the factors that make firms and

*David repeated this observation at a 2003 conference held in memory of Zvi Grilichches when he wrote that "the political economy of growth policy has promoted excessive attention to innovation as a determinant of technological change and productivity growth, to the neglect of attention to the role of conditions affecting access to knowledge of innovation and their adoption." (David 2003). In that paper David also remarked that Griliches's work first on the diffusion of technology and then on the sources of growth of total factor productivity had been path-breaking, yet Griliches had no pursued the connections between the two. Instead, in his later work Griliches had focused on the "upstream", sources of productivity growth, namely R&D efforts and patenting.

individuals more or less willing and able to use innovations. The final section provides a concluding perspective on the policy implications.

2. A pre-occupation with leadership

Writing at a time when the U.S. was concerned about the "productivity slowdown" and the threat supposedly posed by Japanese manufacturing pre-eminence, David (1986) wrote that "success" in the U.S. was "equated with "leadership"… with pioneering on the technological frontiers. To be an assiduous "follower," seems somehow to have acquiesced in defeat, abandoning adventure for the haven of routine"

Concerns about Japan have receded in the last 20 years but the pre-occupation with technological leadership remains. In "America's Technology Future at Risk" Prestowitz (2006a) writes: "American wealth, economic growth and national security have long been based on technological leadership... [T]he United States has always focused on new technology as the main engine of economic welfare. For more than half a century America's broad technological leadership has been unchallenged."

Prestowitz is particularly concerned about the U.S. position in the telecommunications industry, which "has long been an indispensable element of America's technological leadership and economic success." Now however, the U.S. is "well on its way to surrendering leadership in advanced telecom products and services". Prestowitz points to several other alarming developments: In 2005 the US had a "$55 billion trade deficit in Advanced Technology Products." Venture capitalists are "pressing the start-up firms they finance to move R&D to Asia…Many telecom and technology companies [have] cut vital R&D spending by 10-40%. At the same time, Government R&D spending in these areas has also fallen by over 30%"

"Foreign companies make up the majority of the top ten recipients of U.S. patents each year and the United States has fallen behind the EU and lost ground to Asian countries in the publication of scientific articles. The United States is awarding fewer Bachelor of Science degrees than it did in 1985 and far fewer than Japan, the E.U., China, India and even Korea."

The economist Richard Freeman uses different arguments than does Prestowitz (a former businessman and trade negotiator in the Reagan Administration who now runs a think-tank he founded) but reaches similar conclusions. Freeman's (2005) NBER working paper, like Prestowitz's article asserts the significance of leadership: 'leader' or 'leadership' appears in the title and five times on just the first page of the paper. Shorn, perhaps unfairly, of their qualifying clauses and sentences, Freeman's concerns can be stated as follows.

"Leadership in science and technology gives the US its comparative advantage" and "in a knowledge based economy, contributes substantially to economic success." Unfortunately for the U.S, its "global economic leadership" is under threat. "Changes in the global job market" are "eroding US dominance in science and engineering". Freeman forecasts that "the erosion will continue into the foreseeable future". By "increasing the number of scientists and engineers, highly populous low income countries such as China and India can compete with the U.S. in technically advanced industries" and "undo the traditional "North-South" pattern of trade in which advanced countries dominate high-tech while developing countries specialize in less skilled manufacturing."

The evidence that Freeman offers to support his claim that U.S. dominance in science and engineering is and will continue to erode includes the following: In 1970, "over half of science and engineering doctorates were granted by US institutions of higher education." Since then, the U.S. share has steadily declined. As shown in Table 1a, countries in the European Union produced 7 percent fewer PhDs than the U.S. in 1975. By 2001 EU institutions granted 54% more PhDs and by 2010 they would probably grant nearly twice the number of PhDs as U.S institutions. Japanese institutions produced just 11% of the PhDs produced by U.S. institutions in 1975. By 2001 that percentage had more than doubled, to 29%. China produced virtually no doctorates in 1975. By 2001 it was producing nearly a third as many as the U.S. and by 2010 it was expected to produce more doctorates than the U.S. Overall, according to Freeman's projections, the U.S. share of world's science and engineering doctorates is likely to fall to about 15% in 2010.

Like Prestowitz, Freeman points to the fall of U.S. shares of scientific publications, patents, and bachelor in engineering degrees and the expansion of R&D establishments in Asia. "Data on publications and citations by country of investigator show that the US predominance has already begun to drop" writes Freeman. "In spring 2004, the front page of The New York Times reported a fall in the U.S. share of papers in physics journals while Nature reported a rise in the share of papers in China. The NSF records a drop in the US share of scientific papers from 38% in 1988 to 31% in 2001 and a drop in the US share of citations from 52 percent in 1992 to 44 percent. The share of papers counted in the Chemical Abstract Service fell from 73% in 1980 to 40% in 2003."

"Many high-tech companies" continues Freeman "have begun to locate major research installations outside the U.S. In 2004, the CEO of Cisco declared that "Cisco is a Chinese company" when he announced that the firm was setting up its newest R&D facility in China. One of Microsoft's major research facilities is in Beijing. OECD data shows a large increase in U.S. outward R&D investment from 1994 to 2000….As of mid 2004, the Chinese government registered over 600 multinational research facilities in the country, many from large US multinationals. By contrast, in 1997 China registered less than 50 multinational corporation research centers."

The concerns of Prestowitz, Freeman and others have apparently resonated with the U.S. Administration. Noting the "uncertainty" engendered by "new competitors, like India and China" President Bush, in his 2006 State of the Union Speech, announced the "American Competitiveness Initiative" that would (according to a White House Press release) "help the United States remain a world leader in science and technology." The initiative included proposals to double the Federal commitment to "critical basic research programs in the physical sciences"; make permanent the research and development tax credit (to encourage "bolder private-sector initiatives in technology"); and support universities that "provide world-class education and research opportunities."

Policy makers in other advanced countries also apparently subscribe to the thesis and employ similar arguments and rhetoric. In the U.K., the Chancellor of the Exchequer Gordon Brown's 2006 Budget Statement noted that China and India had "4 million graduates a year to Britain's 400,000" as well as more computer scientists and engineers. "Every advanced industrial country knows that falling behind in science" he said "means falling behind in commerce and prosperity." He proposed that the government "do more to support the dynamism and enterprise of business…start[ing] with the importance of Britain leading in scientific invention and discovery." Measures announced in the budget included increasing expenditures on scientific discovery, simplifying allocation of research funding for universities and expanding the scope of R&D credits.

The 'Lisbon Agenda' of the European Union commits to raise research spending in EU countries to at least 3% of GDP. According to a European Commission web-site devoted to the agenda, "the EU invests less of its GDP in research and development than its main competitors" – just 1.96% of its GDP compared to 2.59% for the U.S., 3.12% for Japan and 2.91% for Korea. And Europe "does not have enough scientists and researchers – 5.3 per 1000 workforce compared to 9 per 1000 in the U.S. and 9.7 per thousand in Japan." The proposed solutions to the shortage of scientists include creating a "European Institute of Technology" and making "science a more attractive career option."

The EU and Messrs. Prestowitz and Freeman can't both be right about whether or not the U.S is 'behind' Europe. But putting that aside, why does scientific and technological *leadership* matter to a country or region in the first place? For Prestowitz, the historical correlation of U.S. leadership with prosperity makes it self-evident that any erosion of leadership must impair standards of living.

The economist Freeman relies on models of "North-South" (or rich country-poor country) trade to reach this conclusion. Freeman's reasoning may be paraphrased as follows:

1. In highly simplified classical or neo-classical models, trade always benefits both parties; but when complications like first mover advantages or increasing returns to scale are introduced, the models show that gains to one country may come at the expense of another.

2. Trade models also predict that technological advances in a country may help – or hurt – its trading partners depending on the sector in which they occur. In particular "a country benefits when a trading partner or potential trading partner improves technology in a sector in which the country does not compete but loses when a country improves its technology in country's export sector. It is good for Alaska if El Salvador improves its technology for banana production but bad for Nicaragua.

3. North-South trade is mutually beneficial when "the South competes with the North for production of older products through low wages but is unable to compete in the newest technology." If however, the South starts competing with the North in "the high-tech vanguard sectors that innovate new products and processes" the South gains at the expense of the North. Thus as China increases its supply of scientific and engineering workers and competes with the U.S. for upstream innovations instead of just trinkets and toys, the U.S. begins to lose rather than benefit from trade. ("The loss of comparative advantage can substantially harm an advanced country", writes Freeman.)

Freeman acknowledges that there are models which show that "under some circumstances the loss of technological advantage *could* benefit the advanced country". But Freeman dismisses such a scenario as "more of a theoretical curiosum than a realistic representation of the current economic world." In Freeman's judgment, the "loss of technological superiority overall is likely to be disastrous for US workers and firms."

Trends like the "multinational movement of R&D facilities to developing countries are harbingers" of the difficult "adjustment problems" that await U.S. workers.

But recall Freeman's evidence about the loss of U.S. shares in scientific publications, citations and patent counts. Look again at the data in Table 1 on the ratios of scientific and engineering (S&E) PhDs. Towards the end of his article Freeman says that the increase in S&E workers in Europe and Japan is "recent" whereas the table points to a trend that has been in place for more than two decades. Richard Nelson and Gavin Wright wrote about "The Rise and Fall of American Technological Leadership" in 1992. Table 1b shows there has been no decline in U.S. per capita incomes in either absolute or relative terms. PPP-adjusted per capita income in EU countries was about 75% of per US per capita income in 1975 and the gap has remained more or less at that level since then. Japanese per capita incomes reached 80% of the per capita incomes in the U.S. by 1989; after that, relative incomes in Japan have actually fallen a bit. According to 'convergence theories', European and Japanese incomes should have been catching up with U.S. incomes anyhow; with substantially increases in their share of PhDs, scientific articles and the like, why didn't Europe and Japan roar ahead? Why instead was the growth rate in output per hour over 1995-2003 in Europe was just half that in the United States (Gordon 2004)?

Japan's reconstruction and export led boom for nearly four decades after the Second World War also doesn't sit well with Freeman's account. As is well known Japan grew at miraculous rates as it moved, to use the language of the trade models, from the 'South' to the 'North' and the composition of its exports changed from low end trinkets to cutting edge goods. U.S. per capita income and productivity which started at a much higher base did grow more slowly than Japan's but grow they did. Indeed prosperity increased in most Western countries, all of whom could not possibly have been leaders in science and technology.

What accounts for the gap between the 'technical leadership is a must' assertion on the one hand and many decades of experience on the other? Are Freeman et. al. measuring leadership inappropriately? Or does the problem lie with the models? I will argue the latter. Although the mathematics behind the models may be sound and industrious researchers may even provide evidence that is consistent with their predictions, they are like theories for bridge design that ignore gravity. They omit vital features of the modern innovation system, especially the role of consumers. These I will now examine.

3. The system of modern innovation

Just as a devout Hindu might begin a journey with a prayer to the Lord Ganesh, it is obligatory to start a discussion on modern innovation by invoking Schumpeter. The thousands of pages he wrote over more than four decades contained sharp, unequivocal claims as well as tangles of contradictions: Elster (1993) describes Schumpeter as an 'elusive' writer who could contradict himself in the course of a single paragraph. Nevertheless, because as Rosenberg (1976) puts it, "his model has become the accepted one for all innovative activity", it provides a valuable point of departure.

I do not question Schumpeter's overall thesis – that innovation drives long term growth. – but in my view, the model itself (or at least the common conceptions thereof) contains errors and omissions that help obscure how the modern innovation system works and encourage the techno-nationalist attitudes that I have just described. In particular, I suggest below, the innovation system has the following features that are at odds with the Schumpeterian model.

Destructive ***and*** *non-destructive creation*

According to Schumpeter (1961) "a perennial gale of creative destruction" is an "essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live with." Destruction is the price of innovation: the automobile must displace the buggy makers and mass merchandisers must put the country store out of business. The innovator combines the roles of the mobs of the French revolution who overthrew the *ancien regime* and Napoleon who founded an empire on its remains.

