Between Markets and the State

Scientists in Comparative Perspective

Etel Solingen

This article examines patterns of relations between modern states—in their varying forms—and scientific communities.[1] I trace such relations to broader structures defining the role of scientists in society, arguing that the internal nature of politicoeconomic systems, on the one hand, and of their international position, on the other, leads to different models of interaction between states and their scientific communities. Thus, throughout the twentieth century different patterns of relations developed, for instance, in pluralist market economies with low levels of external conflict and high levels of economic interdependence than in noncompetitive centrally planned systems involved in international conflict but with little exposure to global markets.

This approach aims at making a threefold contribution to the study of scientists and the state: it defines political relations as the main dependent variables, outlines a more systematic comparative framework than attempted hitherto, and suggests the need to understand the domestic and international structural sources of state-scientist relations. The literature on scientists and the state, summarized in Table 1, has for the most part focused on the impact of politics on scientific activities and on the role of scientific advisers. First, the Mertonian tradition of historical macrosociology of science pioneered the comparative analysis of scientific communities. Yet this tradition was mostly interested in cultural differences and the internal norms and output of scientific activity (see cell I) and much less concerned with the political relations between scientists and the state.[2] Even where the external sociopolitical context was taken into account, as in studies included in cell II, the content and development of science remained the main dependent variable in this tradition. The concern with political determinants was relevant mostly to the task of identifying a compatibility between certain politicoeconomic systems and the scientific enterprise itself.

Second, early attempts to understand the political role of scientists in the modern world (cell III) were mostly centered on the concept of scientific advise.[3] The important role played by prominent scientists in national security issues was at the heart of this enterprise. Its major contribution was to link the nature of political processes to the political access and influence of scientific advisers. Yet absent from these efforts was the attempt to explore the broader determinants of the interaction between states and scientists. The growing role of scientists as "symbolic analysts" in the knowledge-based economy of the late twentieth century compels a more collective, structural understanding of scientific communities.[4]

Third, not only were empirical studies of the political relationship between scientists and the state rare, limited in scope, and restricted in their themes, as Jean-Jacques Solomon argued in his seminal work on *Science and Politics*, but most were circumscribed to the American, British, and Soviet experiences.[5] In a comprehensive review of this literature,

Table 1 Summary of the Extant Literature on Science and Society/Politics

SCIENTIFIC DEVELOPMENT	SOCIO/POLITICAL STRUCTURES	REPRESENTATIVE LITERATURE
Sc → Sc′ I. Studies on the influence of internal characteristics of science/scientific communities (Sc) on the development of science (Sc′): "the sociology of science."		Kuhn, 1962 Polanyi, 1962 Hagstrom, 1965 Merton, 1967
Sc ← S/P II. Studies on the influence of socio-political structures (S/P) on scientific developments (Sc).		Veblen, 1906 Barber, 1952 Mannheim, 1958 Shils, 1962 Storer, 1963 Merton, 1967 Kornhauser, 1962 DeSolla Price, 1963 Marcuse, 1964 Ben-David, 1971, 1978 Barnes, 1972 Restivo, 1974 Mendelsohn and Elkana, 1981
III. Studies on the influence of socio-political structures (SP) on the political role of scientific communities (SP′)--mostly on scientific advice.	S/P → S/P′	Kramish, 1959 Gilpin, 1962, 1968 Price, 1965 Lakoff, 1966, 1977 Merton, 1967 Skolnikoff, 1967 Snow, 1967 Haberer, 1969 Holloway, 1970 Ezrahi, 1972, 1974, 1980 Solomon, 1973 Gowing, 1974 York-Grebb, 1979 Golden, 1988 Smith, 1992
[A state's political economy of science] Sc ← S/P [Domestic and international politico-economic structure]; Sc → S/P′; S/P → S/P′ [State-scientists relations] IV. Studies on the direct ($\overrightarrow{S/P\ SP'}$) and indirect ($\overrightarrow{SP\ SC\ SP'}$) influences of political-economic structures on the political role of scientific communities.		Solingen, 1993

NOTE: This table summarizes schematically the main contributions to the literature on science and society/politics. It is a suggestive, rather than exhaustive listing (it excludes, for instance, descriptive accounts of science and technology policy). The arrow denotes the direction of influence.

Sanford Lakoff suggested that the field would be richer, and the opportunities for comparative study much improved, if more of the investigations were made with respect to other political systems.[6] A truly comparative framework—"the theoretical foundations for the comparative study of science and politics"—across different political-economic contexts was never developed.[7] Finally, these earlier efforts did not concern themselves with explaining the impact of broad international political and economic conditions on state-scientist relations, with the exception of Gilpin's study of France.[8] Their emphasis was mostly on how domestic, particularly political, institutional processes influence science policy and the process and outcome of scientific advise.

Building on a set of core assumptions, this article aims more at providing a tentative framework—schematized in cell IV—for the comparative structural analysis of scientists and the state than at identifying a robust, full-fledged body of propositions. The next section explores ways in which domestic politicoeconomic structures influence state-scientist relations. I then examine the impact of external (international and regional) security and economic considerations on the domestic political economy of science.[9] Next, I suggest ways in which the latter influence patterns of political accommodation by scientific communities. The focus throughout is on the natural sciences. I outline briefly four basic models of relations which evolved throughout the twentieth century: "happy convergence," "passive resistance," "ritual confrontation," and "deadly encounters." Economic liberalization and political democratization in eastern Europe and the Soviet Union, the global shift toward market forms of economic organization in the 1980s, the internationalization of production, finance, and research and development, and decreased levels of military competition have blurred these historical differences towards the end of the century, leading to a nascent model of converging characteristics. The final section evaluates the strengths and limitations of this framework.

Authority, Markets, and Persuasion: The Domestic Structures of Scientific Activity

Prevailing political and economic structures and state forms influence the political capacities, ideas, and demands of various sectors of society.[10] They thus affect the nature of scientific organization and the political institutions with which scientific communities interact.[11] Scientists' dependence on the state is almost unparalleled compared to other professions, even where liberal canons of economic organization prevail. As the main patrons of basic research everywhere, states exercise control over public allocations for science, define research boundaries to some extent or another, and regulate degrees of scientific interdependence with the outside world. States rely on science and technology to secure their political, economic, and strategic viability. Decisions regarding the role of science involve a particular distribution of costs and benefits. Scientists may capture a concentrated share of benefits, particularly through research and development allocations and other rewards, but they may also be exposed to unusual physical restrictions and punishment. In light of the centrality of the state in defining frontiers and allocations, it is somewhat puzzling, as Cozzens and Gieryn rightfully point out, that studies of "science in society" have ignored the state as an analytical category.[12]

A crude typology of twentieth century states can be constructed out of Lindblom's contention that, "aside from the difference between despotic and libertarian governments, the greatest distinction between one government and another is in the degree to which market replaces government or government replaces market" (see Table 2).[13] Thus, pluralist market-oriented systems (PMOs) are associated with free and self-regulating markets,

Table 2 State Forms

Economic Organization		Political Systems: Pluralist (P)	Political Systems: Non-Competitive (NC)
	Market-oriented (MO)	PMOs United States Japan FRG France	NMOs Brazil (1964-1985) Nazi Germany
	Centrally-planned (CP)	PCPs India (1940s-1980s) Israel(1950s-1970s)	NCPs USSR (1917-1988) PRC (1948-1970s)

Notes: FRG = Federal Republic of Germany
PRC = People's Republic of China

private ownership of the means of production, the rule by many through orderly and contested elections, and the exercise of individual freedoms. The empirical referents of this ideal-type are the liberal democracies or polyarchies in the U.S. and western Europe.

