Princeton University Press: September 2008

The Venturesome Economy:

How Innovation Sustains Prosperity in a More Connected World

Table of Contents

This research was supported by a generous grant from the Kauffman Foudation

Author’s web page: www.bhide.net

16. First Do No Harm

In previous chapters, I disputed the techno-nationalist prediction that disastrous consequences await the United States should its lead in cutting-edge science diminish. However overly dire forecasts can lead to desirable outcomes, particularly given the human tendency toward optimism and inertia, and people can make good choices for the wrong reasons. “Paranoid” executives like Intel’s Andy Grove, for instance, can drive their businesses to exceptional performance partly by exaggerating the threat their rivals pose. Smokers who take fright from false signs of a heart attack may actually quit. Similarly, even if their analysis of globalization is wrong, the techno-nationalist remedies could, in principle, increase prosperity.

In fact, even though techno-nationalists use the competitive threat from China and India as a rallying cry, they do offer other justifications for their prescriptions. As mentioned in the introduction and chapter 7, the formula for maintaining the U.S. (or European or British) lead vis-à-vis Chinese and Indian upstarts has two main ingredients: expand subsidies and tax incentives to undertake cutting-edge research; and increase public funding for training more scientists and engineers to do this research. Apart from the competitive advantages these policies are supposed to bestow, advocates also claim that they represent a worthwhile investment of public funds because of externalities and spillover effects, regardless of what might happen because of globalization. Economists from the hot new field of “endogenous growth theory” also espouse these measures, again without relying on arguments about globalization.

One possible reason these policies have emotional appeal is that they evoke memories of the vigorous U.S. response to the *Sputnik* scare five decades ago. Politicians and the media vastly exaggerated the Soviet space lead, but it is now widely asserted—by the National Academies’ *Gathering Storm* report among others—that the shock was a galvanizing event that gave science and technology in the United States funding and attention that ultimately had a huge economic payoff. The subtext to the popular narrative is that even if the Chinese and Indian threat turns out to be a false alarm, only good can come out of more investment in scientific research.

In this concluding chapter, I argue that, notwithstanding this apparent consensus, increasing subsidies for scientific education and research will not serve up a free lunch. Constituencies that benefited from the *Sputnik* scare are happy to advertise what they achieved with the resources they secured, but a proper accounting must also include the opportunity costs; in the view of some observers, these have exceeded the benefits. Walter McDougall, for example, says it is wrong to believe "that the American people need 'another Sputnik' to increase U.S.

competitiveness in space or technology." The country "does not need another ill-conceived spasmodic reaction to some humiliation that does not pose an immediate threat."[1]

Modern societies have undeniably derived great benefit from cutting-edge research; but ever more of a good thing doesn’t make it great. Up to a point, proteins are good for you, but an all-protein diet isn’t the most nutritious. More than four decades ago, British economists, Carter and Williams, cautioned 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.”[2] Similarly, I will argue there is little evidence of an “undersupply” or a need for public polices to stimulate the production of more high-level know-how or to subsidize the training of more homegrown scientists and engineers. Rather, given the realities of modern innovation, there is a good argument for *reversing* policy biases against the development—and even more importantly—the effective use of mid- and ground-level innovations. Public policies should stop trying to rob mid- and ground-level Peters to pay high-level Pauls.

An Inevitable Expansion

My skepticism does not derive from any dogmatic belief that the state has no business interfering with business. It is all very well to say that that government is best which governs least; but what’s the least? The legal and regulatory role of governments—at all levels—in the United States and the resources they control have increased vastly since the founding of the Republic. Many public choice theorists suggest that the expansion is the inevitable and unfortunate consequence of special interests politics. Does this mean then that the Founding Fathers made a mistake in their initial design, or does democracy inevitably lead to overbearing government?

My more benign explanation for some of the expansion in the role of government is that the great technological advances that occurred after the eighteenth century increased what most people would consider the minimal roles of government on a variety of fronts.

Consider property rights. These are sometimes considered natural, but they have features that do not occur in nature—territories in the animal kingdom cannot be rented or sold, for instance. Rather, it is the state that permits transactions in land by recording deeds, maintaining land records, settling disputes, and evicting trespassers.* The transformation of U.S. society from agrarian to industrial created the need to define and enforce new kinds of intellectual property.

---

* The idea that state power is necessary for individual rights to property goes back to at least Thomas Hobbes’s writings in the mid<n->seventeenth century.

Initially, this effort comprised patents on “inventions”; then as economic activity became more specialized and diverse, the scope of what could be regarded as intellectual property expanded to include brand names, logos, designs, software code, and even customer lists. Legal protections had to be defined and enforced for such property through new state interventions such as copyright legislation, the policing of counterfeiting, and the expansion of common laws governing trade secrets.

New technologies created the need for new rules to coordinate interactions between individuals or groups. The invention of the automobile, for example, necessitated the formulation and enforcement of driving rules and a system of vehicle inspections. The growth of air travel required a system to control traffic and certify the air worthiness of aircraft. Similarly, radio and television required a system to regulate the use of the airwaves in order to avoid the collision of signals by competing broadcasters.

Modern technology created new forms of pollution that didn’t exist in agrarian economies. Governments had to step in, in one way or the other, making it unrewarding to pollute. Similarly, antitrust laws to control commercial interactions and conduct emerged after new technologies created opportunities to realize economies of scale and scope—and realize oligopoly or monopoly profits. These opportunities were largely absent in preindustrial economies.

Government action has facilitated the provision of “positive” externalities (or public goods) that support the development and use of new technologies. Governments have, for example, financed, built, and operated interstate highways that have catalyzed the use of automobiles and a network of airports that have sustained the expansion of air travel. In principle, private enterprise could have been harnessed for the highways and airports, but it is hard to imagine how such efforts could have been accomplished without a government more active than were governments in the United States in the eighteenth century. For instance, such projects could have been “privately” financed through bond issues rather than through budgetary appropriations. But large-scale bond issuance also requires more extensive legal machinery for enforcing contracts than is necessary for the much simpler and localized process of credit in an agrarian economy.