Although Schumpeter's vivid metaphor has become commonplace, many innovations do not displace existing products and services because they create and satisfy entirely new wants.* This non-destructive creation represents a critical complement to creative destruction for the following reason: Long run economic growth of course requires productivity growth. But productivity growth doesn't just come from improved efficiency – using fewer resources to satisfy our current wants. The creation and satisfaction of new wants can also increase per capita output. For instance, an artist may increase her productivity by developing new techniques that speed up her output of paintings. Alternatively, she may develop a new oeuvre that commands higher prices. She may produce exactly the same number of canvases as before, but, provided her work sells at higher prices, her *economic* output and productivity increases. Moreover, the new oeuvre may serve as a substitute for more traditional paintings, so innovator's productivity gain comes at the expense of the productivity of artists' who face reduced demand. But it doesn't have to: the new oeuvre may appeal to completely new sensibilities and find a place on walls that otherwise would have remained bare.

In fact, economies cannot sustain increases in productivity and living standards simply through increasing efficiencies in the satisfaction of existing wants. In the short run, increased efficiencies reduce costs and as costs decline, people consume more of the good or service. But eventually, the law of diminishing utilities sets in. Sated consumers refuse to buy more even if prices continue to decline. After that, further increases in efficiencies reduce the demand for labor.

In principle, societies could accommodate the reduction in the demand for labor by increasing everyone's leisure. Over the last century, economic growth has helped reduce working hours and increase vacations. But somehow, beyond a certain point, societies seem unable to accommodate reductions in the demand for labor by spreading the work around. Efforts to control unemployment by mandating reductions in work weeks or increasing the number of holidays don't seem to work.

Rather, it is the entrepreneurial activity of creating and satisfying new wants that keeps the system humming. It employs the labor and purchasing power released by increased efficiencies in the satisfaction of old wants. It also creates incentives for continued increases in efficiencies even after demand for old wants has been fully satisfied:

* The following is a condensed version of a prior lecture (Bhidé 2004).

Producers who satisfy old wants have to keep economizing on their use of labor because they must compete for employees (and share of consumers' wallets) with innovators who satisfy new wants.

The historical record shows that the great prosperity brought about by the Industrial Revolution – incomes more than doubled in the 19th century and increased more than eightfold in the 20th century – has both destructive and non-destructive roots. Innovations such as tractors, threshing machines, fertilizers, pesticides and hybrid seeds led to vast improvements in agricultural productivity. As productivity increases reduced costs and increased the affordability of food, per capita consumption grew. But the increase in the consumption of food or other existing goods doesn't come close to accounting for the vast increases in overall per capita G.D.P. According to William Nordhaus's (1997) estimate less than 30% of the goods and services consumed in 1991 bear much resemblance to the goods and services of the late 19th century. "Most of the goods we consume today" Nordhaus writes, "were not produced a century ago. We travel in vehicles that were not yet invented that are powered by fuels not yet produced, communicate through devices not yet manufactured, enjoy cool air on the hottest days, are entertained by electronic wizardry that was not dreamed of and receive medical treatments that were unheard of."

Some of the new goods replaced the goods consumed by our forebears. Cars and buses replaced horses and stagecoaches. Steamships grounded sailing ships and ready-to-eat cereal pushed homemade porridge off breakfast tables. But many new 20th century products created new markets and satisfied new wants. They were like a new oeuvre of art purchased for spaces that would otherwise remained bare. Air-conditioners reduced temperatures in previously un-cooled factories stores and office buildings. Airplanes did not reduce the demand for automobiles – people flew when they would not have driven. New drugs and vaccines offered cures for diseases for which treatments did not previously exist. In 1938, the New York Times observed that the typewriter was "driving out writing with one's own hand," yet Petroski (1990) reports the sale of 14 billion pencils in 1990.

Moreover even those apparently destructive new products also created new markets because they had features that the products they displaced did not. For instance, automobiles provided much faster and not just cheaper transportation than did horse carriages, so people could live in spacious houses located at some distance from their workplace. This helped create demand for suburban housing that did not previously exist. Similarly incandescent lamps didn't merely replace candles and kerosene lamps: their intense luminosity helped create a market for cricket and baseball played at night.

The innovations in digital and information technology of the late 20th century have followed the same pattern as the electro-mechanical innovations of earlier decades. The innovations have certainly involved some substitution. For instance, calculators displaced slide rules, micro-processor based workstations displaced mini-computers and CDs displaced cassette tape recorders. But, there has also been at least as much non-destructive creation. The personal computer (PC) did not blow away the traditional mainframe computer in a gale of creative destruction. The PC's killer application, the spreadsheet, did not displace any existing mainframe based applications. Rather it allowed users, many of whom had not previously used computers extensively, to perform analyses and simulations which they would not have otherwise performed. Similarly the enormous growth of the home market for PCs did not reduce the demand for mainframe computers.[1]

New communications services – E-mail, newsgroups, and "chat" – provided a critical mass of users for the Internet. These services apparently did abate the demand for traditional phone lines in the U.S. – U.S. cities continue to require new area codes. And those new products that displaced old products did so *after* they had created a new market. For instance as I discovered in the course of a consulting study for a now defunct typewriter manufacturer, shipments of word processing units increased fourteen-fold growth between 1977 and 1981. But because word processors increased primary demand by satisfying some hitherto unmet want, the sales for typewriters in the United States remained steady at around a million units a year during this period. Similarly, one day (after standards and coverage issues have been resolved) cell phones may make land line phones obsolete. But not before consumers have purchased hundreds of millions of units in applications where land line phones had not been used.[2]

An evolutionary process

According to Schumpeter, the economically significant innovations that disturbed the "circular flow" were 'large' and 'spontaneous' rather than 'small' and 'adaptive'. They so displaced the "equilibrium point" that "the new one [could] not be reached from the old one by infinitesimal steps. Add successively as many mail coaches as you please, you will never get a railway thereby." Schumpeter also distinguished such innovations ("carrying out of new combinations of the means of production") from their antecedent inventions. "The making of the invention and the carrying out of the corresponding innovation," he wrote, "are, economically and sociologically, two entirely different things." (Schumpeter 1939) Inventions are "economically irrelevant" as long as they are not carried out into practice (Schumpeter 1934).

In his 1976 book, *Perspectives on Technology*, Rosenberg makes a persuasive case for an incremental process, involving on-going rather than one-off inventive activity. Rosenberg writes that Schumpeter created "artificial conceptual disjunctions between innovative activity and other activities with which it is not only linked, but which in fact constitute major parts of the historical process of innovation itself." This leads us to "focus disproportionately upon discontinuities and neglect continuities in the innovative process" and to overlook its crucial later stages.

The inventive activity which precedes a new combination in Schumpeter's model, observes Rosenberg, is "carried on offstage and out of sight. Inventions come onto the Schumpetarian stage already fully grown" and ready for commercial exploitation. In fact, we cannot easily distinguish between invention and innovation: "Whereas for some inventions no serious technical obstacles to their implementation may exist once the basic idea has been established, for other inventions such obstacles are formidable and can be overcome only after much further time consuming search and experimentation."

Rosenberg questions the association of inventions with the "initial basic conceptualization of a product or process," under the assumption that "as soon as the basic conceptual or intellectual breakthroughs have been made, all the "real" problems are solved." Writes Rosenberg: "To date the invention of the fluorescent lamp in 1859, the gyro-compass in 1852, the cotton picker in 1889, the zipper in 1891, radar in 1922, the jet engine in 1929, or xerography in 1937 is to select years in which significant steps were indeed made. But in none of these years was the product concerned even remotely near a state of technical feasibility." Solving the problems that remain after the initial conceptualization takes "protracted inventive activity." Techniques for producing a new material (such as polyethylene) under laboratory conditions may be known, but it may take years to develop ways to produce it commercially. Or, an invention may be technically feasible, but its economic superiority over existing techniques may require many improvements in its "performance characteristics, often in inconspicuous and unspectacular ways." Early diesel engines for instance were too heavy for economic operation, and early jet engines had unacceptably low performance characteristics until the development of materials that could withstand high pressures and temperatures. In such cases, innovators cannot, per the Schumpeter model, merely select inventions which are "already suitable for commercial introduction" and carry out the introduction of a new production function with them. (Rosenberg 1976 p. 72-73)

Rosenberg similarly questions the distinct and secondary role Schumpeter accords to the propagation of new combinations. Schumpeter posits a "sharp disjunction" between "the high level of leadership and creativity involved in the first introduction of a new technique as compared to the mere imitative activity of subsequent adopters." In fact, Rosenberg argues, the diffusion of an innovation requires much more than simple imitation. A "stream of improvements in performance characteristics," "progressive modification and adaptation" to suit the requirements of sub-markets, and the introduction of complementary inputs, "decisively affect the economic usefulness of an original innovation." These ongoing activities are:

> …central to the pace of the diffusion process. It is economically absurd to consider the innovation of the automobile as having been accomplished when there were a few buffs riding around the countryside terrifying horses. Innovation is, economically speaking, not a single well-defined act, but a series of acts closely linked to the innovation process. An innovation acquires economic significance only through an extensive process of redesign, modification, and a thousand small improvements which suit it for a mass market, for production by drastically new mass production techniques, and by the eventual availability of a whole range of complementary activities, ranging, in the case of the automobile, from a network of service stations to an extensive system of paved roads. These later provisions, even if they involve little scientific novelty, or genuinely new forms of knowledge, constitute uses and applications of knowledge from which flow the productivity improvements of innovative activity.

A host of other innovations introduced in the years after Rosenberg's 1976 book involve continuous rather than one shot innovation. Consider the evolution of microcomputers after 1975 – the year in which the pioneering Altair was introduced. The current generation of laptops and desktops, which provides more processing power and functionality than did the computer center of my undergraduate engineering college, has come a very long way from the Altair. Altair aficionados derived less practical use from their machines than did the turn-of-the century automobile buffs. Lacking basic input or output devices (such as keyboards and printers) Altairs could not even scare horses. Numerous innovations turned this oddity into a ubiquitous artifact. Some of these innovations – the mouse, graphical user interfaces, and electronic spreadsheets – represented conceptual breakthroughs. Others (such as word-processing software) were borrowed from mainframes and minicomputers.

Continuous improvements and refinements in performance and features have been a hallmark of the industry -- Excel 2003 has come a long way from the first spreadsheet, Visicalc. Complementary innovations have played a crucial role in such improvements: Excel 2003 could not have been implemented on earlier generations of hardware. The introduction of new microprocessors, storage devices, application and operating system software, communications technologies (such as local area networks and the internet), innovations in manufacturing and distribution (such as the "build to order" process) and the opening of new market segments (such as home computing) have reinforced each other and sustained a virtuous cycle of ever improving price-performance.[3]

Although Rosenberg defers to Schumpeter's analysis for "major innovations" involving "significant shifts to an entirely new production function" he does not provide examples of such one shot breakthroughs. In fact, I can't think of any. Even ventures like Federal Express that started with a revolutionary concept required refinement over several years before they attained commercial viability (Bhidé 2000)

Massively multiplayer game

Schumpeter placed the individual entrepreneur at the center of the innovative process in his early work, but later claimed that the large corporation would inevitably usurp the entrepreneur's role. His 1911 book, *The Theory of Capitalist Development* credited capitalist innovation to entrepreneurs with the 'dream and will to found a private kingdom' and the 'will to conquer.' The 1934 work, *Capitalism, Socialism and Democracy* placed kingdoms ahead of conquerors. In creating the giant enterprise, Schumpeter now declared, entrepreneurs had eliminated their own function. The "perfectly bureaucratized giant industrial unit" could automatically discover and undertake the 'objective possibilities' for innovation. It had "come to be the most powerful engine of progress."

Schumpeter's claim is said to be one of the most extensively tested in the field of economics but with inconclusive results. The studies (reviewed in Acs and Audretsch 1991) typically rely on two types of indirect measures: R&D expenditures and patent filings. Studies of R&D spending, according to Scherer (1983) "tilt on the side of supporting the Schumpeterian hypothesis that size is conducive to vigorous conduct of R&D" whereas the evidence on patents "leans weakly against the Schumpeterian conjecture that [large companies] are especially fecund sources of patented inventions."[4] The results can have "two rather different interpretations: that the largest firms in an industry generate fewer patentable inventions per dollar of R&D than their smaller counterparts, or that they choose to patent fewer inventions (Scherer 1983)."

