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# Technology Policy: A Fixture on the National Agenda

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*Federal government research and development priorities have shifted in recent years away from areas of national security and agency missions, and toward the enhancement of industrial competitiveness in the global economy. This shift has stirred ideological controversy over whether the federal government should be in the business of picking "winners" and "losers," even prompting some to label this practice "corporate welfare." Authors Rycroft, Kash, and Adams suggest that the central issues at stake have little to do with ideological differences and a great deal to do with whether the U.S. will continue to lead the world in technological innovation. They describe a new economic reality--driven by technology--that calls for basic changes to our national technology policy.*

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Technology policy once again became a focus of national public debate in America in the early 1980s. After brief and inconsequential appearances on the federal government's agenda in the 1960s and 1970s,<sup>1</sup> technology policy now seems likely to be a permanent fixture. This is despite initial efforts by the Reagan administration and recent attempts by the Republican majority in Congress to bury it.<sup>2</sup> The new permanence is a consequence of what James B. Conant called a paradigm shift in American society.<sup>3</sup>

Technological innovation has become the most powerful causal force in the contemporary world. As the Clinton administration puts it: "Technology is the engine of economic growth, creating new jobs, building new industries, and improving our standard of living."<sup>4</sup> Initially manifested in the Cold War arms race, where it was seen as the key to our national security, technological innovation now permeates every aspect of our society. From pharmaceuticals to the information revolution to corn planters controlled by microprocessors, we are enveloped by technological innovation.

Technology policy as presently debated was unpalatable to the Reagan administration and is distasteful to the new Republican Congress because it is concerned with commercialization. That is, at its core the debate hinges on whether the federal government should overtly promote the innovation of commercial technologies. A federal role in commercialization generates great passion among those at the ideological extremes because it requires blurring the public-private sector distinction that has long been a sacred icon in U.S. policy rhetoric.

For ideological purists on both the left and right, technology policy has become a classic struggle between good and evil, and thus the debate has been characterized by black-and-white thinking. For those opposed to all but the most minimal government, public sector support for the commercialization of technologies is a sin. For those who believe government is integral to social well-being, technology policy is an opportunity for goodness. However, for the vast

majority of Americans who come to the issue without ideological blinders, technology policy is an area of endless and confusing shades of gray.<sup>5</sup>

Why has technology policy become a major focus of attention? The answer has little to do with grand ideological debates. Rather, two “real world” conditions explain the prominence of the controversy. First, as noted above, there is a consensus that technological innovation is the greatest source of economic well-being in the world. Second, the Japanese are threatening to take the lead in technological innovation away from the U.S.

Over the last three decades, both the sources and markets for technologies have become global, and trade in manufactured goods has become the key indicator of a nation’s technological prowess. Trade performance is now a regular on the television evening news, and for good reason. In 1994 the U.S. ran a trade deficit in goods of \$166.4 billion, \$67.3 billion of which was with Japan. As an aside, it is worth noting that another \$69.4 billion of the deficit was with the developing countries of East Asia<sup>6</sup> (e.g., South Korea, Taiwan), which have adopted much of the Japanese approach to technological innovation.<sup>7</sup>

America’s uninterrupted trade deficit in goods since 1976 totals nearly \$1.5 trillion.<sup>8</sup> Other trends paint a similar picture. In the five years before the end of 1994, Japan’s total economic output rose from 55 percent of U.S. gross national product to nearly 70 percent. Japan now has 56 percent of the world’s savings. As Eamonn Fingleton observes, “while the Western press has talked of collapse, Japan has quietly remained on track toward its reputed goal of surpassing the United States to become the world’s biggest economy by 2000.”<sup>9</sup>

A focus on technology policy is one way the U.S. can deal with this grim situation. The key is manufactured goods, where the cumulative trade deficit between 1987 and 1993 was approximately \$600 billion, more than 75 percent (some \$400 billion) of which was with Japan.<sup>10</sup> In the pages that follow, we investigate what a technology policy focused on manufacturing might look like.