Similarly, the expansion of higher education has supported technological progress. To a degree (unlike, say, traffic rules), private initiatives can support some level of higher education without government involvement. But many believe that availability of higher education to anyone who is capable of doing the work, regardless of parental income, is a valuable public good that governments ought to support. Therefore, even though the private delivery and financing of higher education is unusually high in the United States, college enrollments have almost certainly been raised by direct grants to state universities and by indirect government support through student loan programs.

Technological advances have also stimulated the expansion of the U.S. government's role in redistributing income, through progressive taxation and a variety of income-maintenance programs. This has occurred in two ways. First, technology amplifies differences in economic rewards that can result from differences in individual talent and temperament—and even luck. When agricultural technology was relatively primitive, one settler who received title to 160 acres under the Homestead Act could expect to make roughly the same living from farming the land as his neighbor. With modern technology, however, farmers who have the ability to use tractors, harvesters, hybrid seeds, crop rotation techniques, and futures markets to hedge their output—or have good fortune in their choices—can earn significantly higher returns than those who don't. Like it or not, in democratic societies differences in outcomes create irresistible political pressure to create equal opportunities for the offspring of the less well-to-do.

Second, technology changes workers from undifferentiated providers of simple effort to individuals with specialized skills and knowledge who are not interchangeable. This encourages employers to value continuity—it is costly to replace a programmer who quits in the middle of a project. And, since Henry Ford's audacious five dollars a day in pay was shown to do the trick,[3] U.S. employers have learned to pay "efficiency wages"—a premium over what the worker can earn elsewhere. However,, although efficiency wages provide high earnings as long as workers keep their jobs, they also experience a commensurate drop in earnings if they get laid off. Moreover, in a technologically advanced economy, matching a specific worker's skills and knowledge with a specific employer's requirements can be difficult; therefore, unemployment sometimes stretches on. In technologically backward economies (as I observed in my recent field research in India), labor turnover is high, and many employers regard the very notion of efficiency wages as madness (just as other employers in the United States did at the time of Henry Ford). Therefore, quitting or being fired is of much less consequence.[4] Long-lived bonds of community and family that can provide a cushion during hard times also seem to be weaker in technologically advanced societies. Therefore, there is strong political pressure on governments in modern economies to provide safety nets for workers who face a sharp drop in income when they lose their jobs.

Warranted Interventions?

Even if the "least" that governments should do tends to increase with technological progress, this does not mean that we should embrace the opposite principle, that that government governs best which governs most. It's one thing for the Federal Aviation Administration to manage the air traffic control system, but quite another for the Civil Aeronautics Board (b. 1938, d. 1985) to regulate airfares, routes, and schedules. The Founding Fathers' mistrust of excessive concentration of power remains apt for the modern U.S. economy, especially when it comes to policies to promote innovation.

First, innovation is an uncertain process whose direction is extremely hard to predict. "Markets" can get it wrong, but when many individuals and firms exercise independent judgments, there is a higher probability that *someone* will get it right than when a single judgment is made by a centralized authority. Second, as Hayek pointed out in 1945, centralized authorities lack the specific knowledge of the "man on the spot." Hayek wrote that when "rapid adaptation to changes in the particular circumstances of time and place" is necessary, "decisions must be left to the people who are familiar with these circumstances, who know directly of the relevant changes and of the resources immediately available to meet them."[5] Third, power corrupts, and special interests hijack the good interventions of government for dubious ends. The construction of the interstate highway system may have been a great boon to the U.S. economy, for example, but it did not take long for Congress to start appropriating funds for bridges to nowhere.

Entrepreneurial "leaps into the dark" are therefore best sustained by great caution in expanding the scope of government intervention—the private virtue of daring can be a public vice. The U.S. chief justice has often repeated the maxim: "If it is not necessary to decide an issue to resolve a case, then it is necessary *not* to decide that issue." Similarly, if it is not necessary to intervene to promote innovation, it should be considered necessary *not* to intervene. Among other things, such a maxim makes more attention and time available for interventions that are necessary or at least more useful. Federal regulation of air traffic control and safety is likely to be better if the government avoids expending resources on regulating ticket prices, for instance.

I find it helpful to make a distinction between two kinds of interventions: one in which autonomous private initiative (or Hayek's "spontaneous order") completely fails to coordinate joint activities (as in the case of traffic laws) or control negative externalities (as in the case of pollution); and the other, when private enterprise does supply desirable goods, but allegedly not in socially desirable quantities. In the latter case, it is very hard for anyone to know what the right quantity is, especially in a complex interconnected system where bottlenecks are difficult to identify and unintended consequence difficult to predict. It is also relatively easy for special interests to exaggerate the need. In my view, therefore, advocates of expanding the supply of their favored good should be required to make a strong case for why it would otherwise be undersupplied (or if the good is subsidized, why the amounts are inadequate).

The two kinds of interventions usually proposed by techno-nationalists are intended to correct an alleged *undersupply*—of cutting-edge research and of scientists and engineers—rather than an *absence* of research and scientists. In fact, in absolute terms, more research is being done than ever before, and the number of scientists and engineers trained in the United States has grown, albeit slowly, over the last decade. How strong is the case that they are not enough—that it would behoove society to move money and people from the activity they would otherwise be engaged in to producing more scientific and engineering know-how, preferably of the cutting-edge variety?

As we will see next, it's much less than compelling.

According to the National Academies' *Gathering Storm* report, "The economic value of investing in science and technology has been thoroughly investigated. Published estimates of return on investment (ROI) for publicly funded R&D range from 20% to 67%." The report apparently relies on 11 studies it lists in a table. A footnote records that many of the authors of the studies "caution about the reliability of the numerical results obtained";[6] this is in spite of the authors' presumably not sharing my skepticism about the robustness of econometric methods discussed in chapter 6. That's not all the doubt one can muster, either.

Only one of the studies, by Cockburn and Henderson, published in 2000, tells us anything about the returns earned over the last decade. All the others are more than 13 years old: seven were published in the 1950s, 1960s, and 1970s, and three between 1981 and 1993. Of course, a critical assumption of the natural sciences is that what's happened in the past will also happen in the future. But in human affairs, this is a precarious stipulation. There has been a great expansion in public funding of R&D and significant changes in the nature of the research funded in the last decade. It's a leap to believe that studies undertaken before that expansion are representative of what happened afterward, much less of what any further expansion of funding will achieve.