Around the time of the 1999-2000 internet bubble, the 'Silicon Valley', venture-capital backed model of the firm was popular among management gurus and academic researchers. In a 1999, Gary Hamel *Harvard Business Review* article exhorted large companies to "bring Silicon Valley inside." Kortum and Lerner's "Assessing the contribution of venture capital to innovation" was published in the *RAND Journal of Economics* in 2000. Using a variety of methods, but then "focusing on a conservative middle ground" Kortum and Lerner estimate that "a dollar of venture capital appears to be three times more potent in stimulating patenting than a dollar of traditional corporate R&D" suggesting that "venture capital, even though it averaged less than 3% of corporate R&D from 1983 to 1992, is responsible for a much greater share – about 8% – of U.S. industrial innovations during this decade." After the bursting of the internet bubble however, the VC-backed model has apparently lost some of its luster and there has been no major redeployment of research resources in its direction.

In my view, the Schumpeterian hypothesis and the empirical research it spawned misses the point. Different types of organizations produce different and often complementary innovations; therefore comparisons of their contributions can mislead. The distinctive contributions of large and small companies have in fact been discussed by many authors including Arrow (1982), Winter (1984) and Acs and Audretsch (1991) and their complementarities extensively examined by George Richardson, notably in his 1972 *Economic Journal* article, "The Organization of Industry."

In my previous work (Bhidé 2000 and 2006) I have discussed the comparative advantages of firms not just based on their size but also according to the source of their financing: the public markets, professional venture capitalists, angel investors and self financing by entrepreneurs in undertaking initiatives with different capital requirements and novelty.[*] My on-going research also suggests important differences between the kind of R&D undertaken by VC-backed businesses and by the labs of large companies. VC-backed businesses undertake relatively quick and dirty projects and don't employ many researchers with advanced degrees. And, they often use the innovations coming out of large company and university research efforts.[†]

The broad categories of firms and financiers that I have mentioned themselves contain heterogeneous organizations. VCs can vary in their target investment amounts and capacities and in their preferences for early or later stage investments. Some provide funding to biotechnology firms on the scientific frontier; others provide the coffee retailers Starbucks with the capital needed for geographic expansion. Similarly some self-financed entrepreneurs help shape completely new industries, as Paul Allen and Bill Gates did in 1975. Others create new supply chains and distribution systems after the product category has come of age, as did the company Michael Dell started in 1982 in the computer industry. Non-profit organizations like university research facilities, also contribute to the process of innovation – and in quite different ways. Some undertake basic research whose commercial value, if any, is very indirect; others favor projects with an eye to licensing the intellectual property they develop; and yet others provide a venue for the interactions and tinkering that accidentally result in the start of companies like Cisco and Google.

The innovation system resembles a rain forest rather than a tree farm or, to use a contemporary metaphor, a massively multiplayer on-line game rather than solitaire or

[*] I argue that at one end publicly financed firms can undertake large projects but have a relatively low tolerance for Knightian uncertainty of highly novel initiatives. At the other end, the self-financed entrepreneur tends has a comparative advantage in undertaking projects that are in a broad sense of the word, highly novel.

[†] The basic differences in category may well be responsible for the large difference in the efficiency of patenting efforts reported by Kortum and Lerner and the absence of any significant redeployment of research expenditures after the publication of their results.

chess. It includes a multitude of species (or characters) differentiated along many dimensions, rather than say just by their size or shape, or whether or not they have wings. Their interactions can be predatory or symbiotic, accidental or deliberate, extended or brief. Moreover the system appears to have shown a tendency towards an increasing proliferation of species and characters, although not necessarily in a smooth progression.

In the 19th century, inventions of new products were made by a few individuals. Edison brought forth a remarkable cornucopia including incandescent bulbs, motion pictures, and gramophones, from a facility in Menlo Park (New Jersey, not California) with fewer employees than the typical Silicon Valley startup. Alexander Graham Bell had one assistant. Automobile pioneers were one or two man shows -- Karl Benz and Gottlieb Daimler in Germany, Armand Peugeot in France and the Duryea brothers of Springfield, Massachusetts. The large professionally managed corporation became an important contributor to innovation in the first half of the 20th century. In the second half of the century, the diversity of the entrepreneurial species further increased. Researcher laboratories in universities that had hitherto focused just on creating knowledge began to develop commercially useful technologies. Similarly, professionally managed venture capital funds saw explosive growth.

The emergence of new organizations did not however wipe out the old. Individual entrepreneurs weren't (as Schumpeter suggested) made obsolete by large public firms, who in turn survived the growth of venture capital. Although they sometimes butted heads, the old and the new forms generally complemented each other's contributions – their planned and unwitting collaborations, taking place simultaneously and in sequence, made products that initially were only kind of, sort of, commercially viable. The PC industry and the Internet do not have a solitary Alexander Graham Bell or Henry Ford. Rather, many entrepreneurs, venture capitalists, large companies, standard setting institutions, university and state-sponsored laboratories, and even investment bankers and politicians have revolutionized the way we compute and communicate. Some participants in the revolutions have acquired considerable wealth and fame. Others have received neither. Dan Bricklin and Bob Frankston who created the first spreadsheet, and Sir Timothy Berners-Lee who invented the World Wide Web, did not profit at all from their contributions. And outside specialized circles, mention of their names often evokes puzzled looks.

4. Consumers' Roles – and Rewards

In most standard economic models, the developers of new technologies are absent while consumers of new technologies are at once passive and omniscient. Innovations materialize out of nowhere, and when they do, consumers know exactly whether they should buy the offering and what they should pay. In Schumpeter's model, the innovator is the star, while those who then imitate or modify have secondary parts. Consumers don't appear in the cast at all.

In fact both the neo-classical and Schumpeterian models fail to do justice to the role of consumers. In a system where innovations are carried out by a multitude of players, except for the end consumers, the producers of innovations are also consumers of 'upstream' or "adjacent' innovations. Moreover, as I will discuss next, consumers – including those at the end of the line—often play a venturesome or 'entrepreneurial' functions in leading or participating in the development efforts, bearing 'unmeasurable and unquantifiable' risks and in resourceful problem solving. They also receive, prior research suggests, a significant share of the rewards.

Contributions to development

MIT's Eric Von Hippel has been the leading proponent of the view that innovation often starts with consumers, particularly the so-called "lead users" rather than the manufacturers of the product or service. In a 1988 book, which built on his research dating back to the mid-70s Von Hippel reported that users had developed about 80% of the most important innovations in scientific instruments and most of the major innovations in semiconductor processing. In his 2005 book Von Hippel writes that "a growing body of empirical work shows that users are the first to develop many and perhaps most new industrial and consumer products."

The book recalls Adam Smith's (1776) observation that many labor saving machines were invented by "common workmen" who "naturally turned their thoughts towards finding out easier and readier methods of performing" some simple operation they had been employed to perform. Other historical examples that Von Hippel cites of where most important innovations were led by users include basic machine tools like lathes and milling machines – according to Rosenberg (1976) textile, gun and sewing machine took the lead; oil refining (Enos 1962); and, the most widely licensed chemical processes (Freeman 1969).

On the consumer side, Von Hippel provides examples from extreme sports like high performance wind-surfing, snow boarding and mountain biking. High performance wind-surfing started when competitors in traditional wind-surfing events modified standard boards in order to do "jumps." The modifications were then used in boards used for normal wind-surfing. Similarly, Von Hippel reports that mountain biking started in the early 1970s with young cyclists who put together bicycles, using strong frames, balloon tires, and drum brakes from motor-cycles, for rough off-road use. A fragmented cottage industry then started to supply such cycles for those who didn't want to assemble their own machines, but it wasn't until mountain biking had grown to half a million participants before the mainstream suppliers got into the act.[5]

In the ventures that I am now studying (and have previously studied) user led innovation does not appear to be the norm, except in the very broad sense that most innovators do put themselves in the shoes of users. This could be because of an artifact of my samples or because I have not specifically focused on the issue of user-led innovations. Moreover, although user-led innovation has been critical in many instances, it may not be as pervasive as the academic literature suggests: the academic community, like the newspapers can be prone to a "man-bites-dog" type bias – studies of producer-led innovation would not excite interest and so would not be widely undertaken or published.

My on-going study of venture backed-businesses does however suggest an important role for users, even if they don't initiate or take the lead in developing new products and services. In interview after interview, we were told of the importance of what in the idiom of the industry is known as "customer engagement" with a few potential purchasers – the so-called 'alpha' or 'beta' users. These users engage in a dialogue with the development team that helps determine the attributes of the product or service that is ultimately sold. For instance, developers may start with the core component of a solution to an important problem faced by potential customers, but in the course of the dialogue with users then learn about complementary functions that must be added to the core to make it work. Or developers may conceive of a product with many functions, but then learn that some features add more to the cost of the product than they do to its value. Similarly, customer dialogue can help design an effective "user interface"; as the success of Google's search engine and Apple's Ipod shows, the so-called 'look and feel' of a product can be as important to its utility as the technical features that lie 'under the hood'.

For many of our interviewees, an amorphous agglomeration of the many things learned from their interactions with customers that are incorporated into their products, rather than their core idea, was the most valuable source of their intellectual property. Interestingly, the ownership of patents does not seem to be the norm in our sample or in the VC-backed companies studied by Cockburn and Wagner (2006). Our interviewees claimed that expense of filing patents was not worth it because even if the costs of filing were not very high, the costs of enforcing them would be prohibitive, so there was no point in incurring any filing costs. These claims in conjunction with the nature of the development process suggests that the companies might not have been in a position to file strong patents: the core idea was not particularly novel or non-obvious, while the truly valuable intellectual property, co-developed with customers and embedded in the optimal combination of features, user interfaces and so on, was too amorphous to be captured in a patent.

The contribution of customers to the development process continues after the first full-blown commercial launch. As previously discussed, products can evolve so much over time that the relationship to their antecedents may be all but unrecognizable. Rosenberg (1982) suggests that "learning by using" by customers often plays a significant role in such transformations.

Bearing 'unmeasurable and unquantifiable' risks

According to Knight (1921) the essence of entrepreneurship involves responsibility for 'uncertainty' – facing unmeasurable and unquantifiable risks rather than betting on situations (as in a casino) where the odds have been well established by many prior trials. But it is not just the producers of an innovation who face Knightian uncertainty – its consumers (who may have no role in its development) also cannot form objective estimates of their risks and returns.

One source of uncertainty lies in whether or not the innovation actually does what it is supposed to do. A product that works in the lab or with a few beta customers may not work for all customers because of some unexpected difference in the conditions of its implementation. In addition, a product that works fine at the outset may fail later on. An innovation, like a theory, can never be proven to be 'good' – at any moment, we can only observe the absence of evidence of unsoundness. Repeated use of a product may surface hidden defects that cause malfunctions, increase operating costs or pose health and safety hazards to the user or the environment.

Unanticipated technical failures injure both the producers and the consumers of the innovation. In fact, consumers may face even greater exposure. In many products and services, failures can cost consumers many times their purchase price. Defects in a word-processing or email package that costs just a few hundred dollars, may wipe out many years of invaluable files and correspondence. Or even if the data isn't lost, the costs of transferring the files to a new software package – and learning how to use the package will tend to be substantial. Similarly, a defective battery in a laptop can start a fire that burns down a house – this did in fact happen to a friend. Tires that wear badly can have fatal consequences. A security hole in its servers can cripple an on-line brokerage, and the belated discovery of the hazards of asbestos can lead to tens of billions of dollars of removal costs.

Consumers' investments in products that work perfectly well for them may also be impaired, if they fail to attract a critical mass of other users. If that happens, vendors (and providers of complementary add-ons) will often abandon the product and stop providing critical maintenance, upgrades and spare parts. Or the vendors may go out of business entirely. This has been a common occurrence in the IT industry. Customers may also be left stranded if upgrades and new releases don't have 'backward compatibility' with their forbears, or if a totally new technology makes old products obsolete.

As mentioned, many innovations seek to satisfy new wants rather than just provide a substitute for existing products. In such cases, customers also face Knightian uncertainty about whether and by how much the value they derive from the innovation will exceed its price. In the schema of neo-classical economics, consumers have a gigantic, well-specified utility function for all goods, extant as well as un-invented. Therefore when an innovation that serves a new want (or a new combination of old wants) appears, consumers consult their utility functions, as they might a tax table, and know exactly what its worth to them. As it happens there is however to my knowledge, absolutely no empirical basis for such an assumption. In fact the evidence from 'behavioral' researchers like George Lowenstein points in exactly the opposite direction: people don't have a clue about the value of things they have not experienced before: when researchers ask subjects how much they would pay for some novel experience, such as kissing their favorite movie star, they receive whimsical responses, anchored to some irrelevant piece of data just planted in the subjects' minds by the researcher, such as social security numbers. One interpretation of these behavioral experiments is that people are irrational; the other is that they simply don't know, and blurt the first thing that comes to mind to earn their $5 for participating in the experiment.