Noncompetitive centrally planned systems (NCPs), instead, allow neither market nor popular control over public decisions, cancelling, to different degrees, free economic and political competition. They subordinate economics to politics and place means of production under public control. The classic historical examples of such systems are the former Soviet and East European states. Developing countries have followed variants of these two ideal-types. At times they combined waves of market-oriented economic principles with noncompetitive political systems (NMOs), as with a number of newly industrializing states in the 1970s and the People's Republic of China since the 1980s. At other times, they mixed more or less centralized economies with pluralistic participation (PCPs), as with India and Israel (particularly during the first decades after independence). Older forms of market-oriented authoritarianism include Nazi Germany and Fascist Italy.

What is the relationship between politicoeconomic systems and the nature and functions of science? Although scientific innovation is as much a requirement of capitalist as it is of centrally planned economies, important differences emerge with respect to the instrumentality of science. In pluralist market systems scientific research can be both a public and a private good. It is a public good when the results of nonproprietary research can be diffused in the service of nonexcludable and indivisible values such as welfare, education, and increased security. It is a private good when gains in rents or productivity resulting from scientific research accrue to private sector scientists or their patrons. Science in such systems is also instrumental in reinforcing a pluralistic context; disparate scientific findings can at times support contending positions in a political debate. Among noncompetitive centralized systems, research results solely in the provision of public goods. The political function of science (as within their pluralist counterpart) is to reinforce the particular political context within which it operates. Thus, scientific theories and activities are allowed to flourish on the condition either that they grant legitimacy to core political principles such as historical materialism or racial superiority or at least that they do not challenge those principles. Pluralist systems place limits on scientific activities, for the most part, where they threaten safety, security, and occasionally environmental or ethical considerations.

Given these differences in the political and economic role of science, certain deliberate and unintended mechanisms of social control of scientists operate within different politicoeconomic systems. Lindblom identifies three generic methods of political control which different systems use in varying mixes: those relying on relations of exchange, authority, and persuasion. Control through exchange (of material and nonmaterial goods) allows relatively easy shifts in rewards and penalties. Control through authority is expressed in voluntary or coerced obedience to institutions, including the state, and may include physical restraints. The marginal cost of control through authority is close to zero, while its reach is broad in space and time. It pervades many categories of action and extends over relatively long periods of time. Control by persuasion can be achieved through ideological indoctrination and competition which tend to change scientists' perceptions of rewards and penalties. Such control requires investments in an indoctrination machinery (schools, work, marketplace) and tolerance for time lags until relevant values are internalized.

Politicoeconomic systems differ in the extent of their use of direct or "oblique" authority, exchange, and persuasion mechanisms vis-à-vis their scientific communities. Pluralist market-oriented ones tend to rely on the latter two to a greater extent than their noncompetitive centrally planned counterparts. The latter find different instruments at their disposal when they do rely on authority as a means of control. The party (*partiinost* in the Soviet version), bureaucracies, and professional associations have served as hierarchical transmission belts of centrally defined priorities in noncompetitive models. In pluralistic contexts, subtler ways of handling dissenting scientists may be used, such as exclusion from defense contracts and denial of funding, security clearances, and/or appointments.

Most systems seem to converge in their use of exchange as a basic mode of interaction but differ on the substance (or currency) of exchange. Noncompetitive systems of either the centralized or market-oriented variety are more prone to offer increasing degrees of scientific freedom in exchange for loyalty and subservience, although at times the exchange is terminated and coercive authority is established in its stead. Sociological specialization and differentiation among scientists were of the essence in fascist variants, allowing scientists to become a select elite. The former Communist states have, on the whole, and with mixed success, repressed the tendency of functional expertise to be fungible into political power. Pluralist market-oriented states are, on the whole, in better position to afford material rewards, although these are by no means absent in other political-economic contexts. Reward systems may be built on more or less equitable patterns of pay-scale or on the cooptation of the elite and discrimination of the rank and file. Public recognition as a reward seems to cut across systems, although it does not always come about as a result of an exchange and may derive from scientific achievements and sociocultural valuations of science. Scientists in market-oriented contexts enjoy greater alternatives to political exchanges than those available to their colleagues in centrally planned systems. If the prestige afforded by certain governmental or academic positions is not a paramount preference, scientists may flow towards materially rewarding activities in private enterprise.

The ability to exit from the system of exchange prevailing in noncompetitive centralized systems is constrained by the absence of private sector exchange structures.

As argued, science plays a special role in pluralist systems as an instrument of persuasion. It can be marshalled to defend contending political perspectives and reinforce competition in a truth-seeking society. Science here is generally something to be discovered (or uncovered) and often reflects a partial and limited rather than universal truth. Science is used to reinforce the development of modern liberal-democratic concepts of public action, authority, and accountability.[14] The executive and legislative outputs affecting scientific activities are highly permeable to political, economic, and professional influences from below. Science is also central to another type of persuasion which markets emphasize, that embedded in product advertising. Thus, "scientific findings" are often brought to bear on commercial competition and product differentiation. Persuasion in the form of ideological indoctrination thrives in noncompetitive, particularly totalitarian, systems. The critical role of science there is to legitimate value claims. It is the correct and definitive point of departure for a new social order. When scientists challenge this requirement, authority quickly replaces persuasion as an instrument of control. Table 3 summarizes some of these contrasts, placing pluralist market-oriented and noncompetitive centrally planned systems at different ends of a spectrum. Pluralist centrally planned and noncompetitive market-oriented variants share characteristics with these two. The contrasts are more a matter of degree than of absolute attributes; in fact, most real systems can not be placed at either extreme and may overlap with respect to some of these categories.

Let us sum up the line of argument thus far. Beyond a common recognition of the utility of science in modern states, I associated prevailing state forms with alternative conceptions about the nature and role of science. I also differentiated among state forms according to

Table 3 State Forms, Nature and Functions of Science, Mechanisms of Social Control of Scientists, and Institutional Loci of Authority-Based Control

	State Forms	
	Pluralist market-oriented	Noncompetitive centrally-planned
Nature of science	Public good Private good	Public good
Political function of science	Reinforcing pluralism	Legitimizing a core political value
Economic function of science	Rents Productivity	Distributive Aid to planning
Mechanisms of social control of scientists	Exchange Persuasion Authority	Authority (including physical coercion) Persuasion Exchange
Institutional loci of authority-based control	Legislative Executive	Party Bureaucracy Professional Associations

their use of mechanisms of social control and interaction with their scientific communities. Yet defining the role of science and methods of control is often intertwined with processes beyond national boundaries, to which I now turn.

War-Waging and Trading States: International Sources of the Political Economy of Science

The rationale for exploring the role of external influences on the definition of what amounts to an internal political relationship is rooted in the increasing inability of modern states to untangle these two areas of activity. Science has not only not escaped the secular process of global interdependence; it has been instrumental in strengthening it.[15] In what ways does a state's involvement in the international system influence the domestic conditions of scientific activity?

First, the more a state is involved in regional or global conflicts, the higher are its levels of investment in military-related scientific research and its thresholds of secrecy (including domestic) with respect to scientific research, and the lower are its levels of openness to international scientific interdependence.