Then there is the cherry-picking problem: all but one of the 11 studies cover public spending in specific sectors rather than of the overall public expenditures on R&D. The bias against negative results in academic research is well known. It would be easy to compile extensive lists of projects that almost certainly did not produce an economic return, but it would be virtually impossible to get such lists published—at least in a reputable academic journal. Note also what kind of research the studies cover: nine of the 11 estimate the returns from publicly funded research of hybrid corn, poultry, tomato harvesters, and other agricultural subjects. The

2000 study covered pharmaceuticals. Only Mansfield's 1991 study was broad—it covered all academic science research—but the data on which it was based is now practically ancient history.*

Finally, why should we expect the now much broader portfolio of publicly financed scientific research to yield measurable economic returns? Most proposals aren't evaluated on the basis of their economic returns and rarely contain claims that they will have any such impact—federally funded agricultural research with clear practical goals is the exception rather than the rule. Some kinds of scientific research may end up producing economic returns by accident, but that's not its goal. I have personally reviewed fine National Science Foundation proposals that were likely to produce interesting insights but no economic return to taxpayers.

I'm not arguing for reducing public funding of science. Rich countries ought to give serious consideration to supporting activities such as public gardens, art, museums, theaters, and broadcasts—and scientific research—that can enrich the lives of their own citizens (or even those of other countries) and of future generations, without regard to their measurable economic payoffs. But equally, I believe it is disingenuous to argue for an expansion of public funding for scientific research on the grounds that it will produce high economic returns or other material benefits.

In a thoughtful essay, "The Many Purposes of Science," Dick Teresi recounts the appearance of physicist Robert Wilson's congressional testimony 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, and 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."[7] Similarly, public funding for most scientific research should be justified principally on how it enriches our lives, not how it will increase GDP.

The *Gathering Storm* report also cites studies compiled by the President's Council of Economic Advisors in 1995,[8] of the rates of return on private (rather than publicly funded) investment in research and development. A table summarizes the results of eight studies, each of

---

* A similar cherry-picking can be seen in the glowing reviews of post-*Sputnik* policies: they focus on the initiatives that apparently did some good, such as the National Defense Education Act, rather than perform a cost-benefit analysis of the full package of policies.

which shows that "the ROI [return on investment] to the nation is generally higher than is the return to individual investors," typically by a factor of at least two. Again, the research is not current—the most recent study was published in 1993—and the estimation procedure turns on arbitrary assumptions.[9] But let us grant that private R&D investment has indeed produced much higher returns for society than it has for the investors, through some combination of a consumer surplus or through spillovers of technical knowledge that reduced the costs of someone else's research.

So what? Techno-nationalists would have us believe that a gap between social and private returns indicates money that was left on the table: if individuals and firms had been able to appropriate more of the returns that "leaked" into society, for instance, through a subsidy or tax credit, they would have undertaken more R&D, and everyone would have been better off. This logic, as I argued in the introduction, turns on some heroic assumptions.

First off, greater financial incentives don't always elicit more effort, and more effort doesn't always produce better results. To illustrate: I am highly confident that Roger Federer's superb performances at Wimbledon have produced a huge consumer surplus for fans—very likely (if we could somehow quantify it) far in excess of Federer's prize money and the pleasure he derived from winning the tournament. In technical language, the social return to Federer's effort has probably been much higher than his private return. I am highly doubtful that the expectation of larger financial reward (because of more prize money, or tax breaks on his earnings) would have induced Federer to train or play harder and thus brought even more joy to fans. More likely, the existing level of prize money and prestige, in conjunction with fierce competition from players such as Rafael Nadal, make Federer play as well as he knows how. Similarly, it is far from obvious that providing greater incentives for R&D would actually have generated more useful know-how. It might be easier for a pharmaceutical company to increase its research budgets than it is for Federer to devote more effort to playing tennis at Wimbledon; but as recent experience shows, in the absence of good targets and good compounds to attack these targets, companies can spend billions of dollars without developing a single successful drug.

In addition, as I have repeatedly emphasized, the development and effective deployment of new products entails the development and use of many different levels (high, middle, and ground) and kinds (scientific, engineering, managerial, sales, and marketing) of know-how. R&D investments cannot produce the full range of this know-how; and, if the kind of know-how produced by R&D is not the bottleneck, increasing such know-how may do little good. On the contrary, it could do harm. Returning to the Federer example, inducing Federer to play better through more prize money (even if it could be done) might do less to increase the surplus of viewers than, for instance, buying better courtside TV cameras. Moreover, if paying more prize money requires skimping on cameras, viewers could be worse off rather than better off.

Similarly, the development of other kinds of know-how, and not just technical knowledge, can generate valuable spillovers. As discussed in chapter 15, the professionalization of IBM's marketing and sales processes helped promote wider and more effective use of its computers. But this professionalization didn't benefit IBM alone and its direct customers. The know-how was widely disseminated throughout the high-tech industry to the benefit of a large number of innovators and their customers. Indeed, one of the advantages that upstart innovators enjoy today is an ample supply (a "thick market") of professional sales personnel; so a business that develops an attractive product can ramp up revenues quickly and efficiently. Similarly, as also discussed in chapter 15, developers of the managerial know-how necessary to effectively deploy IT cannot prevent its leakage. As much as companies such as Wal-Mart would like to keep such knowledge to themselves, it inevitably spills over to other companies through employees, consultants who help install the systems, and vendors of the systems.

In other words, the historical difference between private and social returns on R&D investments does not justify even the retroactive claim that policies to divert resources to R&D would have improved the common good. To be true, such a claim would require at least the following conditions: the resources would have been productively used, and more R&D would not have reduced some other activity that played a more critical role in generating consumer surplus or in producing more valuable spillovers. But such a determination is simply impossible to make; studies on the social return of R&D can at best provide an account of what transpired; they are not scientifically controlled experiments: they cannot tell us what would have happened if more resources had been deployed in R&D. Therefore, under the principle that governments should not make wild gambles with taxpayers' funds, the research cited by *Gathering Storm* does not sustain an argument for increasing subsidies to private R&D any more than it does the funding of more scientific research.