### **Policy for complex technologies**

Throughout most of the post World War II period, macroeconomics has generally guided policy with regard to trade in product technologies. Reduced to its fundamentals, the macroeconomic view says the way to deal with a trade deficit is to devalue the currency. If this once worked, it doesn’t anymore. Even with the nearly threefold devaluation of the dollar against the Japanese yen between 1985 and 1995, the U.S. manufacturers’ trade deficit grew. The expectation that U.S. bilateral trade with Japan would benefit from the declining value of the dollar has been countered in large part by the superior Japanese ability to innovate complex technologies.

A complex technology is one which cannot be understood in detail by an individual expert.<sup>11</sup> To illustrate, pharmaceuticals are simple product technologies while an aircraft is a complex product technology. In 1994 the majority of Japanese exports to the U.S. were complex product technologies (e.g., automobiles, semiconductors).<sup>12</sup> A significant portion of the complex product technologies traded in the world marketplace result from fusing previously distinct technologies which were themselves very complex (e.g., opto-electronics).<sup>13</sup>

The continued trade and competitiveness problems the U.S. has experienced have caused many leaders in American industry and in other institutions to support commercial technology policy despite their traditional distaste for government involvement in the economy. One of the curious divisions in the debate about technology policy is that a growing proportion of the leadership of major complex technological sectors support government intervention. It is not that public policy has suddenly acquired legitimacy on its own merits, but that these corporate leaders understand that in the new competitive world, foreign companies producing complex technologies have the active and effective support of their governments. This realization has led a growing number of corporate executives to advocate public-private partnerships as a requisite for enhanced national economic performance.<sup>14</sup>

If policy is to distinguish between complex and simple technologies--to be responsive to the very different needs and circumstances of different technological sectors--then it is no longer appropriate to speak of a generic technology policy. An across-the-board, one-size-fits-all approach is no longer viable. Conventional initiatives like sector-blind R&D expenditures or tax credits or broad intellectual property rights regimes will not only not work, but may be counter-productive. More discriminating policies appear to be needed.

An overview of the new technological reality can be had by looking at Figure 1. In that illustration we have located the thirty most valuable products traded in the international marketplace in 1970 and in 1990 into four cells. Each of these products has been classified in terms of a simple/complex division for both the products and the manufacturing processes which produce them.<sup>15</sup> Note that in 1970, 58 percent of the value of the 30 most valuable manufactured goods were located in the simple/simple cell. By 1990, the value of the goods located in that cell had declined to twelve percent of the total. Note also that the thirty most valuable products in 1970 represented 56 percent of the value of all manufactured goods traded in the international market, but by 1990 they constituted 63 percent of the total. Finally, 27 percent of the most valuable 1970 technologies had been displaced (largely by more complex alternatives) by 1990.

Figure 1 says that manufactured goods are becoming more complex. At some intuitive level, Americans understand this. What is not so well understood, however, is that successful innovation of complex technologies depends on networks of organizations that are able to learn.<sup>16</sup> Network organizational learning, in turn, depends on the ability to rapidly generate and move information, knowledge, and capabilities among the participants. Often this communication is under quite informal circumstances.<sup>17</sup>

The existence of organizational networks with this capability for rapid knowledge creation and movement is critical because the economic winners in the complex technology arenas are those who are able to carry out incremental innovation ahead of their competitors. Nowhere is this point made clearer than in the patterns displayed in Figure 2. The figure displays a wide array of technologies and lists the countries where the initial breakthrough (R&D) took place. When this list is compared to the country in which the first commercialization of products occurred and then is compared to a list of those countries currently leading in advancing the technology, a clear pattern emerges. This is the Japanese success story graphically displayed. They have been able to dominate the downstream benefits that flow from incremental innovations of complex technologies.

Two messages with regard to manufacturers' trade seem clear. First, the big profits in the future will go to those who are the most successful incremental innovators of complex technologies. Second, if the goal of technology policy is to improve the competitiveness of the United States, then a major focus of that policy must be with the creation and maintenance of the organizational networks that increasingly dominate the innovation of complex technologies. As technologies and organizations coevolve into ever more complex forms, the capacity to link diverse companies, university research facilities, and government laboratories has become a requisite. As James Metcalfe has argued, "technology policy is about institutions and their connectivity."<sup>18</sup>

**Figure 1. The thirty most valuable exports: A 1970, 1990 comparison**

<b>Simple Process/Simple Product</b>	<b>Simple Process/Complex Product</b>
1970 = 58% (\$86,708,435)	1970 = 0%
1990 = 12% (\$224,699,631)	1990 = 1% (\$25,549,954)
1970 = 12% (\$17,906,225)	1970 = 31% (\$46,021,270)
1990 = 36% (\$644,454,846)	1990 = 51% \$919,266,926)
<b>Complex Process/Simple Product</b>	<b>Complex Process/Complex Product</b>

Source: Kash. Don E. and Robert W. Rycroft. November/December 1993. "Nurturing Winners with Federal R & D." *Technology Review* p. 64.