A state's involvement in international conflicts is defined here as a function of its participation in direct military confrontations with other states. Levels of investment in military-related research can be measured by the percentage of defense-related research and development within total research and development allocations. The degree of state intervention in or control of transborder scientific flows and exchanges defines the state's openness or closure to international scientific interdependence. These flows include incoming and outbound human resources, knowledge, ideas, and research and experimental equipment. States may be closer to the "liberal" end if they impose relatively few restrictions on exchanges in either direction. If they apply tight controls on such movements, they can be characterized as more "mercantilistic" or nationalistic with regards to science policy.

Second, the more intensely a state is involved in the global economy through trade and investment, the higher are its emphasis on research geared to maintaining a broadly competitive industrial basis over a military one and its levels of openness to scientific and technological interdependence.

The degree of a state's participation in the global economy through trade and investment can be measured by the size of its external sector. Although any specific threshold may appear arbitrary, when exports plus imports represent less than 10 percent of a country's total GNP, its involvement in the global economy is arguably rather low (at least relative to that of "trading states").[16] Emphasis on broad industrial competitiveness rather than narrow military sectors may be inferred from levels of civilian over total research and development allocations. "International comparisons of research efforts tend to indicate that the financial support of research for 'economic objectives' is inversely proportional to the financial support of research for military objectives."[17] Table 4 classifies states according to their involvement in international conflict and trade. Greater reliance on trade deepens the need for "generic" research and development which can be captured by a broad range of industries.

Table 4 States' Involvement in the International System

		Involvement in regional or global conflicts: High	Involvement in regional or global conflicts: Low
Involvement in International Trade and Investment	High	United States Israel	Japan Sweden
	Low	U.S.S.R. Nazi Germany PRC (1948-1970s) India	Brazil Argentina

In other words, these propositions suggest that national scientific mercantilism tends to flourish alongside interstate conflict while openness to scientific interdependence goes hand in hand with a heightened participation in the global economy. How does either pattern affect the domestic structure of scientific communities? If national ruling coalitions identify their instruments of international policy as lying mainly within the realm of trade and economic competition, scientists will tend to be largely attracted to that effort. Such coalitions rely mostly on inducements and exchange and tend to absorb large numbers of scientists in trade, educational, health, and welfare infrastructures. If, on the other hand, global or regional power and security considerations are regarded as paramount in guiding a state's domestic and international priorities, military-related research and development will be likely to employ a significant portion of the scientific community. Such states would tend to rely on a combination of inducements and "oblique" or indirect control mechanisms. The latter may be expressed in abstaining from a more active state intervention in civilian areas of research while maintaining subsidies for military-relevant research and development, thus skewing labor and knowledge markets. These two patterns are reflected, institutionally, in the contrast between a Department of Defense-led research and development effort in the U.S. for most of the postwar era and an overwhelmingly privately based research and development structure in Japan.

The implications of a military-industrial complex or what C.W. Mills labeled "the science machine of the garrison state" are now less contested. The end of the Cold War makes the detrimental impact of military expenditures on scientific priorities and economic performance more transparent than ever before, although the concept of "synergistic" effects of military-related research has not been completely abandoned.[18] High levels of military-related research are far from unique to any single politicoeconomic system. In the U.S., such research accounted for over 90 percent of total federal outlays in 1963, over 50 percent in 1979, and 70 percent in 1987.[19] These levels were a direct response to Soviet advances in nuclear weapons (1948 and 1951), the Korean War, Sputnik, and the Vietnam War. The U.S. trails Japan, West Germany, France, and Britain in civilian research and development spending as a percentage of GNP. The former Soviet Academy of Sciences and at least one-third of its associated institutes—mostly oriented to basic research—had contracts with the military, representing 10 percent and 20 percent of their activities, respectively. Industrializing countries, whether subject to explicit national security threats (such as India and Israel) or not (Brazil, Argentina), have "sheltered" scientific disciplines for their perceived impact on national security conditions, particularly as defined by their military establishments. Military research and development in China accounted for 22 percent of all research and development expenditures in 1973.[20] As the relevance of scientific activities to national security grows, so does the convergence of politicoeconomic systems with respect to the operation of science. Thus, military research and development in pluralist market-oriented systems follows carefully planned political priorities, while in centralized systems it aspires, perhaps more closely than in any other sector, to the efficiency and competitiveness of free markets.

Liberal approaches emphasizing openness and interdependence are associated with at least a theoretical preeminence of market-related forces or, in the realm of science, of private corporate research. However, as suggested earlier, state intervention in research and development funding and priorities is not a characteristic of centrally planned economies alone.[21] Tolerance for a negative "technological balance of payments" and for increasing proportions of foreign scientists and graduate students in national universities may provide measures of relative openness to scientific and technological flows. Mercantilistic policies, often prevalent in countries trying to catch up with the "world frontier," may rely on state power to force the national development of a scientific discipline, evoking an infant-industry argument. Atomic physics in the People's Republic of China and space sciences in Japan are cases in point. This can be done by funding a target discipline with largesse to prevent a country's relative deterioration of scientific resources. A state may also oppose the mobility of its own scientists abroad and the "export" of the fruit of their endeavors, particularly if such fruits can lead to an increase in the relative power of another state. Such a strategy was at the root of Cocom's efforts to prevent the diffusion of scientific and technological capabilities into the former Soviet Union and eastern-bloc countries. States may also protect themselves against incoming foreign scientists and screen incoming knowledge, if these are perceived to be carriers of "subversive" politics embodied in scientific trappings. Export controls, visa controls, and the restriction of international academic exchanges generally obey fears of military or economic competition. These tendencies were prevalent in some of the countries included in the bottom left cell of Table 4. The upper left and bottom right cells are hybrids in that they combine some of the features associated with high (or low) levels of involvement in international conflict and trade activities.

Under liberal models, restrictions on diffusion are, in theory, less stringent, at least in areas without obvious immediate relevance to national security. This stems from the requirements of global scientific "efficiency." In practice, however, growing proportions of research produced in the private sector remain under protective containment for commercial reasons, and even nonmilitary academic research can be threatened with restrictions.[22] The implications of emerging patterns of global economic competition, particularly evident in the area of high technology, for the role of science in science-intensive industries are far from obvious. Current trends may lead to greater secrecy and restrictions on scientists, but they may also encourage increased cooperation—through multinational operations, for instance—on the basis of mutual commercial benefits. Whether economic rationality or political objectives will prevail is largely contingent on unfolding (and contradictory) processes of globalization, on the one hand, and continued state intervention, on the other.

Models of Political Interaction: Past and Future

We are now in a position to explore ways in which external conditions might interact with domestic structures to shape a country's "political economy of science" (see Table 5). The latter can be defined as the set of interacting state and market processes affecting the demand and production of scientific knowledge, its location, and the associated distribution of costs and benefits.[23] The political economy of science provides the global and national contextual boundaries within which state-scientist relations unfold. In other words, the broader structures (domestic and international) discussed earlier influence the size and characteristics of the research community, its engine of growth (whether university, private, or government-created), disciplinary distribution and diversification, social and geographical concentration, levels of engagement in basic versus applied science, nature of rewards, employment patterns and mobility, and arguably even its internal organization (monolithic, pluralistic) and leadership patterns.