The now fashionable "endogenous growth" theory's case for intervention derives from mathematical models rather than empirical research. At the risk of extreme oversimplification, the origins of this theory can be traced back to pioneering work in economist Paul Romer's doctoral dissertation. In what is widely regarded as brilliant mathematical coup, Romer constructed a model of the economy with a revolutionary feature: economic growth was driven by new ideas and advances in technology, and, more importantly, governments could establish incentives to stimulate such advances and thus economic growth. Older growth theories (such as Robert Solow's) also attributed economic growth to technological progress, but they could not mathematically model a role for public policy. Therefore, these theorists were forced to assume that technological advances arrived like manna from heaven—their quantity was “exogenous” rather than “endogenously” determined by government intervention.

But what was the cash value, as the pragmatist philosopher William James might have called it, of this breakthrough? Would the treatments derived from it meet an FDA test of greater efficacy vis-à-vis current therapies? Outside the never-never land of closed-form mathematical models, the ideas do not appear to be especially revelatory. Rules in the Middle Ages knew the value of know-how and were prepared to provide financial incentives to secure it. The U.S. Constitution contained the Copyright and Patent Clause, empowering Congress to “promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries.”

Around 2002, Romer, by then (and as now) a professor at Stanford’s business school, proposed a scheme to boost the number of undergraduates majoring in science, mathematics, and engineering. Under Romer’s scheme, the government would provide grants to universities based on their success in increasing the proportion of students majoring in these fields. "The United States should lead the world in the fraction of 24-year-olds who receive science and engineering degrees,” said Romer. “Unfortunately, by this measure, we now lag far behind many other nations." Romer also proposed a $1 billion program to provide 50,000 fellowships for graduate work in the natural sciences and engineering.[10]

Romer argues that his scheme for subsidizing the supply of scientists and engineers is more market-friendly than is subsidizing research projects. It is also less vulnerable to cronyism and pork barrel politicking—congressional R&D “earmarks” in the 2008 budget amounted to about $2 billion, including more than $500 million for “performer-specific” projects.[11] Nonetheless, the Romer scheme is inarguably interventionist—it assumes that labor markets tend to get it wrong, so that too many students who should do graduate work in physics or engineering wind up going to business school (such as Stanford), or law schools, or don’t go to graduate school at all and become salespersons.

But why is it in society’s interest to bribe them to do otherwise? Romer argues, in an eloquent essay on economic growth, that scientists and engineers “are the basic input into the discovery process, the fuel that fires the innovation engine. No one can know where newly trained young people will end up working, but nations that are willing to educate more of them and let them follow their instincts can be confident that they will accomplish amazing things.”[12]

How much more though, and what’s enough? Filling up the “innovation engine” with scientific and engineering fuel is fine, but not if this means driving with poorly inflated tires.

Recall the paper, coauthored by Romer's colleague Bresnahan, about how the problem of co-invention (developing ground-level know-how in my terminology) held up the adoption of client-server architectures. "Technological progress," the paper concluded, "is not just bits and bytes," and it isn't limited simply by technical difficulties. In the case of many IT systems, because the technology advances more quickly and easily than ground-level managerial know-how, "the co-invention of organizational change" becomes the bottleneck.[13] It is reasonable to infer that such bottlenecks are more likely to be eased by a more ample supply of managers, rather than by scientists or engineers. But this is precisely what Romer's scheme to train 50,000 more scientists and engineers tilts against.

The share of managerial and professional jobs in the United States has increased from about one in six in 1940, to about one in three today.[14] In the last couple of decades, the growth has taken place in a climate of cost-cutting, restructuring, and reengineering, and probably does not reflect a spontaneous increase in bureaucratization of U.S. companies. More likely, it follows from the growth of activities, particularly in the expanding service sector, that are difficult to coordinate and in which economies of scale and scope are difficult to come by. These managers have been responsible for efforts to improve productivity through the use of technologies such as ERP (or client-server computing) that may require a much higher ratio of managerial to technical personnel than did productivity-increasing technologies in the manufacturing sector. In other words, the labor market may not have gotten it monumentally wrong. Interventions to train more scientists and engineers may well impair, rather than increase, productivity growth.

Other endogenous-growth theorists have different proposals to promote cutting-edge research, but none that I'm aware of provides a convincing rationale for their favored scheme for putting the government finger on the market scale. My conjecture is that the prescriptions of growth theorists reflect the assumptions of their models. In order to be mathematically tractable, the models lump all knowledge into a single category, like land, labor, or capital, without making distinctions between the levels or kinds of knowledge or how it is generated. At least some of the theorists fully understand the many forms that knowledge can assume: Romer's essay on economic growth acknowledges that "it takes more than scientists in universities to generate progress and growth," and that the "seemingly mundane … development of new business models can have huge benefits."[15]

The mathematical models used by the growth theorists, however, do not—and in fact cannot—accommodate many distinctions between different kinds of know-how. At the same time, it is hard to imagine policy instruments that could stimulate the production of all the various forms of knowledge generated by the massively multiplayer innovations game that sustains economic growth. Therefore, when theorists try to apply their finding (that it is good for society to invest in knowledge), they conflate knowledge with just one thing—namely, technical knowledge produced by engineers and scientists. The end result is that a theory that is inherently harmless (and without practical implications) can generate negative "cash value," by suggesting policies that may do more harm than good.

Against the Tide

The prescription to subsidize more U.S. science and train more home-grown scientists and engineers also fails to take into account the growing share of the service sector in the U.S. economy; the emergence of China and India as new sources of research, and, finally, technological and managerial developments. As I will argue in this section, these three trends reduce, rather than increase, the value of expanding the domestic supply of research and researchers.