Behavioral research has been criticized for experiments where the subjects, unlike actors in the real world have no stake in the outcome, but in this instance the experiments really do seem to correspond closely to reality. It is highly improbable for instance that anyone who wears glasses or uses contacts has a firm grasp of the economic value of (successful) corrective laser surgery or someone who has a conventional TV set has a good measure of the additional value of switching to the sharper images provided by a digital product. Indeed I am skeptical that people who actually have laser surgery or buy a digital TV set can ever quantify the value. Before or after, the enhanced utility is as much a shot in the dark as the value of the pleasure Lowenstein's subjects anticipate from kissing movie stars. I personally have not seriously considered either laser surgery or buying a digital TV set, but I have been enticed by the 'latest' in personal computer hardware and software for more than two decades. I have no idea of the value of any of any of the numerous upgrades I have experienced (or for that matter, a good estimate of the time and opportunity costs I have incurred in the course of these upgrades.)

Similarly, although I have worried about – and periodically endured – the consequences of technical defects and abandonment of favorite programs by vendors, I have never actually made any effort to quantify the probability distributions. I cannot even imagine being able to enumerate all the dire possibilities. Similarly people who have corrective eye surgery may ask about the probability that something might go wrong, so that the operation won't give them 20/20 vision. But what basis could they possibly have for evaluating the consequences twenty or thirty years later? I suspect that most don't even try.

Organizations who purchase expensive systems do often expend many man-years of effort to evaluate the costs and benefits. For example, as of this writing, Columbia Business School is in the process of acquiring a new "courseware" platform. A committee has been formed, long Requests for Proposals have been issued, short lists have been made, vendor proposals have been studied, consultants have been retained …. but for all the effort and the availability of the finest analytical minds for the exercise, the value of the new courseware will remain elusive. The monetary value of enhancing the student satisfaction and learning, saving faculty time and so on can only be a blind guess. Similarly, although the out of pocket costs of purchasing a system will play a role in picking a vendor, the magnitude of the much larger 'all in' opportunity costs (e.g. the time of faculty and staff) of switching to any new courseware platform are unfathomable.

The problem of assessing the costs and benefits of what is now misleadingly called 'Enterprise Resource Planning' (ERP) software is even more acute. According to the current *Wikipedia* entry on the topic, ERP software is used for the "control of many business activities, like sales, delivery, billing, production, inventory management, quality management, and human resources management." The systems are supposed to integrate many functions including "manufacturing, warehousing, logistics, Information Technology, accounting, human resources, marketing, and strategic management." In principle, all these activities and functions are supposed to use a single data-base, rather than, for instance, the Human Resources department and the Payroll department maintaining records on the same employee in two different and incompatible data bases.

Most ERP systems are not built to suit – rather they are based on packages provided by software companies like Oracle and SAP. The premise, according to Eric Roberts (2004) Professor of Computer Science at Stanford is that "software systems are expensive and complex. What's more, the expense of a software system lies almost entirely in its development; once a system is built and tested, the marginal cost of delivering that same system to other users is typically quite small. The concentration of cost in the development phase creates a strong incentive to share development expenses over a large user base. If it costs $10,000,000 to develop a system, it seems foolish for a single institution to bear that cost alone. Given that the bulk of that $10,000,000 represents development, it makes far more sense—at least in theory—for a consortium of institutions to purchase software from a vendor that can then distribute those costs over the community of users."

There is however a catch, writes Roberts: "The success of any enterprise system depends on refashioning the business practices of the institution to match the software rather than trying to change the software to accommodate the idiosyncrasies of the institution. Changing the software violates the underlying economic assumption that allows for the reduction in cost. If each institution tailors the system to suit its needs, the cost advantage vanishes."

Enterprise software vendors claim that their systems incorporate the best possible business practices. Therefore customers gain significant advantages in refashioning their business practices to fit the standard packages. In fact, although the packages draw their "best practices" from a variety industries and situations there can be a considerable gap between the "best practice" configuration available in the package and the practice that in fact works best for a particular organization. In *The ABCs of ERP* published on-line by CIO Magazine, Christopher Koch writes that:

> While most packages are exhaustively comprehensive, each industry has quirks that make it unique. Most ERP systems were designed to be used by discrete manufacturing companies (that make physical things that can be counted), which immediately left all the process manufacturers (oil, chemical and utility companies that measure their products by flow rather than individual units) out in the cold.

Moreover it is simply infeasible for organizations to adopt all of the specified best practices. Therefore we usually find a compromise: organizations change some of its practices to suit the system, but they also "struggle" to "modify" core ERP programs to their needs. All this makes it extremely difficult to assess the value or the costs. Koch writes that the value of the systems is hard to pin down because.

> … The software is less important than the changes companies make in the ways they do business. If you use ERP to improve the ways your people take orders and manufacture, ship and bill for goods, you will see value from the software. If you simply install the software without trying to improve the ways people do their jobs, you may not see any value at all—indeed, the new software could slow you down by simply replacing the old software that everyone knew with new software that no one does.
>
> Similarly, there "aren't any good numbers to predict the costs" because:
>
> [T]he software installation has so many variables, such as: the number of divisions it will serve, the number of modules installed, the amount of integration that will be required with existing systems, the readiness of the company to change and the ambition of the project—if the project is truly meant to be a battering ram for reengineering how the company does its most important work, the project will cost much more and take much longer than one in which ERP is simply replacing an old transaction system. There is a sketchy rule of thumb that experts have used for years to predict ERP installation costs, which is that the installation will cost about six times as much as the software license. But this has become increasingly less relevant …Research companies don't even bother trying to predict costs anymore.

As is apparent from the discussion above, in many innovations, ranging from corrective laser surgery to enterprise software, the downside faced by users in the aggregated (and sometimes even individually) matches or exceeds the downside of the innovator. Indeed one of the important challenges faced by innovators is to persuade entrepreneurs to take a chance on innovations in the absence of any hard demonstration that the returns are worth the risks. And one of the notable features of the modern innovation system lies in the great many individuals and organizations who are willing to be so persuaded. At the dawn of the automobile era only a few very rich buffs served as the guinea pigs. Now the not so well-off use their credits cards – or what they "save" by buying paper napkins in bulk at a Wal-Mart – to take their chances on laser surgery and flat panel TVs without much foreknowledge of the utility their purchase will provide. Similarly large corporations, run by the book with the help of squadrons of financial analysts, will spend tens of millions of dollars on enterprise software based on the crudest of guesses of the costs and the benefits.

Resourceful Problem solving

Innovators often face situations that require "resourceful problem solving" in the following sense: although the situation may be similar to ones the innovator has faced before, it also contains novel elements, so the innovator cannot simply repeat what has worked in the past. Experience (or "human capital"), which we may think of as the accumulated knowledge of similar past situations helps, but this is not enough. An innovator is more than just a dexterous and knowledgeable surgeon performing difficult but routine arthroscopic knee surgery. The innovator must also act resourcefully in the face of novel situations with a can-do attitude, imagination, willingness to experiment and so on.

Although consuming something novel requires coping with the Knightian uncertainty about its utility, it does not necessarily require resourceful problem solving. Drinking a new soft-drink or showing up for an appointment for corrective surgery is not especially demanding. Other kinds of consumption – such as assembling model airplane may require patience, dexterity and experience but as long as the instructions are clear and complete, do not require resourcefulness or creativity. Indeed creative deviations from the prescribed instructions can lead to undesirable outcomes. But, not all innovations come with clear and complete instructions. Many high-tech products, especially those with complex architectures and features, for instance very rarely do, and deriving any utility from them requires a great deal of resourceful problem solving.

Manuals for Windows based personal computers and software, for instance, are famously bewildering. This is not simply because of the incompetence of the authors of the manuals. In considerable measure, the sometimes bewildering instructions reflect the complexity of the internal architectures of the systems, the many options and features they contain and the difficulty of anticipating how the components will interact. But whatever its cause, my experience has been that the alluring features of new products rarely work 'out of the box' simply by following the instruction manual. I have spent countless hours to get new gizmos to work or to stop inexplicable crashes. And the toil is far from mechanical: I have to guess what might be wrong, conduct experiments, and troll through postings of user groups on the internet trying to find solutions to similar problems. Indeed writing and testing the code that I developed for a real-time trading system some years ago, required less resourceful problem solving than what I have often needed to get a new software package to work.

The effective use of complex enterprise software requires solving both technical and organizational problems. As Koch writes in *The ABCs of ERP*,

> The inherent difficulties of implementing something as complex as ERP is like, well, teaching an elephant to do the hootchy-kootchy. The packages are built from database tables, thousands of them, that IS programmers and end users must set to match their business processes; each table has a decision "switch" that leads the software down one decision path or another… [F]iguring out precisely how to set all the switches in the tables requires a deep understanding of the… processes being used to operate the business.

Inevitably business processes themselves have to be "re-engineered". As mentioned, for a user to take advantage of the re-usability of off-the-shelf software packages, they must align their processes with the "best practices" incorporated into the software. And to have a system that is truly enterprise wide, organizations have to figure out processes that work best across their different units. Also inevitably, individuals and organizational sub-units tend to resist changing the way they do things; and even if they didn't, business processes and their associated information systems cannot be changed overnight. Therefore in addition to figuring out what their businesses processes should ultimately look like (and how the "switches" in the software need to be set to match the processes) organizations also need resolve how they will overcome the resistance to change and the transition from 'legacy' processes and systems.

Consultants who have implemented ERP systems in the past can help ameliorate these problems. However, the issues facing different organizations are never identical, so the consultants and their clients have to solve many novel problems. Moreover, ERP packages and the other applications – for instance supply chain, customer relationship management (CRM) and e-commerce software – that ERP is supposed to work with also change, which adds to the difficulty of deriving a 'tried-and-tested' formula for implementation. Researchers and industry experts who have expended considerable effort to investigate what works and what doesn't work have been unable to get beyond long and seemingly wooly lists. For instance Somers and Nelson (2001) have formulated a list of twenty four "critical success factors" that starts with "top management support" and includes items such as "project team competence", "inter-departmental co-operation" and having "clear goals and objectives". For obvious reasons, such lists are just starting points and do little to obviate the need for situation-specific problem solving.

The mixed record of ERP systems also points to the difficult problems that users have to solve to realize the potential benefits. According to Holland and Light (1999), successful implementations at Pioneer New Media Technologies and Monsanto have been well publicized, but "less successful projects have led to bankruptcy proceedings and litigation." Similarly, Plant and Wilcocks (2006) note the success of ERP at companies like Cisco as well as "spectacular" failures at Hershey Foods and FoxMeyer and disappointments at Volkswagen, Whirlpool and W.L. Gore.

Benefits of Innovation.

Baumol (2002) suggests that a free market system of innovation provides a positive but small share of the gains to the innovator whereas consumers get the rest. The proposition makes intuitive sense but is difficult to prove. The profits of the producers can provide at least a crude handle on what they get, but we cannot directly observe the "surplus" secured by the consumers. And for the reasons already discussed, estimates of the value they derive from their consumption are highly problematic. Researchers have tried several ways of getting around the problem, and although the estimates vary with the method used and the industry studied, they all support the Baumol conjecture, that consumers rather than the producers secure the lion's share.

For instance, Nordhaus (2005) analyzed data for the non-farm business economy and for major industries in the U.S. He finds that producers captured a "miniscule" fraction of the returns (of the order of 3 percent) from technological advances over the 1948-200 period, "indicating that "most of the benefits of technological change are passed on to consumers." Other studies reporting or implying large consumer surpluses include Mansfield (1977), Bresnahan (1986), Trajtenberg (1989), Hausman (1997) and Baumol (2002)

5. Matters of origin

The critical question for the purposes of this article is whether and how it matters if the producers of upstream innovation are located abroad rather than at home? Do consumers benefit from innovations that originate abroad, or could they as in the North-South models, invoked by Freeman, actually suffer harm? "Economists worry about another place owning the very next big thing" -- the next groundbreaking technology", Stanford's Dan Siciliano told Kronholz (2006). "If the heart and mind of the next great thing emerges somewhere else because the talent is there, then we will be hurt." Are such concerns in fact well-founded?