Pluralistic market-oriented, nonprotectionist systems are often hosts to an array of international and transnational actors including multinational corporations in the economic realm and private nonprofit as well as intergovernmental organizations such as the International Council of Scientific Unions and the Pugwash Conference on Science and World Affairs in the professional one. These transnational links strengthen the scientific community at home while decreasing the ability of the state to control scientific exchanges.

Table 5 Domestic and International Sources of the Political Economy of Science

Involvement in the International System

		High Security High Economic	High Security Low Economic	Low Security High Economic	Low Security Low Economic
State Forms	Pluralist market-oriented	U.S. Israel (1980s)		Japan (1945-) Sweden	
	Pluralist centrally-planned	Israel (1950s-60s)	India (1950s-70s) Iran (post-1979)	Egypt (post-1979)	Tanzania
	Noncompetitive market-oriented	S. Korea (1960s-70s)	Nazi Germany		Brazil (1960s-70s) Argentina (1960s-70s)
	Noncompetitive centrally-planned	PRC (1980s) Cuba	PRC (1940s-70s) USSR (1917-80s)		

In a cyclical path of influence, therefore, states which are at the outset less prone to intervention are in turn weakened in their ability to impose controls on scientists by the implications of the very openness they predicate. The openness of these systems to the outside world also broadens the range of employment opportunities for scientists to include foreign firms and institutions; this, in turn, expands the autonomy of the scientific community vis-à-vis the state.

The former U.S.S.R. throughout much of its twentieth century history resembled a noncompetitive centrally planned system little integrated in the global economy and highly involved in international conflict. There, most relevant research was traditionally conducted within the over 600 state institutes, rather than in universities.[24] In contrast, between 50 and 80 percent of total research and development activities in the U.S. and Japan—prototypes of pluralistic market-oriented systems—are carried out by private industry, only about 14 percent by government agencies, and the rest in academic institutions.[25] Academic institutions in the U.S. accounted for over 57 percent of basic research funded by the Department of Defense. The proportions of total research and development financed by industry, rather than by the state, are much higher in Japan, Germany, and other European states than in the U.S. as a result, perhaps, of their low involvement in external conflict and high integration in the global economy.[26] In industrializing countries, investment resources available to the state, such as research and development allocations, are clearly more limited than in advanced economies. Such resources grow in tandem with greater involvement in the world economy and in regional conflict (see Israel, South Korea, India, and Cuba in Table 5). Private sector investments in research and development are particularly meager in centralized developing countries (Cuba) but also among some noncompetitive market-oriented ones, where most scientists are employed by poorly funded academic centers or by the state.[27]

Before the demise of the old Soviet state, about 50 percent of Soviet scientists worked in the academy and associated institutes and the rest in ministerial institutes, state enterprises, and universities. As argued, a very small percentage of research and development manpower was employed in state enterprises themselves. The consequence of this structure was a lag between research outputs and their industrial application.[28] Although researchers at the ministerial institutes aimed their output at industrial needs, their lack of proximity to plant requirements prevented effective contributions. Strengthening the weak links between industry and research institutions has also been a primary target of science and technology policy in industrializing countries like Brazil and India; the two have differed, however, in their degree of openness to international economic and technological interdependence and in their perception of regional security threats. The characteristics of their scientific communities and their relations to the state reflect these differences.[29]

There was generous support for the science establishment in the former U.S.S.R. Incentives included favorable differential salaries and compensatory benefits as well as honorific rewards and the promise of social and geographical mobility. Salaries and prestige were lower in industrial institutes than in theoretical institutes, and they doubled or tripled in the military sector, where scientific instruments were also the best.[30] The prestige associated with a scientific career may be lower in the U.S.; universities find it hard, in general, to compete with salaries in private industry, let alone those in military-related research. Still, the state funds about 50 percent of all research and development, of which 70 percent, as argued, is carried out in the private sector.[31] Only 5 percent of government research and development funds go to industry in Japan; the rest goes to government labs and universities. In slowly industrializing countries, deficient private sector demand for scientists is often attributed to dependence on imported technology and research and development; state salaries for those who succeed in obtaining an academic position are less than enviable. These conditions have exacerbated brain-drains which were often primarily a response to political repression.

The share of experimental scientists in industrialized countries—of either the pluralist market or centralized varieties—is greater than in industrializing ones. Theoretical work is prevalent in the latter because of low industrial demand for the scientists' output by either the state or the private sector; experimental science is too costly for the budgets of most countries in this category. As to the appropriate mix of basic and applied research, historical studies seem to suggest that noncompetitive systems (either market-oriented or centrally planned, developed or industrializing) tend to be particularly resistant to basic research. However, even the Nazi regime's emphasis on applied research and technology did not completely repudiate purely intellectual pursuits.[32] The ambivalence towards basic science—which accounted for 2.4 percent of all research and development expenditures in 1973—in the People's Republic of China was not a product of the Cultural Revolution but preceded it.[33] By the mid 1970s the debate over the role of basic science stood at the center of the struggle between Mao and Zhou Enlai, who supported it, and the Gang of Four, who opposed it.

The specific characteristics which the political economy of science imparts to the scientific community influence the way in which the latter reacts to various forms of control and inducements. In other words, the political economy of science affects the mode, institutional means, and issues triggering collective action by scientific communities. For instance, international processes have influenced the content of politicization or the process by which phenomena are brought into the public domain and are in turn shaped by public considerations.[34] Few issues have galvanized scientists' positions across different systems as sharply as war and peace. Andrei Sakharov personified this concern, but he himself traced its origins to "the milieu of the [Soviet] scientific and technological intelligentsia." The French, German, British, and Soviet scientific communities were mobilized with World War I. The politicization of scientists in Japan was heavy during the first years of the postwar occupation.[35] Issues of development, international equity, and economic rights have politicized scientific communities in industrializing countries across the political spectrum. Scientists in these countries often challenge the premises of the Nonproliferation Treaty and of the London Nuclear Suppliers Club (which prevents the diffusion of "sensitive" nuclear technologies) as attempts by the developed world to freeze the current international stratification of power. Political repression and human rights violations have also been a source of politicization, particularly within authoritarian contexts. Yet scientists rarely act as a community in defense of its own integrity and that of its members. More often than not they have acquiesced in state strategies and tolerated abuses of power, even where these involved the destruction of colleagues and scientific institutions.[36] Finally, collective action is more likely—particularly, but not solely, in noncompetitive systems—when scientific freedom is at stake or when states attempt to intrude into the substance of scientific debate.

As Merton eloquently argued: "A tower of ivory becomes untenable when its walls are under assault."[37]

Strategies employed by scientists have varied according to the opportunities and constraints offered by different politicoeconomic contexts. Under authoritarian conditions, for instance, scientists have been more likely to rely on "cognitive subversion," that is, using the technical inadequacy of a policy to point to more profound political problems.[38] This strategy was used by Brazilian scientists challenging the technical characteristics of the nuclear program embraced in the 1970s to point to alternative paths of socioeconomic and industrial development, particularly with respect to the use of foreign versus domestic scientific and technological resources. The strategy of advancing political viewpoints in the guise of technical considerations can be used in pluralist contexts as well, as in the debate over the Strategic Defense Initiative in the U.S. Here, however, overt political opposition is allowed, and lobbying the executive and legislature is a routinized strategy.[39] French scientists act mostly through trade unions.