A report by the National Association of Manufacturers points out that the manufacturing sector, which produces just 12 percent of U.S. GDP, accounts for 42 percent of R&D undertaken in the country and "employs 25% of scientists and related technicians and 40% of engineers and engineering technicians."[16] The service sector, which produces about 70 percent of U.S. GDP, presumably accounts for a disproportionately low share of R&D and scientific and engineering employment. But this doesn't mean that the service sector shuns innovation. Rather, as Dirk Pilat notes: "R&D in services is often different in character from R&D in manufacturing. It is less oriented toward technological developments and more at co-development, with hardware and software suppliers, of ways to apply technology, in particular ICT, to deliver services. The research may, for example, be aimed at improving interfaces with customers, and also increasingly involve human factors, psychology and design."

"Most service innovations," continues Pilat, "are non-technical and mostly involve small and incremental changes in processes and procedures [and] often do not meet the criteria for patenting." Patent counts therefore understate the true extent of service-sector innovation. Moreover, "Expenditure on R&D is only one element of firms' expenditure on innovation. For manufacturing, R&D generally amounts to about half of total investment in innovation," whereas "R&D expenditure captures only a small part of the total innovative effort of service firms" that typically "involves changes in processes, organisational arrangements and markets."

In other words, whatever might be the level of resources a manufacturing-dominated economy should devote to formal research and the education of scientists, we should expect this level to be lower in a predominantly services-based economy.

The growth of research capabilities in China and India also dampens the need for governments in the United States (and other rich countries) to direct more resources to science and engineering. As I have argued in several chapters of this book, cutting-edge research, regardless of where it is produced, is either a free public good for the world at large or available at a low cost to users everywhere. Similarly, less well-to-do countries such as India have arguably over invested in engineering education and trained many individuals who, given the opportunity, would eagerly migrate to the United States.

Moreover, U.S. industry would not have to learn any new tricks to capitalize on overseas research and technology. Technologies used in the United States have never been fully or even largely homegrown—there is a long history of adapting for domestic use technologies developed abroad. According to the British economist Von Tunzelmann, the United States "borrowed British industrial products and technologies in the nineteenth century, but wasted little time before re-engineering them to suit American conditions. While the new technologies developed in the USA were rather modest contributions to the sum total of human technological knowledge before the twentieth century, it would also be inaccurate to describe those used in U.S. industry as simple copies of the British. It was less a case of imitation than of re-invention in the eyes of Marshall. A major element in that re-invention procedure was speeding up British practices; examples include the ring spindle in place of the mule in the U.S. cotton spinning industry, and hard driving in the U.S. steel industry."

That reinvention also involved a greater focus on mass markets: "Whereas many British items were customized for wealthy purchasers, Americans concentrated on cheaper, more standardized items for the whole community—an example much referred to in the mid-nineteenth century was guns, where (military purposes aside) the British concentrated on sporting pieces for the aristocracy, while the Americans produced rifles and, later, pistols in large quantities for the small farmers and cowboys." A mass-market focus favored adapting technologies for standardization and high-volume production: "Even items that might be expected to be individually tailored were vastly more standardized in the USA, such as boots and shoes."[17]

By the end of World War I, according to Maddison, the United States had become the leading developer of new technologies. Yet considerable technological give-and-take with other advanced economies continued. Eaton and Kortum examined the growth in productivity in West Germany, France, the UK, and the United States between 1950 and 1990. According to their analysis, the growth of the first four countries, which started far behind the United States at the start of the period, was "primarily the result of research performed abroad." Notwithstanding its overall lead, "even the United States obtain[ed] over 40% 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 United States, such as Mueller's[18] description of "the foreign inventions underlying DuPont's innovations."[19]

We have no reason to suppose that the U.S. capacity to use technologies developed abroad declined after 1990. Rather, because of factors such as the increasing flows of information, ("the death of [communications] distance") and the growing operations of U.S. firms abroad (and of foreign multinationals in the United States), it has very likely increased.

This is not to suggest that, either from an economic or moral point of view, the United States should become a freeloader and rely exclusively on research (or researchers) produced abroad. Rather, my argument is that just as the rich make larger contributions to the arts than the not-so-well-off, prosperous countries can and should contribute more to research on string theory or the decoding of the genome than poor countries. As prosperity becomes more widespread, we should expect more countries to contribute to the world's stock of scientific knowledge. This helps, rather than hurts, the countries that once took the main responsibility. The declining share of U.S. scientific research and researchers that so alarms economists such as Romer and Freeman does not, in fact, require the U.S. government to increase its funding for these activities. Rather, the expansion of the overseas supply of research and researchers should to make the U.S. government *more*, not less, willing to let markets determine what kind of innovative activities secure capital and talent.

Finally, new technologies and better management techniques contribute to reducing the proportion of the workforce that needs deep scientific and engineering training. As mentioned (in chapter 14), new programming tools and techniques and cheap hardware allow individuals of modest ability or training to write code. In fact, for many programming tasks, it is not even necessary to have formal training in computer science. Similarly, as mentioned (in chapter 11), in 2005, an estimated 80 million individuals in the United States used computers in the workplace. While most users likely made a significant investment in learning to use computers, the great majority weren't trained programmers. Yet, they could "develop applications" to suit their needs because spreadsheet and database programs (with increasingly easy-to-use interfaces) have made it possible for them to do so.

Better management techniques have also helped individuals without deep technical training harness new technologies. The legendary architect Frank Gehry provides an interesting (if extreme) example. According to an article in the *Wall Street Journal*, “Mr. Gehry's buildings are as much feats of engineering as they are of architecture,” but there are no computers in his office. Gehry told Sharma that he didn’t know-how to turn on a DVD and could “barely use the technology” in his car. “The actual physics and engineering of Mr. Gehry's buildings,” Sharma wrote, “are managed by teams of employees. Some 150 people work for him, and when Mr. Gehry talks about what exactly he does that leads to a building, it seems that he is almost more a manager of personalities and processes than he is someone who sits down with pencil and paper.”[20] Similarly, Wal-Mart’s founder, Sam Walton, was also very far from a computer whiz; he was nonetheless able to use IT to build the world’s largest retailing chain by hiring and supervising IT executives, who in turn built a large IT staff.

Here, too, I’m not suggesting that technological advances have made training in computer science obsolete. To a great degree, Google has become a valuable and universal tool because of the contributions of superbly trained engineers and scientists. My argument is simply that new technologies and management know-how provide much more leverage: the talents of a few great programmers go a much longer way than they once did, so a smaller proportion of users need to actually learn how to program.