An important determinant of whether or not innovations abroad help or hurt consumers at home depends on whether the innovations themselves are internationally 'tradable'. If innovators are able and willing to sell their innovations to users everywhere at the same, low price compared to the value, it would not matter a great deal where the innovation originated. In fact, if international financiers provide the capital and share in the returns, the location where the innovation originates would be particularly inconsequential.

Suppose however that innovators export the products that embody their innovations but not the innovations themselves. Now the picture gets more complicated: the country of origin secures both the profits from the innovation as well as the wage income associated with the production of the goods and services. Moreover, to the degree that exports from the innovating country lead to the 'creative destruction' of wages in businesses located in other countries, innovations that help consumers at home hurt consumers abroad by reducing their purchasing power. Innovations that improve the ratio of value to price don't do much good to consumers who have lost their incomes.

Such in fact are the assumptions embedded in the North-South models that Freeman relies on to predict "disastrous" consequences for U.S. workers from the loss of the U.S. lead in cutting edge research and technical development. In these models, upstream innovations do not cross national borders. Intermediate goods and services also don't exist or cannot be traded. Only goods and services for final consumption cross national borders. Moreover, as in the Schumpeterian model, all innovation is 'destructive', because the set of goods and services is fixed. For one innovator to win, its competitors have to lose.

But how realistic are these assumptions? I have already argued that modern innovation involves both non-destructive as well as destructive creation. Next I will suggest that the other assumptions are also off base: upstream innovations (and their associated goods and services) often move more easily across national borders, especially of advanced countries, than mid-stream or downstream innovations, goods and services. Moreover, a large and increasing proportion of downstream activity in an advanced economy is not traded at all – it is both produced and consumed in the same place.

In pre-industrial times, monarchs sometimes took extreme measures to prevent the export of the distinctive know-how of domestic craftsmen, but even then there was a fair degree of cross-border learning. For instance, to realize his dream of making Russia a naval power, Peter 1 the Great personally studied ship-building in Deptford (in Britain) and in Amsterdam. While in Amsterdam, Peter 1 worked for four months in the largest private shipyard in the world, belonging to the Dutch East India Company. He also hired many skilled shipwrights and seamen who he took back to Russia.

In modern times, countries do impose restrictions on the export of some sensitive technologies but otherwise technology moves across borders without much let or hindrance. Advanced countries which lead in some sectors and technologies import technologies in others. The U.S. which has, according to Prestowitz, Freeman and others, long been the "overall" leader in science and new technology has also benefited from technologies developed overseas. As Carter and Williams (1964) wrote: "All advanced countries draw on the research and development results of other countries, freely or by payment of licence fees or through foreign subsidiaries." In 1960 France "paid abroad" 273 million francs and received 63 million. In 1963 Germany paid 540 million marks and received 200 million. Even the U.S, which enjoyed undisputed technological leadership, and received more than it paid abroad both imported and exported a "great deal of technical knowledge."

Eaton and Kortum (1995) examined the growth in productivity in West Germany, France, the U.K. and the United States between 1950 and 1990. According to their analysis, the growth of the first four countries which started far behind the U.S. at the start of the period, was "primarily the result of research performed abroad." Moreover, notwithstanding its overall lead, "even the United States obtain[ed] over 40 percent of its growth from foreign innovations." These findings, according to Eaton and Kortum are "consistent with historical accounts" of the importance of foreign technology to the U.S. such as Mueller's (1962) description of "the foreign inventions underlying DuPont's innovations."

Certainly, not all innovations travel easily across borders. According to David (2003) innovations are "most efficient as elements of a production system when they have been designed for a specific environment". As mentioned, my on-going research suggests that VC-backed businesses do indeed expend considerable effort in an iterative dialogue with customers in order to determine an optimal bundle of functions, interfaces and so on. Variations in local conditions naturally affect optimal bundles, so products that are well suited to one country maybe inappropriate for another. But such problems are usually less severe with scientific knowledge and upstream innovations, where Freeman and others are most concerned about leadership, than with mid-stream or downstream innovations. Scientific knowledge and upstream innovations tend to be relatively simple and universal.

As proximity to end-users increases however, so does the complexity and localization of innovations; moreover, the localization (and often the complexity) grows as innovations evolve over time.

To illustrate: Sir Timothy Berner-Lee's path breaking invention of the core technology of the World Wide Web had no problems from moving out of the CERN lab in Switzerland to anyone anywhere with an internet connection. Browsers that were built around the core technology acquired some localization, most obviously in the language used in the interfaces: a browser with English language menu was of limited use to someone who only spoke Swahili. Many subsequent web-based applications then became extensively tailored to local conditions: e-commerce applications for instance reflect local shopping habits, and the business practices of local banks, credit card companies, merchants and privacy regulators.*

The e-commerce example incorporates another feature of advanced economies because of which innovations – be they up, mid, or downstream – abroad aren't much of a threat to the purchasing power of consumers at home: As is well known, services account for much of the consumption and output in high wage countries. Moreover within the services sector, according to a McKinsey & Co. (2005) projection for 2008, no more than 11 per cent of the 1.46 billion service jobs world wide could even theoretically be performed in an overseas location. The McKinsey estimates also projected that actual off-shore employment in 2008 would amount to just 3 per cent of the theoretical maximum or less than one quarter of one per cent of total service jobs world wide

Of course technological change could allow jobs that have to be performed locally now to be performed remotely in the future or cause such jobs to vanish altogether. Famously, the jobs of most bank tellers have been replaced by a combination of mechanized ATMs and human operators in remote call centers. But history suggests that that 'new want machine' keeps replenishing the demand for service jobs that have to be performed locally.† Unless these historical trends change dramatically, locally performed services will continue to account for a very large share of economic activity.

Since, like Willie Sutton, innovators and entrepreneurs tend to go where the money is, it is not surprising that much of their attention in advanced economies has been directed to improving the productivity of the service sector. Crucially, because most such services are domestically produced and consumed, innovations that improve the productivity in one country do not have much of an impact on other countries. An innovative e-commerce application that improves the efficiency of retailing in the U.S. doesn't reduce the well-being of the Japanese, and the development of a better hospital management software system in Sweden doesn't hurt the U.S. Similarly if the e-commerce application is eventually adapted for Japanese use and hospital software for use in the U.S. the

* Not all consumer goods and services show great variance across markets and multi-national companies that sell consumer goods do try to standardize their offerings across geographies to minimize costs: Apple for instance sells the same iPod in Europe as it does in the U.S. That said, there are many examples where the upstream components are more localized than the downstream offerings.

† Notwithstanding automation and off-shoring the number of support and administrative staff at Columbia has increased not decreased. The job of cutting paychecks may have been outsourced and there are no punch card operators in the computer center. But twenty years ago there was no one on campus to install and service LCD projectors, personal computer, local area networks or email systems.

productivity improvements in Japan and the U.S. the countries where these innovations were first introduced aren't hurt either.

Unlike most services, physical goods can and increasingly are being produced far away from where they are consumed. But there does not seem to be much of connection any longer between the locations where innovations occur and the sites where goods are physically produced. Rather, multi-national companies design global supply chains, where factors such as wages, skills and distance from the market determine the placement of the individual links. For instance, the Singapore-based Creative Technology Ltd. invented a hard drive MP3 music player which it started selling in January 2000 as the Nomad Juke-box. About two years later, in October 2001, Apple introduced the competing iPod (which Creative alleged infringed on its patent) and the iPod soon displaced the Nomad as the market leader. But most of the production of MP3 players takes place in mainland China, not in the U.S. or Singapore.

Similarly, in recent decades the process and product innovations of Japanese car companies have allowed them to substantially increase their share of the U.S. market at the expense of the market shares of U.S. companies. But note: although the innovations have largely originated in Japan, the car companies have increasingly moved the production of cars for the U.S. market to plants located in the United States. In other words not only have consumers in the U.S. benefited from innovations originating in Japan that lowered prices and improved the quality of cars, the wage income derived from the manufacture of such cars has increasingly shifted to the U.S. Thus, even in many manufacturing sectors, the 'make where you innovate' assumption of the North South models does not seem to be the norm.

6. Explaining the U.S. lead.

Let us return to the question raised earlier: Why, contrary to 'convergence' theories, and in spite of the alleged erosion of its lead in science and cutting edge technologies, has the U.S. maintained its lead in per capita incomes vis-à-vis Europe and Japan? The analysis above suggests that the exceptional 'entrepreneurial' capacity of firms and individuals in the U.S. to take advantage of upstream innovations regardless of where they might originate, has helped maintain the U.S. lead. (From this perspective, the historical 'primacy' of the U.S. in many scientific and technological fields may be more a by-product rather than a cause of U.S. prosperity. Just as the rich make larger contributions to the Arts than the not-so-well off, prosperous countries are more likely to contribute to research on string theory or the decoding of the genome than poor countries.[*] And as prosperity becomes more widespread, more countries contribute to the world's stock of scientific knowledge. This helps rather than hurts the countries that once took the main responsibility.)

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[*] Accroding to Teresi (2004 p.38) the physicist Robert Wilson appeared before Congress to secure $250 million for building Fermilab, the largest particle accelerator in the world. A friendly Congressman tossed a "softball" question, that gave Wilson the opportunity to justify the new atom smasher using national defense." Wilson insisted that it had "nothing at all" to do with national security. Rather Wilson said "It has only to do with the respect with which we regard one another, the dignity of men, our love of culture. It has to do with, are we good painters, good sculptors, great poets? I mean all the things we really venerate and honor in our country and are patriotic about. It has nothing to do directly with defending our country except to make it worth defending."

Venturesome consumption of innovations in IT – a sector which according Nick Bloom, Raffaella Sadun and John Van Reenen (2005) has accounted for much of the acceleration of U.S. productivity since 1995 – appears to have played a particularly important role in maintaining the U.S. lead. As mentioned, Prestowitz (2006a) sees the U.S. trade deficit in IT and other advanced technology products as a symptom of a faltering economy. In my interpretation, this deficit is an indicator of economic strength and dynamism, not weakness. As we will see next, the U.S. has a voracious appetite for IT goods and services, many of which are made in countries in China, Taiwan and other countries where wages and manufacturing costs are relatively low. A high propensity to consume IT generates deficits but it also, as the evidence we will review suggests, enhances productivity in IT-using industries which account for a much larger share of economic activity than the IT industry itself.

Consumption patterns

Tables 2a and 2b contain data on the sales of Windows, Linux and other operating systems for personal computers and servers by selected regions and selected countries for 2001.* To construct this table, sales of operating systems (as available, in terms of units and revenues) were divided by GDP for the region or country. The sales to GDP ratios were then 'scaled' by the sales to GDP ratio for the U.S. The tables show that Windows operating systems sales to GDP ratios for Western Europe were about 25% lower than in the U.S. and in Japan more than 10% lower. Within Western Europe, only two countries, namely Sweden and Denmark, had higher sales to GDP ratios than the U.S. The GDPs of these two countries are however small so their total sales amounted to about one twentieth of U.S. sales. Among the relatively large West European countries, GDP to sales ratios were about a third lower than the U.S ratios in Germany, France and Italy and about 10 percent lower in the U.K.

The U.S. isn't the leading consumer of IT in every category. As has been pointed out by Prestowitz (2006) and many others, The U.S. has become a laggard in broadband deployment. As of 2005 the U.S. was behind 15 other countries in terms of the number of broadband subscribers per 100 inhabitants. Similarly, Prestowitz also cites data showing that the U.S. is 42nd in the world in cell phone usage: In 2003 cell phone subscriptions per 100 inhabitants in the U.S. were almost half the subscriptions in Italy. The U.S. has also lagged Korea, Japan and many countries in Europe in the deployment of 3G high-speed wireless data systems. But these exceptions apart, the US leads in terms of *overall* IT consumption, just as it does in the purchases of operating systems.