As to the impact of collective action, occasionally the politicization of scientists helps catalyze broader political movements through their access to fellow intellectuals, students, and the media. High levels of internal cohesion within the community have increased the scientists' ability to coalesce political support from lay movements. Internal cohesion itself has been affected, in turn, by international processes such as war and the struggle for political independence. The aggregate political leverage of scientists working at the margins of the productive system (as in many industrializing states) is smaller than that of their counterparts in the industrialized world.

Four models—analytic constructs more than empirical descriptions—have characterized state-scientist relations for most of the twentieth century. They differ in the ratio of autonomy to accountability of scientists and in the extent of constraints on international scientific-technological interdependence. The first model, "happy convergence," assumes a high degree of consensus between state structures and scientists, who enjoy internal freedom of inquiry and relatively comfortable material rewards.[40] State-scientist interactions take place in a pluralistic, decentralized environment of competing funding agencies and contending political institutions. High levels of interdependence—domestically between scientists and the state and transnationally—reinforce resistance to state intervention in or control of the direction of scientific research. "Happy convergence" often implies a relatively passive scientific community not particularly salient, in political terms, among other groups. Greater "happy convergence" tends to flourish among pluralist systems, particularly where levels of external conflict are low.

The second model is characterized by "passive resistance," or an underlying tension between states and their scientific communities, often originating in moderate dissatisfaction with systems of domestic control or with the effects of constraints on international scientific exchanges. For the most part, this pattern appears to have been prevalent during "benevolent" (Leninist) periods of Soviet history, reformist cycles in the People's Republic of China, and Nazi rule in Germany. The terms of the science pact in this variant reduce scientific autonomy and international interactions to a more or less tolerable degree from the point of view of scientific inquiry. The high relevance of security concerns and the relatively low levels of involvement in the global economy tend to skew the scientific community towards military-related research. The latent, albeit passive, tension between scientists and the state falls short of the heightened levels of conflict under the third model, characterized by "ritual confrontations." Here there is a routinized and expected expression of grievances on the part of the scientific community, on the one hand, and a built-in animosity towards them among state officials, on the other. Many authoritarian regimes in the industrializing world, such as Brazil and Argentina during the 1970s, provide examples of this model. "Ritual confrontations" can slide into a final, more extreme model, likely to lead to "deadly encounters" of the kind evoked by Stalinism, the Chinese Cultural Revolution, and some authoritarian (mainly military-ruled) developing countries. Political accountability replaces any vestiges of scientific autonomy in this model. Entire generations of scientists and whole scientific disciplines have disappeared, either through internal physical elimination in "gulags" or through enforced exile.

These historical models are discussed in greater detail elsewhere.[41] It is important to note that they attempt to capture more or less prevailing patterns of interaction, but in reality state-scientist relations evolve constantly in response to changes in the definition of external security and economic considerations and to domestic political conditions. Most notably, the following structural changes are likely to result in increasingly converging patterns towards the end of the century.

From high-tech weapons to trade competitiveness The military-industrial complexes of the former U.S.S.R. and the U.S. are increasingly being blamed, to one extent or another, for these countries' respective internal socioeconomic difficulties. The conversion to civilian industries able to withstand the pressures and exploit the opportunities of a global market is changing the domestic political economy of science in the former superpowers.[42] Fear of the decline of American hegemonic power is underpinning a call for socially and industrially relevant research priorities in the U.S. Other countries, particularly some would-be regional powers, are learning these lessons as well. As a consequence, the ability of scientists to exploit security threats to exert domestic political influence will decline in tandem with the rise of "symbolic analysts" as powerful constituencies linking the global economy with local political considerations.[43] The process of demilitarization of science and technology will be influenced by the degree of success of multilateral institutions in preventing international conflict.[44]

From public to patented knowledge Increased economic competition and the increased protection of intellectual property rights are expanding the share of private—relative to public—goods research. Private sector influence over the direction of research priorities grows concomitantly, directly through university-private industry partnerships or indirectly through corporate influence over governmental policy. Yet the fundamental rationale for state support for research and development efforts (market failure, externalities, and resulting underinvestment) remains intact in areas such as environmental, agricultural, high energy physics, and public health research. The ability to privatize scientific knowledge deals a significant blow to old canons of scientific activity—such as "communism" (common intellectual property rights)—embedded in the "ethos of science."[45]

From state-centered to transnational scientific communities Declining military-industrial complexes and the globalization of markets, production, finance, and research and development activities will increasingly strain the definition of "national" scientific communities. First, the "borderless labs" of multinational corporations are expanding in spite of states' attempts to concentrate research and development activities and their synergies on their soil. High temperature superconductivity was first demonstrated by a Swiss and a German scientist working in a Swiss industrial research lab operated by the U.S. giant IBM.[46] Even university-private industry cooperation is becoming increasingly transnational; technology-intensive Japanese firms seek the world-class leadership of American universities in fundamental research. In this sense, U.S. investments in basic research can be considered an international public good. Calls for the internationalization of this expenditure, either by increasing outside support for basic research in the U.S. or by encouraging basic research abroad, are growing.[47] The transnationalization of European Community research, following mostly economic imperatives, is often considered the paradigm of future global trends. Second, the erosion of state-centered research may result not only from market forces but also from dedicated transnational political efforts. The idea of an internationally funded science and technology center in Moscow, conceived to help former Soviet scientists through these grand transitions, is an example of institutional innovations weakening state-oriented research. The increased transnational role of private professional scientific organizations such as the Federation of American Scientists and the Natural Resources Defense Council is another powerful political input in the definition of scientific research priorities, as their current input into the transformation of the former Soviet military-scientific infrastructure clearly shows. Third, the cost-driven push for international collaboration in basic science is accelerating and strengthening the transnational allegiances of scientists. Initially conceiving it as a national project, the U.S. began seeking foreign (mostly Japanese) cosponsorship of the Supercollider. Similarly, the high costs of the quest for nuclear fusion have planted the seeds for an unprecedented and genuinely international cooperative science program. Finally, global environmental threats are strengthening planetary-centered scientific activities that aggregate scientists into a transnational network capable of exerting political power locally.

From noncompetitive to liberal democratic politics The expansion of liberal democracy into most of the old centralized models in eastern Europe and in developing countries foreshadows a more homogeneous pattern of state-scientist relations in the twenty-first century. It is too early to assess the extent to which emerging states (particularly in Central Asia and the Middle East) will resist the transition toward pluralist politics. The processes outlined in the preceding paragraphs are likely to strengthen market-oriented liberalism of one form or another, which will create a new political economy of science (new property rights, research priorities, international trade and security orientations). As a consequence of this transformation of politicoeconomic state forms, "brain drains" will be triggered less by political repression, as in the past, than by transnational (labor/"symbolic analysts") market forces. Hundreds of scientists from the economically depressed Russian and East European states are already flowing into foreign private employment (particularly in multinational corporations), university positions, and even public research projects. These include none other than the Pentagon, particularly in areas related to space technologies.[48] On the one hand, there is increased concern with the possibility that this supply-push of scientists could intersect with a political demand-pull by aggressive or pariah states in search of military-relevant scientific talent. On the other hand, increased transnational demand for scientific "services" performed within former eastern bloc countries may help those transitional regimes sustain the demands of scientists for a new social compact.