Redressing the High-Level Bias

If increasing government support for high-level research is unwarranted, are there any other changes or policy adjustments that the modern U.S. economy would benefit from? I argue next that there is a worthy case for reversing long-standing policy bias in favor of high-level innovation and against the development, and even more importantly, deployment of innovative mid- and ground-level products.

A useful starting point is a paper that Stanford economist Paul David wrote in 1986, in the midst of high anxiety about the Japanese threat to U.S. competitiveness. David wrote that innovation had become a “cherished child, doted upon by all concerned with maintaining competitiveness … whereas diffusion has fallen into the woeful role of Cinderella, a drudge like creature who tends to be overlooked when the summons arrives to attend the Technology Policy Ball.”[21] Pointing out that diffusion (the use of new technologies) was at least as important, David made the following points about how this was affected by public policies.

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 United States) 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.[22]

My analysis suggests implications that are in many ways similar to David's observations, save in two respects. First, I question the utility of a case-by-case approach. I have little doubt that the binding constraints or pinch points vary significantly from situation to situation, but the record of case-by-case interventions is not inspiring. The approach obviously invites efforts, both overt and covert, by lobbies to secure results that suit their private ends. The process of public policymaking is also slow, and, indeed, to secure the legitimacy of openness and the accommodation of many points of view, public policy ought to be formulated with all due deliberation in most cases. 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.

Moreover, suppose policymakers could identify the "right" bottlenecks across all industries in a timely manner: they would face the problem of formulating effective responses. As I have argued in this book, 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 and more elusive barriers to progress, but may actually increase them.

Second, the same concerns about our profound ignorance of the underlying factors make me skeptical about “integrated approaches” to promoting technology development and diffusion. Integrated approaches may be fine in principle, but do we know enough to implement them?

A proper appreciation of the complexity and elusiveness of the modern innovation systems does not lead to new interventions but rather suggests the removal of a long-standing bias in favor of high-level research and the neglect or even impairment of other activities involved in the development and use of lower-level innovations. One obvious example is the provision of subsidies and grants for R&D but not for the marketing of products or the development of ground-level know-how by their users. As we have seen, sales and marketing play a crucial role in realizing the value of innovations. Buyers of new products face significant Knightian uncertainty about the utility of their purchases, and in addition to good information they need some persuasion. In fact, persuasion is an essential ingredient of technological progress—and even when done in the most professional way, often involves the use of smoke and mirrors or psychological manipulation. But far from providing tax credits or subsidies for this important activity, policymakers (and others)* often treat it with indifference or disdain.

Similarly, companies like Wal-Mart may have very large IT budgets and staff who have to develop a great deal of ground-level know-how—and may even develop some in-house systems. But none of this qualifies for R&D incentives. Even mid-level innovators, such as the VC-backed firms I studied, often miss out. They may in principle qualify for R&D subsidies, but in practice, many such firms not only lack the earnings needed to take advantage of tax credits, but often cannot easily segregate R&D outlays and activities from their other functions, such as marketing and sales.

Subsidies to train more scientists and engineers obviously have the same—and in my view unwarranted—bias. They increase the supply of labor for producers of high-level know-how and reduce it for other players in the innovations game.

Other biases against the development and use of mid- and ground-level products that need to be reevaluated are more subtle.

One is the effort to stimulate savings and investment. There appears to be a consensus among policymakers of many stripes that, except possibly in recessions, saving is always virtuous and consumption always undermines long-term growth—a mind-set exemplified by Prestowitz’s alarm that the United States “is building its economy into a giant consumption machine.”[23]

* I once attended a seminar where a leading developmental economist presented the results of a research project to study why farmers in Africa did not use fertilizer when it was obviously in their interest to do so. The research team had tried a large number of “interventions”<m->except the use of a commissioned sales force. In any real-world, for-profit business, such an omission would be inconceivable.

Mechanisms to mobilize savings, such as the stock market and retirement plans, are thus regarded with favor, while mechanisms that facilitate consumption—such as credit cards—are regarded with suspicion. But as I have argued, Max Weber's thesis that capitalism is synonymous with capital accumulation ignores the role of venturesome consumption of innovative goods 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 a 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 providing tax credits for capital outlays also seem 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 spending by users of mid- and ground-level products is, in fact, risky, long-term investment. For instance, as discussed, the purchase price of an ERP system is a fraction of the total cost of ERP projects, but businesses eligible for investment-tax credits for their purchases of computer hardware or software don't receive a tax break for the costs of training users, adapting the system to their needs or reengineering their business processes. It may be that a tax credit for computer hardware 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 roundabout and inefficient way to achieve this purpose. (The tax credit may, for instance, encourage a business to invest more in computers and less in user training and reengineering.)

Immigration policies favor high-level research by preferring highly trained engineers and scientists (i.e. those with PhDs and master's degrees) to individuals with just a bachelor's degree. Supposedly, highly trained individuals required to undertake cutting-edge R&D are scarce, 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 argued, the highest valued use of talented, native-born individuals may not be scientific and engineering jobs at all; therefore, immigrants who don't have advanced degrees probably make as valuable a contribution as those who have advanced degrees by, for instance, working in the IT departments of, say, retailers and banks. As we also saw in book 1, unlike the R&D labs of large companies, the technical staff of mid-level innovators employ high proportions of immigrants without advanced degrees.