Table 3 compares total IT expenditures (as estimated by the Gartner Group in its *Market Data books*) across selected regions and countries for 2001-4. As in the previous table, total expenditures are divided by GDP and this ratio is compared to the US expenditure to GDP. Here too we find that the IT expenditure to GDP ratio in Western Europe is between 15-20% lower than in the U.S. and in Japan it ranges from 10 to 30% lower than in the U.S. over these four years.

* The data used to construct the table was generously provided by Pankaj Ghemawat and Ramon Casadesus-Masanell who had collected and used the data (in a very different way) for their 2006 article.

Productivity gains

Until not so long ago, there was debate about whether the IT investment had done the U.S. economy much good. In 1987, Robert Solow wrote: "We see the computer age everywhere, except in the productivity statistics." The following year, Steven Roach (1988) of Morgan Stanley dubbed this the "productivity paradox". In 1991, the *Economist* pointed out that the returns from IT investments were so low that firms "would have done better to have invested their money in almost any other part of their business." On the other side, Paul David (1990) argued that it was too early to judge the value of computers – it took decades for the productivity benefits of the electric dynamo (whose technical development had been largely completed by 1880) to be realized. Griliches (1994) and others also suggested that the productivity paradox reflected a measurement problem: consumers realized many benefits from IT in forms such as greater variety, convenience or quality which are missed in standard GDP accounting.

By 1996 the annual IT spending of U.S. firms had crossed half a trillion dollars and organizations like Nations Bank had annual IT budgets of $2 billion a year (Lucas 1999). Yet Gordon (1999) suggested this was all for naught, as far as the economy was concerned. According to Gordon, the acceleration of productivity in the U.S. that occurred after the mid-1990s was almost entirely due to more efficient production of IT, particularly computers, rather than to the use of IT. Jorgenson and Stiroh (2000) came to similar conclusions: the acceleration of productivity growth after 1995 could be "traced in substantial part" to improvements in the production of IT. On the user side there had been some "capital deepening"—as computers got cheaper, firms bought more of them. The evidence was clear they wrote that "computer-using industries like finance, insurance, and real estate (FIRE) and services" had "continued to lag in productivity growth" in spite of their "massive high-tech investment."

As someone who studies entrepreneurs and businesses from the ground up, I find the Jorgenson and Stiroh claim puzzling. First, by the year 2000, computer using industries had undergone vast changes over nearly two decades. The rise of new big-box retailers, most notably Wal-Mart, had displaced many traditional players. Similarly small regional banks had been merged into mega-sized national institutions like Citicorp and the Bank of America or had disappeared. With the new players came new ways of doing business – Wal-Mart established global supply chains and regional distribution centers for instance. The old players and ways of doing business didn't fall like trees stricken with Dutch elm disease. The old order was pushed out by the new after a competitive struggle in the marketplace. How could this have happened unless in some way shape or form the new was more 'productive' that the old?

Second, could business facing relentless pressure from rivals and the capital market simply have thrown away the greater part of half a trillion dollars in IT spending a year? I once suggested (Bhidé 1986) that banks and other financial institutions overestimate the sustainability of the competitive advantages they can derive from investing in technologies because they overlook the possibility of imitation: if one bank builds ATMs that customers value, others soon will as well. But, this simply means that customers, not the banks derive most of the benefit. For the technological 'arms race' to have no productivity benefit, competitors must all invest in innovations that even customers don't value – much of the half a trillion dollars invested in IT would have to have been totally wasted.

Third, could IT-using industries really improve their output per worker just from ‘capital deepening’, without finding new ways to use that capital? It is one thing to say that as the costs of vacuum cleaners and dishwashers decline, less labor will be required to clean floors and dishes because more capital equipment will be used. But I don’t think that my writing will go faster if I had two computers instead of one (or got a computer with twice the processor speed as my current model). The idea of simply plugging more IT gear into the existing production function of a large organization becomes particularly far-fetched in light of the extensive reengineering that the implementation of new systems actually entails. Finally it is surprising to find that the models assume perfectly competitive product and factor markets. If this was in fact the case, why would anyone try to develop productivity enhancing techniques in the first place? Does not the assumption preclude the phenomena?[*]

In any event, the debate seems to be largely over now. As Dedrick, Gurbaxani and Kraemer (2003) conclude after reviewing the literature, “the productivity paradox as first formulated has been effectively refuted. At both the firm and the country level, greater investment in IT is associated with greater productivity growth.” Moreover, at the firm level, “IT is not simply a tool for automating existing processes, but is more importantly an enabler of organizational changes that can lead to additional productivity gains.”

The literature also suggests that the U.S. is at the forefront of realizing the productivity gains. Bloom, Sadun and Van Reenen (2005) write that whereas in the U.S., significant gains in productivity have been realized in sectors that intensively use and produce IT, the EU has seen similar productivity acceleration just in the IT-producing sector. In sectors “that *use* IT intensively”, such as retail, wholesale and financial intermediation European countries have not enjoyed the “spectacular levels of productivity growth” as in the U.S. “Britain has done better than France or Germany, but not as well as the U.S.[†] Similarly Robert Gordon, who in 1999 had written that there had been virtually “*no* productivity growth acceleration in the 99 percent of the [U.S] economy located outside the sector which manufactures computer hardware” was subsequently persuaded that: “After fifty years of catching up to the U. S. level of productivity, since 1995 Europe has been falling behind… studies of industrial sectors suggest that the main difference between Europe and the U. S. is in ICT-using industries like wholesale and retail trade..”(Gordon 2004)

Venturesomeness of IT Users

The significantly higher propensity of US businesses to buy IT does not seem to reflect a generally higher propensity to invest in fixed capital, because of some general economy-wide factors like low interest or discount rates or a tax breaks for long term investment. The tables (2a-b and 3) on operating system sales and total IT expenditures also contain columns on the ratios of total Gross Fixed Investment (in all categories) to GDP. These

[*] Brynjolfsson (1993) made a strong case that the IT “productivity paradox” reflected deficiencies in the measurements and methodological tool kits. This apparently did not dissuade researchers from continuing to use these measurements and methods.

[†] See also O’Mahony and Van Ark, 2003

columns show that the U.S. *lags* in overall fixed investment by about the same degree as it leads in IT spending. The ratio of gross-fixed investment to GDP is about 50% higher in the Japan than in the U.S. and in Western Europe about 25% higher. Table 2b also shows that there is not a single country in Europe where the ratio of Gross Fixed Investment to GDP is lower than in the U.S.[6]

My hypothesis is that the comparatively high propensity of the U.S. to buy IT (which is available throughout the world at roughly similar prices) *in spite* of a low overall rate of investment reflects an exceptional level of 'venturesome consumption': First, buyers of IT in the U.S. are willing to take their chances on novel technologies where no one has much evidence on the risks and the returns. I have no systematic knowledge about buying habits outside the U.S. but at least some of the vendors of enterprise software we have interviewed said that European IT staff tend to be "risk averse" and prefer more stable, older generation products. Second, U.S. purchasers of IT may be more bold and resourceful in making the organizational changes needed to derive the full benefit of ERP and other such systems.

The venturesomeness of IT users in the U.S. – and the large size of the market – helps attract suppliers. According to the entrepreneurs we have been interviewing recently, the U.S. is the market of first resort for most IT vendors. Indeed the attractiveness of the U.S. market had caused some of our interviewees who had started their businesses in Europe to relocate to the U.S. to be close to their target customers. And to the extent that suppliers refine their products through a dialogue with U.S. customers, their features are optimized to the U.S. market. This in turn makes the product more attractive to U.S. customers rather than to customers outside the U.S.; it also creates an incentive for suppliers to continue to focus their sales efforts on U.S customers (because selling outside the U.S. might require additional costs to adapt the product to local conditions.)

Bloom, Sadun and Van Reenen's (2005) research suggests that the unusual willingness to invest in IT and the capacity to derive value from such investments is sufficiently embedded into the structures and routines of U.S. based companies that they carry this capacity to their operations outside the U.S. They compared the establishments based in the U.K that were owned by U.S. multinationals, non-U.S. multinationals and domestic (i.e. U.K.-based) companies. They found that establishments owned by U.S. multinationals invested about 41% more per employee in IT than the average for the industry; non-U.S. multinationals about 20% more, while domestic companies invested about 15% less than the industry average. U.S. multinationals also apparently got more for their IT buck; they enjoyed "significantly higher productivity of IT capital" – this effect accounted for "almost all the difference between the overall productivity of resources used by U.S. owned and all other establishments. And, they found that that the 'IT edge' of U.S. multinationals was "confined to the same 'IT using intensive' industries that largely accounted for US productivity growth acceleration since the mid 1990s.

I should emphasize that success of IT-using industries in the U.S. has not in any material way reduced incomes in the rest of the world, because their outputs are usually not 'tradable' exports. When U.S. multinationals use their productivity advantages to establish operations abroad, they may wipe out local *firms* but their activities (like those of Japanese owned automobile plants in the U.S.) generate wage incomes and consumer surpluses that remain almost entirely with their host countries. And, investors abroad have the same opportunity to share in the profits of U.S. multinationals (buy buying their shares) as do U.S. nationals.

I should further note that although developed countries in Europe and elsewhere may be somewhat behind the U.S. in using IT, they are well ahead of emerging and underdeveloped countries. My interviews suggest that in spite of the economic boom in China and other Asian countries, after the U.S., the European market is the next port of call for most IT innovators. And even if products are initially optimized for the U.S., firms and consumers in Europe are not so very different that the products cannot be 'Europeanized' or that Europeans cannot learn to live with products developed for the U.S. Arguably, the superior capacity of Europe to use advanced products vis-à-vis most other countries has mitigated the effects of what many consider to be dysfunctional public policies. To slightly extend Adam Smith's adage, there is much ruin in a nation, once its consumers are sufficiently advanced.

7. Elusive underpinnings.

In the Parente and Prescott (1994) model, all countries draw their technologies from a common pool that keeps getting bigger and better; however the investments that firms have to make to take advantage of the ever-improving pool depends on the "barriers to technology adoption" in their countries. Parente and Prescott mention "regulatory and legal constraints, bribes that must be paid, violence or threats of violence, outright sabotage, and worker strikes" as examples of the forms that the barriers can take, but that is not their focus. Rather, according their theory, whatever form the barriers may take, the differences in their magnitude do not have to be "implausibly large" to account for the "huge observed income disparity" across the rich and poor countries.

But what form do these barriers in fact take and why do they vary across countries? David (1986) reviews the extensive theoretical and empirical research on the economics of technology diffusion. The review shows that a great deal of work has been done on the incentives that firms face and the costs they incur in adopting new technologies. These findings help explain differences in the rates of the adoption across industries and firms and help us analyze whether, from a social welfare point of view, the rates are too slow or fast. The research does not however examine the sources of the differences in rates of new technology adoption across countries (whose economies comprise many industries and firms). Similarly Cohen and Levinthal (and other researchers such as Cockburn and Henderson 1998) who have worked on 'absorptive capacity' peek 'under the hood' of firms to examine how their strategies affect their adoption of new technologies, but not why such strategies might vary across countries. Moreover, this line of research focuses on 'upstream' high-tech businesses, and it is difficult to extrapolate the findings to service sectors that now dominate advanced economies.

Nelson and Phelps (1966) offer the general (i.e. economy-wide) hypothesis that "education speeds the process of technological diffusion." The "better educated farmer" will adopt a profitable process more quickly since "he is better able to discriminate between promising and unpromising ideas." In large industrial corporations, educated scientists keep abreast of technological improvements and educated top managers who make the final decision. Therefore as a general principle, the "time lag between the creation of a new technique is a decreasing function of ...average educational attainment."

Although this is surely right, education cannot be a sufficient condition for the rapid adoption of new technologies. The Soviet Union had a well-educated population and few qualms about infringing on foreign patents; nonetheless it remained far behind the Western technological frontier. Nor does the 'supply side' prescription of low taxes, free markets and property rights seem to ensure a high level of venturesome consumption. As a native of India who grew up under avowedly socialistic government, I am acutely aware of the debilitating consequences of confiscatory tax rates, pervasive regulation and expropriation of private property.

But, the economic record before Independence under a colonial regime strongly oriented towards maintaining a low tax regime, free domestic markets, free international trade, and the rule of law, was even worse. Not only did India miss the Industrial Revolution, in its manufacturing industry, as Bhidé and Phelps (2005) have pointed out, under colonial rule it even failed to 'learn' how to consume modern goods. Although, according to the prevailing imperial ideology (and Marxist analyses) colonies were supposed to provide captive export markets for their European *metropoles* India's imports were persistently lower than its exports.