Conclusions

This article emphasizes structural (international and domestic) influences on the political relations between scientists and the state. The approach is offered with an understanding that structural influences may account for only some of the characteristics of that interaction but that they nevertheless provide a most useful analytical point of departure. A focus on the role of individuals, elites, the sociology and culture of scientific communities, and political-ideological tendencies can be valuable but is often residual in explaining broad patterns of state-scientist relations.[49] Political entrepreneurship by scientists, after all, always takes place in a given context. Different politicoeconomic milieus may give rise to alternative belief systems among scientific communities. Polanyi's Smithian concept of the Republic of Science, for instance, has been traditionally more acceptable to scientists in pluralist market systems than to those of developing countries, which found Bernalist principles of scientific activity—subsuming a social function—more compatible.

A structural perspective helps identify differences among systems which have otherwise been overlooked by the classic focus on a generic "ethos of science" among scientific communities.[50] It allows us to propose, for instance, that industrializing states such as India and Israel—with significant central planning, a mercantilistic approach to technological modernization, a pluralistic political system, and a relatively prominent concern for national security—are likely to integrate their scientists into a model of "happy convergence." Mechanisms of integration or cooptation include effective participation in policymaking, generous funding of scientific activities, strengthening of socioeconomic and cultural demand for scientific expertise, and toleration of a reasonable degree of professional autonomy. Conversely, industrializing authoritarian populist states such as Argentina and Brazil under Peron and Vargas and totalitarian states like Nazi Germany, the Stalinist U.S.S.R., and the People's Republic of China during the Cultural Revolution are often unwilling to reconcile a nationalist-mercantilistic approach to scientific and technological modernization with domestic political tolerance vis-à-vis their scientists. As a result, not only are both external and national sources of scientific growth truncated, but their scientific communities tend to assume a particularly visible political role, often in "ritual confrontations" with the state. Further research on structural influences may require us to explore the relationship among "state strength" (the state's ability to impose painful costs on societal actors), the strength of market forces bearing on scientific activities, and the political strength of scientific communities.

The approach suggested here offers a new perspective on the underpinnings of collective action by scientific communities. For instance, such action may be less likely in contexts where competing patrons (state, private industry, and universities) provide alternative systems of reward and more likely where the state monopolizes scientific research. The content of collective action—the major issues triggering and sustaining it—as well as its modality and the institutional means used to advance it can vary not only in response to domestic considerations but also as a function of the external context. For most of the postwar era physicists were regarded as the paradigm of science in modern societies. Their political visibility grew in tandem with the role of nuclear weapons in settings as disparate as the U.S., the U.S.S.R., India, Brazil, West Germany, and the People's Republic of China, as did their capacity to exploit relevant social beliefs and attitudes.[51] Strategic policy, with its domestic and international ramifications regarding the content and context of research, thus became a classic arena for political exchange.

Towards the end of the twentieth century a new structural context, more global than ever before, is likely to alter not only the relative political saliency of scientific disciplines but also the collective role of scientists and their relations to the state. The old sources of scientific "brain drains" (most notably political oppression) are likely to be superseded by market forces affecting the movement of "symbolic analysts" worldwide. The economic rise of newly industrializing countries and the global labs of multinational corporations may offset scientists' pressures to migrate to old metropolitan centers. A few of these centers will be themselves afflicted, at least in the near future, with the costs of transition from a military-based to a civilian-oriented political economy of science. Changing structures may also affect the public perception of scientists (as a privileged group or as contributing to redistribution) by defining new benchmarks against which their return to social investment can be measured. These new realities are likely to replace the variety of state-centered science compacts characteristic of the past.

NOTES

The paper's basic conceptual framework has been applied to case studies of the U.S., the former U.S.S.R., Germany, Japan, France, Israel, Brazil, and India, which will appear in *Scientists and the State: Domestic Structures and the International Context* (Ann Arbor: University of Michigan Press, 1994). I would like to thank Sanford Lakoff, Patrick Morgan, Judith Reppy, and two anonymous referees for their helpful comments and criticisms. The University of California's Institute on Global Conflict and Cooperation and UCLA's International Studies and Overseas Program funded the early stages of research for this article.

1. The terms "scientists" and "scientific community" are used interchangeably here, without implying a *Gemeinschaft*, but merely referring to a group sharing common professional norms and ties.

2. The major studies here include Thorstein Veblen, *Veblen on Marx, Race, Science, and Economics* (New York: Capricorn, 1906); Robert K. Merton, "Science and Democratic Social Structure," in Robert K. Merton, *Social Theory and Social Structure* (New York: The Free Press, 1967), pp. 550–561; Robert K. Merton, *Science, Technology and Society in Seventeenth Century England* (New York: H. Fertig, 1970); Robert K. Merton, *The Sociology of Science: Theoretical and Empirical Investigations* (Chicago: University of Chicago Press, 1973); Bernard Barber, *Science and the Social Order* (Glencoe: The Free Press, 1952); Bernard Barber, "Resistance by Scientists to Scientific Discovery," in Bernard Barber and Walter Hirsch, eds., *The Sociology of Science* (New York: the Free Press, 1963), pp. 539–556; Joseph Ben-David, "Emergence of National Traditions in the Sociology of Science: The United States and Great Britain," in Jerry Gaston, ed., *Sociology of Science* (San Francisco: Jossey-Bass, 1978); Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962); William Kornhauser, *Scientists in Industry: Conflict and Accommodation* (Berkeley: University of California Press, 1962); Michael Polanyi, "The Republic of Science: Its Political and Economic Theory," *Minerva* 1 (Autumn 1962), 54–73; Derek deSolla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963); Norman W. Storer, *The Social System of Science* (New York: Holt, Rhinehart, and Winston, 1966); Edward Shils, *Political Development in the New States* (Gravenhage: Mouton, 1962); Joseph Ben-David, *The Scientist's Role in Society* (Englewood Cliffs: Prentice Hall,

1971); Sal P. Restivo, "The Ideology of Basic Science," in Sal P. Restivo and Christopher V. Vanderpool, eds., *Comparative Studies in Science and Society* (Columbus: Charles E. Merrill, 1974), pp. 334–351; and Everett Mendelsohn and Yehuda Elkana, eds., *Sciences and Cultures: Anthropological and Historical Studies of the Sciences* (Dordrecht: D. Reidel, 1981).