Interconnectedness would be significant if only because of the increasing demand everywhere for speed in the innovation process. But connectivity has become absolutely critical for complex technological sectors because of the growing significance of tacit or experiential knowledge for organizational learning. That is, organizational learning in complex sectors is more and more dependent on knowledge that cannot be written down and transmitted in cognitive ways. To use Walter Vincenti's words, tacit knowledge is the "implicit, wordless, pictureless knowledge essential to engineering judgment and workers' skills."<sup>19</sup>

Tacit knowledge and learning are more diffuse and more difficult to transfer than explicit knowledge because it is based in experience and know-how.<sup>20</sup> And tacit knowledge is especially important for those process innovations (i.e., advances in manufacturing technology) that are increasingly dominating incremental innovation in complex sectors.<sup>21</sup> Not surprisingly, it is in exactly this area that the Japanese seem to have such a striking advantage. That advantage flows, in part, from the characteristics of Japanese culture. What does that mean? It means that Japanese culture places a high value on a process of continuous incremental improvements which emerge from group-oriented innovation processes.

Even the briefest look at Figure 2 shows the dominance of the U.S. and Europe as the source of major R&D breakthroughs. A similar pattern is quite obvious with regard to the introduction of the first technological products. In both of these areas, Japan's record is weak. Evidence of this type has led to a popular perception in the West that the Japanese are not very creative or innovative. This view rests on defining creativity and innovativeness in terms of radical breakthroughs. It is becoming clear, however, that creativity and innovativeness in Japanese culture has always been concerned with adaptation, improvement, and enhancement and less focused on dramatic breakthroughs. Perhaps the best way to encapsulate why the Japanese appear to have a cultural advantage in the innovation of complex technologies is to quote Shuji Hayashi:

Japanese are widely criticized for lacking creativity and being incorrigible imitators of foreign products. The standard apologia has been that Japan was a developing country and tried to catch up quickly by copying what westerners had created. I think national character is a better explanation. To say that we are talented at refining things is more accurate. In the philosophical dichotomy between the Ideal and the Real, Japanese favor the latter. Instead of a soaring flight of inventiveness that results in something totally new, our forte is a more pedestrian approach--the steady refinement of extant objects. Japanese are always implementing variation. Minor changes will do.<sup>22</sup>

If it is true that Japanese culture tends to encourage incrementalism, it is also the case that it gives much higher value to accumulating tacit knowledge and to group processes which integrate diverse cognitive and tacit knowledge than is true in America. Given the critical significance of tacit knowledge and synthetic learning in the incremental innovation of complex technologies, again the Japanese cultural predisposition turns out to be a commercial advantage. This point is made nicely by Ikujiro Nonaka and Tim Ray:

Product development in successful Japanese firms often involve overlap and extensive collaboration between different sections of the organization. Moreover, team members might move with the project "rugby style" as it progresses from conception towards fruition--in some cases staff might actually follow a project through the departmental locations associated with its development: thereby increasing the chance that solutions to current problems can be triggered by reference to first-hand experience of earlier difficulties. By contrast, Western approaches often involve considerable demarcation between departments which have rigid boundaries. There is widespread support for the idea that procedures should be well documented and less reliant on tacit knowledge which could be lost with the movement of a key individual. Product development can be characterized by being more analogous to a "relay race" in which the "baton" of project development is handed over from department to department with minimal interaction. Since "socialization" is impeded by such a rigid division of labor, the degree of tacit knowledge that can move with a project is relatively limited.<sup>23</sup>

If future economic advantage is with the incremental innovation of complex technology and if the Japanese appear to have a cultural advantage at this point in time, what does this mean for U.S. technology policy?