The 'institutions', or what Ohzawa and Rosovsky (1973) called 'social capabilities', that sustain the venturesome consumption and other sources of prosperity of advanced economies cannot be reduced to a few well-defined elements. The formula is both complex (see Nelson 2006) and ever changing. For instance, the common beliefs that now undergird the demand for new products and services have distinctively modern features.

The widespread belief in the inevitability and desirability of technological progress is an important case in point. In earlier times, a relatively small number of visionary inventors and scientists held such views. Now many popular magazines, TV shows and management books are predicated on the assumption of scientific and technological progress. Their growing acceptance has turned such beliefs into self-fulfilling prophecies. Consider for instance Gordon Moore's famous observation that the number of transistors that built on a chip doubles every eighteen month. Semi-conductor companies, who believe in this so-called "law", invest the resources needed to make it come true. Downstream customers, (such as PC manufacturers) and providers of complementary goods to their customers (such as applications software companies) design products in anticipation of the eighteen months cycle. So when the new chips arrive they find a ready market, which in turn validates beliefs in Moore's Law and encourages even more investment in building and using new chips.

In principle, expectations of change can also slow it down – as David (1986) puts it "if it is expected that every one will quickly adopt the [new] technology, the inducements to bear the costs are of adopting it early are reduced". Why buy the $5000 flat panel TV set now, when a year from now the price will surely drop and the reliability of the models will increase? Apparently, a sizeable number of consumers derive utility not just from the functions that the new products provide but from the fact of being early adopters. As Keynes (1930. p. 326) pointed out, people have both 'absolute' needs (e.g. for health and survival) as well as 'relative' needs that we feel "only if their satisfaction lifts us above, makes us feel superior to, our fellows". Early purchasers of goods like flat panel TVs apparently enter into a tacit bargain with other consumers: they incur the higher risks and costs which then drives down prices and improves the quality for the consumers who 'wait'; in return, those who wait, give the early purchasers the gratification of being first.

The gratification that many modern consumers enjoy may be contrasted with the long-standing propensity to consume expensive goods for the sake of displaying status or wealth – the "conspicuous consumption" of the Gilded Age that Thorstein Veblen wrote about in *The Theory of the Leisure Class.* Only the wealthy can indulge in conspicuous consumption; moreover as Veblen put it, to satisfy its purpose – the demonstration of wealth – the consumption "must be wasteful." In contrast, many early purchasers of the latest gadgetry aren't flush with cash (or even pretending to be); they seek to display, to themselves and to others, their technological sophistication, not their wealth. (The classic form of conspicuous consumption has certainly not disappeared however.)

The propensity of consumers to open their hearts and wallets to new offerings also involves the dilution of prior beliefs in the moral and economic value of thrift. Through the end of the 19th century, according to Max Weber's thesis, religious convictions about thrift sustained the 'spirit of capitalism'. Weber argued that merchants and industrialists accumulated capital believed they had a moral duty to strive for wealth as well as to lead austere lives. In fact, because venturesome production requires venturesome consumption, excessive thrift can injure rather than helps modern capitalism. As it happens, modern consumers have been more inclined to keep up with the recently acquired baubles of their neighbors (if not stay ahead) than towards excessive thrift.

The utility that individuals now derive from using cutting edge technology can also stimulate business purchases of IT if the IT staff put their love for the latest toys ahead of their employers' interests. Astute managers who are aware of this tendency can resist this however. But even managers who have no love for technology *per se,* may embrace its large scale use for another reason, namely the pressure they face to grow their organizations. As I have argued (Bhidé 2000 Ch. 9) in a dynamic modern economy, competitors, customers, capital markets, and labor markets make it difficult to avoid growth; as David Packard and William Hewlett (the founders of H-P) concluded, the growth of a company is "a requirement for survival." Growth in turn facilitates and encourages firms to use of IT and other innovative technologies in several ways.

First the scale effects documented by Davies (1979) in the adoption of innovations in the manufacturing sector continue to be found in the adoption of many IT products by service companies. Unlike Wal-Mart, a small retailer cannot afford to purchase a license for a sophisticated supply chain management software package or pay for the in-house IT staff necessary to install and maintain the package. Moreover, since the vendors' cost of marketing their packages also tends to be fixed, they tend to favor large customers who buy large (or many packages).

Second, growing companies often start new facilities, where it is both easier and more economical to adopt new technologies. As David (1986) writes, while an old plant may be technologically obsolete, it may still cover its variable costs and make it rational for profit maximizing to defer replacing it with a state of the art plant. Moreover it can be operationally disruptive to pull out the old technology. Neither consideration applies with a green-field facility. It is worth noting here that the main differences in the productivity of European and U.S. retailing are in the arena of "big box" retailers (like Wal-Mart) and within this category, the U.S. edge derives mainly from its newly opened retail outlets.

Third the effort to grow can stimulate the search for innovative technologies that can be used to realize economies of scale and scope. For instance in 1988 Physicians Sales and Services (a company I have written a case series about) was an "itty bitty company in Florida". In 1989, the founder Pat Kelly declared that PSS would become the first national distributor of medical products to physicians' offices in the U.S. With just $20 million in revenues, it had no significant economies of scale that would justify nationwide operation. Like a lot of young companies Kelly recalls, PSS relied on "hard work", "good people", "seat of the pants navigation", and "a lot of luck." The goal of becoming a national company, (which was displayed in big banners in every branch and repeated endlessly by Kelly and his top managers) provided the impetus to search for economies of scale. For instance the company invested in an order entry system based on hand held computers which increased the speed of deliveries and enabled PSS to reduce the inventories it had to carry. Such initiatives allowed PSS to create national level scale economies where none had previously existed.

These kinds of underpinnings – the pervasive belief in change, the value placed on being the first user, and the pressure faced by managers to grow – cannot be easily measured, nor can we identify the nature of their interactions or their 'ultimate' sources. But to ignore such factors on the grounds of their elusiveness is to exclude from considerations the essential and distinctively modern ways in which innovation sustains the prosperity of advanced countries.

8. A Concluding Policy Perspective.

David (1986) makes several noteworthy points about how public policy affects the use of new technologies: 1) Overt efforts to promote the diffusion of innovations are modest in terms both of money and attention devoted to them. They usually comprise efforts to disseminate information (such as agricultural extension or "technology transfer" programs in the U.S.) or the payment of subsidies to adopters of new technologies (such as those offered to purchasers of robots in Japan). 2) The range of policies that actually affect the adoption of new technologies is quite broad. These include the "tax treatment of investment, the funding of R&D, the education of scientists and engineers, regulation and standard setting, as well as the monetary and fiscal measures shaping the macroeconomic environment." 3) Speeding up the rate of technology innovation isn't always in the public interest; sometimes, slowing it down could be more beneficial. 4) Policies to quicken or retard the adoption of new technologies should only be undertaken after "explicit assessments" of the varied and changing environments of different industries: an "absolutely indispensable ingredient in the formulation of rational economic policies" vis-à-vis diffusion is "detailed assessments on an industry-by-industry basis". 5) The processes of the development and diffusion of new technologies are closely intertwined; therefore "intelligent" policymaking would take a more "integrated" approach to designing innovation and diffusion policies.

The policy implications of this paper are in many respects similar to David's observations, save in two respects, namely in the utility of a case by case approach and the feasibility of formulating an integrated approach to promoting technology development and diffusion. On the first issue: I have little doubt that the binding constraints or pinch points vary significantly across markets and sub-markets. Looking at the health care sector for instance we can see some diseases whose cures await an "upstream" scientific breakthrough. In other instances improved management of hospitals and patient data-bases using tried and tested technologies can lead to vast improvements in productivity. And in yet other cases, the social value of the increased use of therapies and techniques that can be called medical only the broadest sense of the term seems dubious under a system where the users don't pay.

The record of 'case-by-case' interventions however does not strike me as inspiring. The approach obviously invites efforts, both overt and covert, by lobbies to secure results that suit their private ends. The process of public policy make is also slow – and indeed, to secure the legitimacy of openness and the accommodation of many points of view – in most cases public policy ought to be formulated with all due deliberation. But technologies and their associated bottlenecks keep changing so interventions that might have been apropos yesterday may be irrelevant tomorrow. There is no point for instance in promoting "hardwired" broadband connections to the internet if we are on the verge of a cheaper or better wireless alternative.

Finally suppose policy makers could identify the 'right' bottlenecks across all industries in a timely manner: they would still be faced with the problem of formulating effective responses. As I have argued in this paper, the development and the use of new technologies has entrepreneurial features that lie outside the domain of mainstream economics; and while we may crudely describe their manifestations their underpinnings are elusive. But economic and policy analysts tend to focus on measurable indicators and relationships. The danger is that such an orientation may not only fail to touch the larger but more elusive barriers to progress, they may actually increase these barriers.

The same concerns about our profound ignorance of the underlying factors make me skeptical about integrated approaches to the development and diffusion of innovation – a fine principle perhaps, but, do we know enough to implement it?

The arguments in this paper do however suggest the removal of the tendency of policy makers to favor upstream innovation and neglect or even impair what happens mid- and downstream. Such a bias is apparent in the promotion of research and the denigration of marketing; thus pharmaceutical companies who receive substantial tax credits or subsidies for their R&D programs get a tongue lashing for their marketing. Spend more on developing new drugs Big-Pharma is told instead of spending so much on peddling "frivolous" drugs. But, the frivolous drugs also start in a lab. Moreover even useful drugs can only be effective if they are properly incorporated in a therapeutic regime; and as McGettigan et. al. (2001) study suggests, whereas doctors may say they get their information from reading medical journals, pharmaceutical company salesmen play a more important role in influencing their prescribing habits.

Without a marketing push, breakthrough treatments may fail to catch on. Consider the history of using antibiotics to treat ulcers which suggests an important role for marketing beyond the passive dissemination of information. Warren and Marshall demonstrated a link between *helicobacter pylori* to peptic ulcers in the early 1980s. In 1987 Couglan *et. al,* published an article in *Lancet* showing that the eradication of *H. pylori* with antibiotics could effectively cure peptic ulcers. This further milestone was then followed in the first half of the 1990s by the publication of national and international guidelines on the treatment of *H. pylori.* But although the consensus guidelines were clear, pharmaceutical companies did not have an incentive to promote the therapies. A literature review by O'Connor (2002) showed that although there was "widespread acceptance of *H. pylori* as a causal agent" among physicians in principle, there was "significant under-treatment" of peptic ulcers with *H. pylori* therapies. And, physicians who did use the therapies often used "treatment regimens of doubtful efficacy" instead of following the consensus guidelines.*

Marketing plays an even more important role in realizing the value of innovations where there are no guidelines offered by authoritative professional bodies and users face significant Knightian uncertainty about the utility of their purchases. Even consumers who are innately venturesome need some persuasion. In fact persuasion is a crucial entrepreneurial function and often involves the use of smoke and mirrors and psychological manipulation. Policy makers and others may find the misrepresentations and manipulations distasteful but they are an essential ingredient of technological progress.

Conversely incentives to promote R&D may help upstream innovators but do little good for the downstream and mid-stream players. Retailers like Wal-Mart may have very large IT budgets and staff who may even develop some in-house systems. But none of this qualifies for R&D incentives. The output of mid-stream innovators (such as the VC-backed firms I have been studying) may in principle qualify for R&D subsidies; in practice however, many such firms not only lack the earnings needed to take advantage of tax credits, often they also cannot easily segregate R&D outlays and activities from those of their other functions such as marketing and sales.

Efforts to stimulate "savings and investment" also tilt against mid and down-stream innovations. There appears to be a consensus among policy makers of many stripes, that except possibly in recessions, saving is always virtuous and consumption undermines long term growth. – a mindset exemplified by Prestowitz's (2006c) alarm that the U.S. "is building its economy into a giant consumption machine". Mechanisms to mobilize savings such as the stock market and retirement plans are thus regarded with favor while mechanisms that facilitate consumption, like credit cards with some suspicion. But, as I have argued, Max Weber's thesis that capitalism is synonymous with capital accumulation ignores the role that the venturesome consumption of innovative goods plays in a modern economy. Moreover, the young and the impecunious are more likely to have the recklessness of spirit necessary to perform this role. At least up to a point, their spendthrift ways and the credit cards that sustain them are boon to economic growth; and because there is no knowing what that point might be, there is no justification for promoting or discouraging their behavior.