3. See Robert Gilpin, *American Scientists and Nuclear Weapons Policy* (Princeton: Princeton University Press, 1962); Robert Gilpin, *France in the Age of the Scientific State* (Princeton: Princeton University Press, 1968); Robert Gilpin and Christopher Wright, eds., *Scientists and National Policy-Making* (New York: Columbia University Press, 1964); Don Price, *The Scientific State* (Cambridge: Belknap Press of Harvard University Press, 1965); Joseph Haberer, *Politics and the Community of Science* (New York: Van Nostrand Reinhold, 1969); Sanford Lakoff, ed., *Knowledge and Power: Essays on Science and Government* (Toronto: The Free Press, 1966); Sanford Lakoff, "Scientists, Technologists, and Political Power," in Ina Speigel-Rosing and Derek deSolla Price, eds., *Science, Technology, and Society* (Beverly Hills: Sage Publications, 1977), pp. 355–392; Eugene B. Skolnikoff, *Science, Technology, and American Foreign Policy* (Cambridge, Mass.: MIT Press, 1967); Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (New York: Alfred Knopf, 1978); C. P. Snow, *Science and Government* (Oxford: Oxford University Press, 1961); Yaron Ezrahi, "The Political Resource of Science," in Barry Barnes, ed., *Sociology of Science* (Penguin, 1972), pp. 211–230; Yaron Ezrahi, "The Authority of Science in Politics," in A. Thackray and Everett Mendelsohn, eds., *Science and Values: Patterns of Tradition and Change* (New York: Humanities Press, 1974); Yaron Ezrahi, "Utopian and Pragmatic Rationalism: The Political Context of Scientific Advice," *Minerva*, 17 (1980), 111–131; Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy, 1945–1952* (New York: St. Martin's Press, 1974); Arnold Kramish, *Atomic Energy in the Soviet Union* (Palo Alto: Stanford University Press, 1959); David Holloway, "Scientific Truth and Political Authority in the Soviet Union," *Government and Opposition*, 5 (Summer 1970), 345–367; and Herbert F. York and G. Allen Greb, "Military Research and Development: A Postwar History," *Bulletin of the Atomic Scientists*, 33 (January 1977), 13–26. This literature has been followed by a prolific output since the 1960s, including most recently William T. Golden, ed., *Science and Technology Advice to the President, Congress and Judiciary* (New York: Pergamon, 1988); and Bruce L. R. Smith, *The Advisers: Scientists in the Policy Process* (Washington, D.C.: Brookings, 1992).

4. Reich places scientists at the forefront of this economic category. See Robert Reich, *The Work of Nations* (New York: Knopf, 1991). "Symbolic analysts" engage in problem solving, problem identifying, and problem brokering, which can result in services traded worldwide. They manipulate symbols with analytic tools (mathematical algorithms, scientific principles, systems of induction or deduction) sharpened by experience. On the growing political power of scientific communities in postindustrial societies, see also Daniel Bell, *The Coming of Post-Industrial Society* (New York: Basic Books, 1973).

5. Jean-Jacques Solomon, *Science and Politics* (London: The Macmillan Press, 1973).

6. Lakoff, "Scientists, Technologists, and Political Power."

7. See Haberer, p. ii.

8. Skolnikoff and Gilpin pioneered studies on the impact of nation-states' scientific and technological capabilities on foreign policy and international affairs. On their contribution, see Brigitte Schroeder-Gudehus, "Science, Technology and Foreign Policy," in Spiegel-Rosing and Price, eds., pp. 473–506. In this article I am more concerned with the impact of changes in the external context on the domestic political economy of science, a tradition known in international relations theory as "second image reversed" effects. See Peter A. Gourevitch, "The Second Image Reversed: The International Sources of Domestic Politics," *International Organization*, 32 (Autumn 1978), 881–911. For an analysis of science in supranational or transnational contexts, see pioneering studies by John G. Ruggie, "International Responses to Technology: Concepts and Trends," *International Organization*, 29 (Summer 1975), 557–583; Ernst B. Haas, "Is There a Hole in the Whole? Knowledge, Technology, Interdependence and the Construction of International Regimes," *International Organization*, 29 (Summer 1975), 827–876; and Ernst B. Haas, Mary Pat Williams, and Don Babai, *Scientists and World Order* (Berkeley: University of California Press, 1977).

9. Science can be defined as "conceptual knowledge involving mental models applicable in a large number of concrete situations." See Harvey Brooks, "Technology, Evolution, and Purpose," *Daedalus*, 109 (Winter 1980), 65–81. Technological knowledge can be scientific and abstract but can also be concrete and empirical; it is often a mix, although new technologies tend to have a greater scientific component. Pure science and technology, in other words, lie at two extremes of a continuum of overlapping domains. See Gilles Paquet, "Science and Technology Policy under Free Trade," *Technology in Society*, 2 (1989), 221–234. Our analysis of "scientific" communities, therefore, includes technologists whose work overlaps with scientific activities. On the interaction between basic research, applied research, and commercial development, see D. C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of*

Economic Growth (Cambridge: Cambridge University Press, 1989). On the "ideological" commitment to basic science, see Sal P. Restivo, "The Ideology of Basic Science," in Restivo and Vanderpool, eds., pp. 334–351.

10. See Theda Skocpol, "Bringing the State Back In: Strategies of Analysis in Current Research," in Peter B. Evans, Dietrich Rueschemeyer, and Theda Skocpol, eds., *Bringing the State Back In* (Cambridge: Cambridge University Press, 1985), pp. 3–43. On the gap between the comparative politics and international relations perspectives on the state, see James A. Caporaso, *The Elusive State: International and Comparative Perspectives* (Newbury Park: Sage, 1989).

11. The term "state" alone points to the bureaucratic, legal, and coercive organizations through which policymakers operate. "State structures," broader than governmental agencies, include the socioeconomic and political but not merely class-based networks which sustain the state. For a thorough discussion of structures, "the state," political systems, and political regimes, see David Easton, *The Analysis of Political Structure* (New York: Routledge, 1990).

12. Susan E. Cozzens, "Autonomy and Power in Science," in Susan E. Cozzens and T. F. Gieryn, eds., *Theories of Science in Society* (Bloomington: Indiana University Press, 1990).

13. See Charles E. Lindblom, *Politics and Markets: The World's Political-Economic Systems* (New York: Basic Books, 1977), p. ix; and Robert A. Dahl and Charles E. Lindblom, *Politics, Economics, and Welfare* (New York: Harper and Brothers, 1953). This typology contains "ideal types," which, in contrast to "concrete types," are classifications denoting "combinations of elements that seem to fit logically from the theorist's point of view." On ideal types, see Harry Eckstein, *Internal War: Problems and Approaches* (New York: The Free Press, 1964), p. 20. The systems presented here are no more than analytical abstractions aimed at highlighting particular aspects of structures and illuminating essential differences; in the real world they tend to share more than meets the eye.

14. On the compatibility between the values of liberal democracy and those underpinning scientific inquiry, see Michael Polanyi, *Science, Faith, and Society* (London: Oxford University Press, 1946), and Merton, "Science and Democratic Social Structure." For a superb analysis of the political functions of science in the liberal-democratic state, see Yaron Ezrahi, *The Descent of Icarus* (Cambridge, Mass.: Harvard University Press, 1990).

15. Eugene B. Skolnikoff, "Science, Technology and the International System," in Ina Speigel-Rosing and D. deSolla Price, eds., pp. 507–533. On the relationship between scientific knowledge and the perception of interdependence see Haas.

16. On "trading states" see Richard Rosecrance, *The Rise of the Trading State: Commerce and Conquest in the Modern World* (New York: Basic Books, 1986). The 10 percent threshold places the U.S. in the "low" end of the spectrum until the early 1970s; by 1975 foreign trade accounted for over 17 percent of the country's GNP. Mowery and Rosenberg trace the quickening pace of change in the U.S. research and development system to the increased openness of the U.S. economy to international trade.

17. Solomon, p. 56. On economics and national security, see Ethan Kapstein, *The Political Economy of National Security* (New York: McGraw-Hill, 1992). On the interdependence between trade and science and technology policies, see Mowery and Rosenberg.

18. On the debate over spinoffs, or science, technology, and military research and development, see Harvey M. Sapolsky, "Science, Technology and Military Policy," in Spiegel-Rosing and Price, eds., pp. 443–471; Harvey Brooks, "National Science Policy and Technological Innovation," in Ralph Landau and Nathan Rosenberg, eds., *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (Washington, D.C.: National Academy Press, 1986), pp. 119–167; Philip Gummett and Judith Reppy, eds., *The Relations between Defense and Civil Technologies* (Dordrecht: Kluwer, 1987); and Barry Buzan and Gautam Sen, "The Impact of Military Research and Development Priorities on the Evolution of the Civil Economy in Capitalist States," *Review of International Studies*, 16 (October 1990), 321–339.