A liberal patent system seems more attuned to the needs of R&D labs than to those of innovators developing mid- and ground-level products. As we saw in book 1, the latter often do not produce patentable IP, whereas patents are the stock in trade of R&D labs. Easily obtained patents by high-level players also pose significant legal risks for developers of mid- and ground-level products whose innovations often combine high-level know-how and inputs. Such a bias would seem particularly perverse in a globalizing economy where the United States has an absolute and comparative advantage in using high-level know-how in lower-level products. Nevertheless, the reflexive high-level bias—the dogma that technological strengths depend on patentable cutting-edge research—is so strong that recent bipartisan efforts to make life easier for users of IP (by making it harder to secure and protect patents) hit "resistance because of concerns that the United States might be exposed to greater foreign competition."*

Treating Health Care

The health-care industry provides an important illustration of the high-level bias of public policy—and of the large potential benefits of paying more attention to the development and use of mid- and ground-level innovations. The United States spends more of its national income on health care—about 15.3 percent of 2003 GDP—than any other country in the world. In 1999, U.S. health-care spending stood at 13.1 percent[24] of GDP and, by 2016, is expected to rise to about 19.6 percent. This is not necessarily bad: for instance, if the "nondestructive" development and use of innovations is greater in health care than in the rest of the economy, we should expect health care's share of GDP to increase over time. Similarly, if U.S. citizens prefer to spend more on health—and receive care commensurate with their greater expenditures—than the citizens of other countries, what's the harm?

The development of many treatments for previously untreatable diseases and conditions does point to a high level of "nondestructive creation." Similarly, at the top end—the "best health care that money can buy" in the United States is stellar—premier institutions (such as the Mayo Clinic) attract wealthy patients from all over the world (including those from countries that have advanced health-care systems). But the overall picture suggests that the United States isn't, on average, getting good value for money spent on health care. According to a 2000 World Health Organization study, the performance of the U.S. health-care system ranked forty-seventh in the world. Such rankings are sensitive to what indicators are included, but even if we consider only the most basic of indicators, the U.S. performance rank is far below its spending rank. According

---

* Rep. Howard Berman, the lead sponsor of the patent reform, said it is "hard for me to understand" how it would hurt the United States. "To the contrary," he argued, "it is the weakness and abuses of the current system that are impeding American innovation." Nonetheless, in the teeth of opposition from the producers of high-level research like the pharmaceutical companies and large research universities, Berman's view did not carry (and, as of this writing, has not carried) the day (Hitt 2007, A3).

to the *CIA World Factbook,* in 2007, 40 countries had lower infant mortality rates than the United States,[25] and 44 countries had higher total life expectancy.[26]

The problem most certainly doesn't lie in skimpy government support for high-level medical research. The U.S. government doubled its funding for the National Institutes of Health between 1998 and 2003. According to an OECD study, "Health R&D in government budgets, as a percentage of GDP in 2004" in the United States, was six times the level in Japan and more than 10 times the levels in Austria, Sweden, and Switzerland[27]—all of which had lower infant mortality and higher life expectancy. For-profit companies and foundations like the Howard Hughes Medical Institute put up even more funds: in 2003, tax-funded NIH paid for 28 percent of medical research,[28] while private sources accounted for most of the remaining 72 percent.

But while the U.S. government provides handsome support to research—through direct grants and tax credits for R&D programs—pharmaceutical companies are pilloried by politicians (and other opinion leaders) for their marketing efforts. Big pharma is told to spend more on research and less on peddling "frivolous" drugs; but the frivolous drugs also start in a lab, and even useful drugs can only be effective if they are properly incorporated in a therapeutic regime. As one study suggests, doctors may say they get their information from reading medical journals, but pharmaceutical company salesmen play a more important role in influencing their prescribing habits.[29]

As one salesperson who works for a biotech company told me: "Doctors sometimes dismiss me with 'I already know everything about your product.' But when a patient asks this same omniscient doctor for my product, I get a call needing immediate answers to questions like 'What dose do I use? How do I write the script? Is it IM or IV? Do I inject it in the arm or the butt? Both butt cheeks or one? What does it interact with? What are the contraindications? Will insurance plan X cover it? How do I store it?'"

Without a marketing push, breakthrough treatments may fail to catch on. As Harvard economist David Cutler says, "The biggest failure of the American health care system is not that we overuse stuff, but that we underuse stuff."[30]

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* and peptic ulcers in the early 1980s. In 1987, an article published in *Lancet* reported that the eradication of *H. pylori* with antibiotics could effectively cure peptic ulcers. Medical opinion leaders took nearly a decade to be persuaded that ulcers could in fact be cured by antibiotics. Marshall went so far as to infect himself by drinking a

Petri dish of *helicobacter pylori* to produce evidence for his theory. Eventually, the establishment was persuaded, and in 2005 Warren and Marshall were awarded the Nobel Prize in medicine.

All this is well known. Equally interesting is what happened after the opinion leaders were persuaded (in the first half of the 1990s) and national and international guidelines on the treatment of *H. pylori* were published. 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. Furthermore, physicians who did use the therapies often used "treatment regimens of doubtful efficacy" instead of following the consensus guidelines.[31]*

Organizational, legal, and regulatory issues (in the "untraded" services subsector of health care) pose an even bigger problem for the health-care system. While the development and pricing of prescription drugs attract a great deal of attention, expenditures on pharmaceuticals in the United States accounted for just 12.9 percent of health-care costs in 2003. While the costs of drugs in the United States are higher than in other OECD countries (which often impose de facto price controls) and the per capita spending on drugs is also higher, the expenditures on pharmaceuticals as a percentage of health-care costs is lower in the United States than for the OECD as a whole. (In 2003, the OECD average was 17.7 percent). This suggests either that the United States gets more, or better, "nonpharmaceutical" health care, or—more likely, given the overall performance of the system—that the United States receives really poor value for nearly 90 percent of its health-care expenditures.

Health-care experts have different views about what needs to be done. Some advocate a broader role for the government, such as mandatory health-care coverage for all or a "single payer" government program to replace private insurance. Others favor more market-oriented solutions. What most experts agree on, however, is that there is a very big problem, the solution of which has nothing to do with the quality or quantity of medical research. Rather, it has to do with changing the rules of the game so that hospitals will be better managed, IT will be used more effectively and extensively, and insurance schemes will be better organized. Regardless of whose script you read, the cast comprises hospital administrators, IT managers, entrepreneurs, lawyers, actuaries, and financiers, not MD PhDs decoding genomes.

---

* 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."