Similarly, policies to promote long term investment by, for instance, providing tax credits for capital outlays also seem to be outdated. The modern knowledge economy appears to have erased the old boundaries between long-term investment and (supposedly undesirable) short-term spending. Much of what would traditionally have been categorized as the spending of mid- and downstream players is in fact, risky, long term

* This data led O'Connor to suggest the use of "some of the methods used by pharmaceutical manufacturers to educate physicians about their products, which are known to be effective and often overshadow the information available in the medical literature." But who could do this? Replicating a good marketing system is easier said than done.

investment. For instance, as discussed the purchase price of an ERP system is a fraction of the total project cost; but businesses eligible for an investment tax credit for their purchases of computer hardware and software don't receive a tax break for the costs of adapting the system to their needs, training users, reengineering their business processes and so on. It may be that a tax credit for the computers also encourages the other, larger outlays. But to the extent that promoting long term investment is in fact a worthy goal for tax policy, this seems like a round-about and inefficient way to achieve this purpose. (The tax credit may, for instance, encourage a business to invest more in the computers and less on user training and reengineering.)

The goals of educational and immigration policies are more attuned to the labor requirements of upstream innovation. For instance, there is a long-standing claim in the U.S. that it should train more engineers and scientists. If this were done, the costs or labor supply constraints faced by organizations undertaking R&D activities would be reduced. But this invites the question: whose labor supplies would tighten – what have all the people who otherwise might have become scientists and engineers been doing? And has this been less productive than if they had been working as engineers and scientists?

The data suggests that many individuals who could have been engineers or scientists have been working as managers. The progressive increase in the proportion of service sector jobs is well known; many have not noticed however, the increasing share of managerial and professional jobs – in the U.S. from about one in six in 1940 to about one in three today (Bird 2004). Some of the managerial positions may be filled by individuals who have engineering degrees but such training is probably not a job requirement.

The growth in managerial jobs, which in the last couple of decades has taken place in a climate of cost-cutting, restructuring and re-engineering, probably does not reflect a spontaneous increase in bureaucratization of U.S. companies. More likely it follows from the growth of activities and businesses, particularly in the expanding service sector where activities are difficult to coordinate and economies of scale and scope are difficult to come by. Moreover, these managers have been at the forefront of the challenging effort to improve the productivity of services sector. As we have seen, the use of technologies such as ERP pose organizational as well as technical challenges; arguably their implementation requires a much higher ratio of managers to technical personnel than did the productivity increasing technologies in the manufacturing sector. In other words, the labor market may not have gotten it monumentally wrong and interventions that increase the supply of trained personnel for upstream innovators may impair productivity growth by reducing the availability of the personnel in downstream firms.

We find a similar bias in the area of immigration policy which takes the form of preferring highly trained engineers and scientists (i.e. those with PhDs and Masters degrees) to individuals with just a bachelors' degree. Highly trained immigrants, it is believed, can make out of the ordinary contributions to innovation because they are in such short supply whereas engineering and scientific jobs that don't require advanced degrees can easily be filled in the local labor market. In fact as I have just pointed out, the highest valued use of talented locally born individuals may not lie in scientific and engineering jobs at all, and as a result immigrants who don't have advanced degrees have probably made as valuable a contribution as those have advanced degrees. As mentioned in my ongoing study of VC-backed businesses for instance we have found that a relatively small proportion of employees in these ostensibly high-tech firms have masters and PhDs. Correspondingly, the number of immigrants who have PhDs or Masters degrees is also much smaller than the number of immigrants (who usually work in a technical function) whose highest degree is a bachelors. I do not have data on the composition of immigrants on the technical staffs of organizations such as retailers and banks; I would suspect however that they have an even lower proportion of immigrants with advanced degrees.

I could go on to discuss policies in the areas of anti-trust enforcement, land use and labor mobility that encourage or discourage the adoption of new technologies by influencing the incentives and ability of downstream players to grow their organizations. But rather than make this survey even more cursory, let me conclude by returning to the main topic of this conference: whether or not Continental Europe is sinking, and if so, why?

As must be apparent, I have not much of a notion. But my perspective, from having had the good fortune to spend my adult life in a place that has enjoyed unparalleled prosperity, is that a vibrant economy is a many-splendored thing. Although depending on from where one looks one or the other facet may sparkle its wonder is in the system as a whole. And, like the innovations it generates, the system evolves constantly. Although basic human nature may remain the same, our expectations, desires, social compacts, relative positions, and technologies all change. Not so long ago, we might have worried about the rust in manufacturing sector; now concerns about the productivity of services seem more pressing. This is not our grandfather's economy or Adam Smith's, or Karl Marx's or Max Weber's economy. And while parsimonious models may provide a starting point, any useful ideas – ones which a pragmatist like William James would say have "cash value" – about why the economy is surging or stalling must incorporate the many distinctive features of modern life.

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Table 1 a. Ratio of Number of Science and Engineering (S&E) PhDs from Universities in selected countries outside the US to S&E PhDs from the U.S.

	U.S	All EU countries	France, Germany and UK	Japan	China
1975	1.00	0.93	0.64	0.11	na
1989	1.00	1.22	0.84	0.16	0.05
2001	1.00	1.54	1.07	0.29	0.32
2003[a]	1.00	1.62[b]			0.49
2010[a]	1.00	1.92[b]			1.26

Table 1 b. Ratio of PPP adjusted per capita GDP in selected countries and regions to U.S. per capita GDP and annualized growth rates

	U.S (PPP adjusted GDP per capita)	All EU countries	France, Germany and UK	Japan	China
1975	19,830	0.74	0.76	0.72	0.03
1989	28,090	0.72	0.75	0.80	0.06
2001	33,983	0.75	0.77	0.77	0.12
2003[a]	35,373	0.73	0.75	0.74	0.14
Annualized growth rates of per capita GDP (percent)					
1975-1989	2.52%	2.36%	2.39%	3.25%	7.15%
1989-2001	1.60%	1.91%	1.86%	1.26%	8.65%

Table 2a: Ratios of Sales of Operating Systems (in units and revenues) to GDP and of Gross Fixed Investment to GDP in 2001
(US ratios= 100)

Region	Units sold/GDP			Revenues/GDP			Gross Fixed Investment/GDP
	Windows OS	**Linux**	**All Systems**	**Windows OS**	**Linux**	**All Systems**	
USA	100	100	100	100	100	100	100
Canada	141	106	137	116	102	115	121
Latin America	60	36	57	58	36	55	116
Western Europe	74	65	73	*NA*	*NA*	*NA*	123
Central/Eastern Europe	96	54	91	*NA*	*NA*	*NA*	139
Middle East and Africa	38	23	36	*NA*	*NA*	*NA*	118[a]
Japan	*NA*	*NA*	*NA*	87	34	80	152
Asia Pacific excl. Japan	*NA*	*NA*	*NA*	88	24	80	175

[a] For MEA Gross Fixed Investment, calculation is the weighted average of two regional aggregates provided by EIU: "Middle East and North Africa" and "Sub-Saharan Africa"

Sources: GDP data from World Development Indicators Online; Operating System sales data generously provided by Pankaj Ghemawat and Ramon Casadesus-Masanell (as described in the text); Gross Fixed Investment to GDP ratios from EIU database.

Table 2b: Ratios of Sales of Operating Systems (in units) to GDP and of Gross Fixed Investment to GDP in 2001
(US ratios= 100)

Country	Units sold/GDP			Gross Fixed Investment/GDP
	Windows OS	**Linux**	**All Systems**	
USA	100	100	100	100
Austria	71	53	69	136
Belgium	86	65	83	125
Denmark	127	92	123	122
Finland	100	73	97	125
France	68	65	68	120
Germany	65	63	64	123
Greece	72	36	68	146
Ireland	92	56	88	143
Italy	63	42	60	125
Netherlands	93	80	92	130
Norway	87	62	84	112
Portugal	94	54	89	163
Spain	47	29	45	160
Sweden	117	91	114	106
Switzerland	92	73	90	137
UK	87	93	87	102

Source: Same as in Table 2a

Table 3: Ratios of IT expenditures to GDP, and gross fixed investment (GFI) to GDP, where US ratios =100

	2001		2002		2003		2004	
Region	**IT Ratio**	**GFI Ratio**	**IT Ratio**	**GFI Ratio**	**IT Ratio**	**GFI Ratio**	**IT Ratio**	**GFI Ratio**
United States	100	100	100	100	100	100	100	100
Canada	90	121	90	130	90	130	88	126
Latin America	83	116	89	123	93	120	98	121
Western Europe	83	123	81	129	81	127	84	122
Central/Eastern Europe	98	139	105	144	90	143	83	134
Middle East and Africa	64	118[a]	68	133[a]	76	133[a]	81	123[a]
Japan	71	152	74	155	84	152	87	143
Asia/Pacific	83	175	85	193	88	200	88	198

[a] For MEA Gross Fixed Investment, calculation is the weighted average of two regional aggregates provided by EIU: “Middle East and North Africa” and “Sub-Saharan Africa”

Source: IT spending estimates from Gartner Dataquest Market Databook for December 2005 and December 2003, GDP data from World Development Indicators Online, Gross Fixed Investment to GDP ratios from EIU database.

Notes:

[1] Over 30 years after the introduction of minicomputers and more than 20 years after the introduction of microcomputers, the mainframe remains an important category. Total worldwide revenues of large-scale computer processors (or mainframes) amounted to $16 billion in 1997 compared to $16.2 billion in 1982. But because total demand grew from $38 billion to $183 billion, mainframes' share of the total computer market dropped considerably, from 42% to about 9%. (Bhide 2000)

[2] Innovations that created markets for new goods and services gave lie to predictions that mechanization and mass production would create mass unemployment. Productivity improvements on the farm reduced agricultural employment in the U.S. from 11.7 million in 1900 to 5.9 million in 1960. Changes in production technologies also put many highly skilled artisans out of work. But, total employment more than doubled – from 29 million in 1900 to 68 million in 1960. The labor released by the farm and workshop was quickly absorbed by factories established to serve new markets (and the increased demand for old goods). The assembly line worker also earned more than the farmer or skilled artisan. For instance by 1900, the average annual manufacturing wage was more than twice the agricultural wage and this gap continued to widen through the first seven decades of the 20th century.

Products that satisfied new wants also created jobs in new service industries. Refrigerators and air-conditioners had to be transported, advertised, sold by a new kind of retailer, installed and periodically serviced. The transportation, advertising, retailing and other such 'service' industries in fact created more jobs than the manufacturing sector. As early as 1920 – long before the term the 'service economy' had been coined – employment in trade, transportation and other private service providing sectors was 15% greater than in the manufacturing. By the end of the 1960s, employment was nearly 70% greater. Although wages in the manufacturing sector stagnated after the 1970s, and manufacturing jobs topped out at about 20 million in 1980, overall employment and incomes in the U.S. continued to rise. The number of gainfully employed Americans in 2000, for instance, was 135 million – a nearly 35% increase over the 99 million employed individuals in 1980. Real U.S. GDP per capita during this period rose by 57%, and disposable personal incomes by nearly 50%. Apparently the growth of businesses that used information technology to satisfy new wants helped to compensate for the lack of growth in manufacturing.

[3] On-going rather than one shot innovation extends beyond high technology into fields such as publishing and retailing. Jan Wenner, who started Rolling Stone, built on the experiences of several predecessor rock and roll magazines. Sam Walton opened his first Wal-Mart (in Rogers, Arkansas) after making dozens of trips to study discount retailers that were emerging in other parts of the country, including Ann and Hope (considered the creator of the concept) in Rhode Island and Fed-Mart in California. And, Walton, apparently never stopped innovating, continuing to borrow and integrate new ideas into Wal-Mart practically until the day he died.

[4] Scherer (1982) 234-235, cited in Acs and Audretsch (1991) 42

[5] Von Hippel also argues that "the contribution of users is growing steadily larger as a result of continuing advances in computer and communications capabilities"

[6] Moreover, the Gross Fixed Investment numbers in the tables include investments in residential real estate. The ratio of true 'business' investment to GDP is likely to be even lower in the U.S. than in Japan and in the countries of Western Europe.