19. See David Dickson, *The New Politics of Science* (Chicago: University of Chicago Press, 1988); Judith Reppy, "More for the Military," *Science Policy* (January–February 1989), 46–48; Mowery and Rosenberg. Military-related research and development attracted about a third of all U.S. scientists and engineers. *New York Times*, Dec. 17, 1989.

20. Richard P. Suttmeier, *Science, Technology, and China's Drive for Modernization* (Stanford: Hoover Institution Press, 1980).

21. For the broad range of possible state intervention in research and development in pluralist market systems, see Jurgen Schmandt, "Toward a Theory of the Modern State: Administrative versus Scientific State," in Joseph S. Szyliowicz, ed., *Technology and International Affairs* (New York: Praeger, 1981), pp. 43–97.

22. On the restrictions placed by the Reagan administration, such as excluding certain foreign visitors from university campuses, limiting the outbound flow of basic scientific information, prepublication agreements, voluntary self-censorship agreements, and tightened classification rules, see Reppy, pp. 46–48, and Malcolm L. Goggins,

Governing Society and Technology in a Democracy (Knoxville: University of Tennessee Press, 1986). On more direct restrictions in Japan, through concentration of basic research in the private sector, see Stephen D. Krasner, "A Trade Strategy for the United States," *Ethics and International Affairs*, 2 (1988), 17–36. On attempts to urge Japan to share more of its basic research findings with the rest of the world by publishing them, see the statement by the president of the U.S. National Academy of Sciences, Frank Press, *Los Angeles Times*, Apr. 25, 1990.

23. On the nature of political economy see Robert Gilpin, *The Political Economy of International Relations* (Princeton: Princeton University Press, 1987).

24. On industrial research in the U.S.S.R., see Loren R. Graham, "The Place of the Academy of Science System in the Overall Organization of Soviet Union," in John Thomas and U. M. Kruse-Vaucience, eds., *Soviet Science and Technology* (Washington, D.C.: George Washington University Press, 1977), pp. 44–58.

25. Lakoff, ed., *Knowledge and Power;* and Ann Markusen and Joel Yudken, *Dismantling the Cold War Economy* (New York: Basic Books, 1992), p. 110.

26. In Germany the private sector provides five-sixths of research and development expenditures. See T. Dixon Long and Christopher Wright, eds., *Science Policies of Industrial Nations.* (New York: Praeger, 1975).

27. On scientific communities in "peripheral" countries, see Christopher K. Vanderpool, "Center and Periphery in Science: Conceptions of a Stratification of Nations and Its Consequences," in Restivo and Vanderpool, eds., pp. 432–442.

28. Graham, pp. 44–58.

29. See Vandana Shiva and J. Bandyopadhyay, "The Large and Fragile Community of Scientists in India," *Minerva*, 18 (1980), 575–594; and Etel Solingen, *Bargaining in Technology: Industrial Policy and Nuclear Programs in Brazil and Argentina*, (ms., 1993).

30. Albert Parry, *The New Class Divided: Science and Technology versus Communism* (New York: Macmillan, 1966); Nicholas De Witt, "The Policy of Russian and Soviet Science: A Century of Continuity and Change," in Kalman H. Silvert, ed., *The Social Reality of Scientific Myth* (New York: American University Field Staff, 1969); Yacov M. Rabkin, *Science between the Superpowers* (New York: Priority Press, 1988).

31. Dickson; *OECD Science and Technology Indicators*, 2: (Paris: OECD, 1986).

32. Merton, "Science and the Social Order"; Walter Hirsch, "The Autonomy of Science," in Restivo and Vanderpool, eds., pp. 144–157; Haberer.

33. See George F. Kneller, *Science as a Human Endeavor* (New York: Columbia University Press, 1978); Suttmeier; and Merle Goldman, *China's Intellectuals: Advise and Dissent* (Cambridge, Mass.: Harvard University Press, 1981).

34. On politicization see Ruggie.

35. Seymor M. Lipset and Richard B. Dobson, "The Intellectual as Critic and Rebel: With Special Reference to the U.S. and the Soviet Union," *Daedalus*, 101 (Summer 1972), 137–198; Lakoff, "Scientists, Technologists, and Political Power"; F. Roy Lockheimer, "Prerequisites, Receptivity and Change: Government and the Development of Science in Japan," in Silvert, eds., pp. 154–170.

36. Ben-David, *The Scientist's Role in Society;* and Haberer.

37. Merton, "Science and Democratic Social Structure."

38. The term was coined by Joseph Ben-David, "The Profession of Science and Its Powers," *Minerva*, 10 (1972), 362–383.

39. On the U.S. scientific establishment as reflecting political pluralism and the fragmentation and decentralization of political power, see Lakoff, *Knowledge and Power*, and Solomon, *Science and Politics*.

40. I have borrowed the term "happy convergence" from the literature on the relationship between private economic forces and the state. See Stephen D. Krasner, *Defending the National Interest* (Palo Alto: Stanford University Press, 1978); John K. Jacobsen and Claus Hofhansel, "Safeguards and Profits: Civilian Nuclear Exports, Neo-Marxism and the Statist Approach," *International Studies Quarterly*, 18 (1984), 195–218.

41. Solingen, *Scientists and the State*.

42. Russia has cut its military spending by 89 percent in 1992. On high unemployment among scientists and engineers in the U.S., see the *New York Times*, Mar. 4, 1992.

43. On the role of scientific entrepreneurship in fueling the arms race in the former superpowers, see York and Greb; and Matthew Evangelista, *Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies* (Ithaca: Cornell University Press, 1988).

44. For a pioneering analysis of the impact of international organizations on a future world order, see Harold K. Jacobsen, *Networks of Interdependence* (New York: Knopf, 1979).

45. This ethos is discussed in Merton "Science and Democratic Social Structure."

46. Mowery and Rosenberg.

47. See Kenneth Flamm and Thomas L. McNaugher, "Rationalizing Technology Investments," in John D. Steinbrunner, ed., *Restructuring American Foreign Policy* (Washington, D.C.: Brookings Institution, 1989). In fact, foreign companies accounted for at least 13 percent of private industrial scientific research in the U.S. in 1989. *New York Times*, Feb. 22, 1989, June 30, 1992.

48. *New York Times*, Mar. 1, 6, 1992.

49. On sociological ("ethos of science") and cultural influences in the evolution of scientific communities, see Storer.

50. Other internal characteristics likely to influence scientists' political behavior, such as a "naive utopianism" and "naive belligerence" in facing problems of national security, are discussed in Warner R. Schilling, "Scientists, Foreign Policy, and Politics," in Gilpin and Wright, eds., pp. 144–173.

51. See Ezrahi, "The Political Resource of Science"; Anne H. Cahn, "American Scientists and the ABM: A Case Study in Controversy," in Albert H. Teich, ed., *Scientists and Public Affairs* (Cambridge, Mass.: MIT Press, 1974), pp. 41–120; and Dorothy Nelkin and Michael Pollack, *The Atom Besieged* (Cambridge, Mass.: MIT Press, 1981).