**The future: Technology policy in a complex world**

We believe America's technology policy must emphasize information flows that move innovation-relevant knowledge and capabilities across organizational boundaries. If nothing else, this involves removing obstacles to communication and interaction. Of primary importance is accelerating the process of knocking down the walls of separation standing between our public and private sectors. Those barriers only serve to ensure that both sectors are constantly confused about the intentions and actions of the other.

A growing number of observers of technological innovation are finding it useful to speak in terms of national innovation systems,<sup>24</sup> and we concur. A national innovation system encompasses the range of institutions (e.g., the education system, industrial relations, technical and scientific organizations, cultural traditions) that contribute to the advance of technology for commercialization. Thus, rather than focusing technology policy on discrete actions (e.g., support of R&D), in the future policy-making must take into account, in a systematic way, the relationships among sets of national institutions.

**Figure 2. Countries originating, commercializing, and leading in technological innovation**

<b>Technology</b>	<b>R&amp;D Originator</b>	<b>Commercial Innovator</b>	<b>Current Leader</b>
Advanced Composite Materials	U. S.	U. S.	Japan/U. S.
Automobiles	U. S.	U. S.	Japan
Biotechnology	U. S.	U. S.	U. S.
Commercial Aircraft	Europe	U. S.	U. S.
Consumer Electronics	U. S.	U. S.	Japan
Desktop Computers	U. S.	U. S.	Japan/U. S.
Fiber optics	U. S.	U. S.	U. S.
Flat Panel Displays	U. S.	U. S.	Japan
Fuzzy Logic	U. S.	U. S.	Japan
Jet Engines	Europe	Europe	U. S.
NC-Machine Tools	U. S.	U. S.	Japan
Robotics	U. S.	U. S.	Japan
Software	U. S.	U. S.	U. S.
Television Sets	U. S.	U. S.	Japan
VCRs	U. S.	U. S.	Japan

Bold indicates a change in leadership.

Source: Gover, James. December, 1994. "Optimizing Federal Transfer to Promote Commercialization." Technology Transfer p. 37.

Like Harvard economist Michael Porter, we believe the intensification of global competition has made the role of the nation-state more important, not less,<sup>25</sup> and thus national technology policy is far from obsolete. This is especially the case to the degree that the interactions among national institutions comprise much of the tacit knowledge that seems so essential to modern innovation.<sup>26</sup> But now technology policy has to be integrative, synthetic, and dynamic across the entire national landscape, particularly for complex technologies. Moving the U.S. national innovation system in this direction is a huge challenge. But unless policy changes of this magnitude can be undertaken, there is no way America will solve its trade and competitiveness problems.

While we will not attempt prescriptions in any detail, it is possible to identify four functions government, on occasion, has served in the past. They are: Climate setting, surveying, marriage brokering, and gap filling.<sup>27</sup>

Climate setting refers to government creating an environment conducive to commercial innovation, e.g., providing appropriately trained and educated personnel, adequate quantities of appropriately priced capital, a tax system that encourages innovation, the ability for organizations to work together without being accused of collusion, and the assurance of equal treatment in other countries' markets.

Surveying refers to the need for continuous monitoring of what is going on worldwide with regard to commercial technologies. Surveying provides a country and its industries with intelligence and is critical in an environment of continuous and rapidly changing technologies.

The need for marriage brokering flows from two characteristics of much of contemporary technology. This technology is complex and it is the product of networks that carry out complex synthesis. Minimally, a government marriage brokering role is designed to assure that organizations that can contribute to a technological innovation know about each other's capabilities and find it possible to interact with each other with relative ease.

Gap filling is the most controversial of the technology policy functions. Gap filling implies that government will actively intervene to fill gaps if none of the other organizational components is willing or able to serve the needed functions. Historically, gap filling has been common in the commercial sector, for example, the National Bureau of Standards, now the National Institute of Standards and Technology, played a critical standards setting role. Gap filling remains highly controversial, however, because it is where the "picking winners" issue arises. But it must be recognized that the very existence of a technology policy implies that winners are being picked. It is precisely because our national well-being has come to rest heavily on success in technological innovation that technology policy is a permanent fixture on the nation's policy agenda.

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