Harvard's Regina Herzlinger notes that the United States spends $2.2 trillion on health care, yet "more than 40 million Americans lack health insurance, mostly because they cannot afford it." Hospitals account for $400 billion in excessive health-care costs but provide services of increasingly poor quality—hundreds of thousands patients have been killed by hospital medical errors in the past few years. Innovative entrepreneurs have improved the productivity "in almost every sector" of the U.S. economy, but in the "bloated, inefficient health-care system," innovation has been restricted to medical technologies and health insurance. In health services "entrepreneurs are nowhere to be found," because "status quo providers, abetted by legislators and insurance companies, have made it virtually impossible for them to succeed." Herzlinger's solution (detailed in her book, *Who Killed Health Care?*) is a system that will "allow consumers to reward those entrepreneurs who lower costs by improving health."[32]

Medical research, which already accounts for a large share of taxpayer-funded research, would be a natural beneficiary of its expansion: program administrators can easily justify putting large amounts of money to work, because individual projects have large price tags; they are backed by real—and glamorous—science and often aimed at diseases crying out for a cure. Now proponents of funding more medical research can also evoke the fear of "losing out to the Chinese." According to *BusinessWeek*, in February 2006, "China's State Council announced a big boost in research and development spending," with biotech "as a top priority." The story highlights an experimental gene therapy for treating cancers in which China "is racing to a lead" with "substantial funding and encouragement" from the Chinese government.[33]

But should the U.S. government invest in making U.S. companies winners of every possible such race? How would it hurt U.S. health care (or economic prosperity) if the Chinese government subsidies enabled more cancers to be cured? A techno-nationalist obsession with staying ahead in every possible frontier of medical research, at least on the margin, takes away money and attention from reforming health services, solutions that would provide far greater payoffs and, to a very large degree, remain in the United States (because of the largely nontraded nature of these services).

And Finally …

In 1779, Adam Smith wrote in a letter to Lord Carlisle, head of the British Board of Trade: "Should the industry of Ireland, in consequence of freedom and good government, ever equal that of England, so much the better would it be not only for the whole British Empire, but for the particular province of England. As the wealth and industry of Lancashire does not obstruct but promote that of Yorkshire, so the wealth and industry of Ireland would not obstruct but promote that of England."[34]

At that time, the First Industrial Revolution had not yet broken out, or (according to some interpretations) may have just started. No one could have foreseen how technology, business, the organization of society, the legal system, and so on would evolve over the next centuries. They could have evolved along the lines of North-South models, in which the economic development of one country could injure well-being in another. As it happens, they didn't. Rather, as discussed in previous chapters (see box, "Why Embrace? A Summary"), as matters actually evolved, advances today, particularly technological ones, tend to raise—not reduce—living standards everywhere. Adam Smith's observation still holds, although for reasons that no one in 1779 could have anticipated.

Why Embrace? A Summary

• The United States need not worry about an expansion of cutting-edge research (high-level know-how) produced abroad because high-level know-how is highly mobile and cheap: developed in country A, it can be put into production in country B and create a consumer surplus in country C.

The United States, in fact, stands to gain from such an expansion:

>• More high-level research provides more raw material for developing mid- and ground-level products.

• A high level of venturesome consumption in the United States encourages innovators to develop products optimized for U.S. customers and to promote their widespread use in the United States.

• These products not only generate a large surplus for U.S. consumers, to the extent they are aimed at the service sector (which now comprises about 70 percent of its GDP), but they also increase the productivity and wages of the U.S. workers.

Moreover:

• Technological innovations could, in principle, upset the apple cart by promoting the offshoring of these service jobs, but nondestructive creation is likely to create new service-industry jobs that don't currently exist.

• Immigrant scientists and engineers don't depress U.S. wages; rather, they (even the nonstellar majority) are a valuable resource in the process of developing and deploying innovations.

This is not to say that the economic and technological development of populous and previously impoverished countries poses no threat to the West. Rapid growth in China and India significantly increases the demand for fossil fuels and may require U.S. consumers to pay much more to drive their cars and to heat their homes. Similarly, as per capita incomes of China and India rise, so does their capacity to pollute the planet. And to turn Mao's maxim around, gun barrels can grow out of economic power—and China's growing military strength naturally disturbs the prevailing geopolitical order.

These problems are neither insurmountable nor unprecedented. Poverty in India has denuded forests on a large scale, as those who could not afford any other source of fuel chopped down trees for firewood. While technology can increase pollution, it can also reduce it. Tractors may burn gasoline, but a plow-horse requires two acres of pasture to graze on, which could be a forest. Thanks to the tripling of its agricultural productivity in the last century, and starting in about 1920, the United States has progressively turned farmland back into forests. Globally, the land area it takes to feed the world is 20 percent less than in 1950, while the population has more than doubled from 2.5 billion to more than 6 billion.[35] New energy-efficient products allowed the U.S. economy to grow by 126 percent from 1973 to 2000, when energy use grew by just 30 percent. Who knows? With enterprise, the right incentives, and some luck, we could see growth with reduced carbon-releasing energy.

China's growing military changes the power balance, but does it necessarily make the world a more dangerous place? Recall that it fought three wars—in Korea, India, and Vietnam—*before* it undertook radical economic reforms. The real danger spots (such as North Korea) aren't the ones supposedly menacing U.S. technological primacy. Developing new approaches that reflect the reality of the new China would improve international security—and that's an investment well worth making. What is perverse and futile, from both an economic and moral point of view, is for the West to try to dial back to the old conditions—or to throw resources at maintaining the technology differential at its current level.

Complacency is dangerous, but jumpy reactions to false alarms can also do real harm. It is one thing to nip trouble in the bud, but going full tilt against imaginary dangers can consume blood, treasure, and attention that could be applied to meaningful threats.* The unduly paranoid can also miss out on attractive opportunities. Perennial pessimists who anticipated another Depression after the 1987 stock market crash missed out on an extraordinary two decades during

* Not to carp, especially since the *Gathering Storm* has offered a fine foil for me, but might the common interest have been better served if the National Academies had produced a study of carbon taxes that might have helped stiffen some political backbones instead of a report that gives politicians more cover for easy votes to expand research subsidies?

which prices increased more than fivefold. For the United States to hunker down or to obsess about international technology races is folly. The world has changed and will continue to change, and perhaps one day nations may have to engage in economic combat. But that is not the case now. Today's conditions allow nations to gain from each other's advances, and our challenge lies in making the best of this good fortune.