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Valuing S&T activities

Public values and public failure in US science policy

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Domestic science policy in the United States is linked inextricably to economic thinking. We seek to develop a practical analytical framework that confronts the manifest problems of economic valuing for science and technology activities. We argue that pervasive use of market valuation, market-failure assumptions and economic metaphors shapes the structure of science policy in undesirable ways. In particular, reliance on economic reasoning tends to shift the discourse about science policy away from political questions of "why?" and "to what end?" to economic questions of "how much?" Borrowing from the "public values failure framework", we examine public values criteria for science policy, illustrated with case vignettes on such topics as genetically modified crops and the market for human organs.

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THE PROCESSES OF economic valuation do not easily accommodate public values (Sen, 1987). However, in part because of their concreteness, a focus on economic values sometimes displaces consideration of public values in political discourse. In science policy, market-based arguments and outcomes dominate political thinking and action, despite the fact that science and technology hugely influence public values in ways that are independent of the marketplace.

In this paper, we apply a new analytical and rhetorical framework — public-failure theory (Bozeman, 2002) — to science policy. Our goal is to make available an intellectual approach that can compete with market logic in thinking about, and making, science policy decisions.

We start out by briefly discussing the ways in which marketplace logic has become dominant in science policy. We then discuss the concept of public values and introduce the theory of public failure as a complement to the idea of market failure. Using brief case discussions, we illustrate six criteria of public failure in science policy. We then present a simple graphical tool for conceptualizing the relationship between market failure and public failure, before concluding with a brief discussion of why public failure might succeed in breaking the hegemony of economic rationality in science policy.

Background

Domestic science policy in the United States is linked inextricably to economic thinking, making it no different from many other policy domains. When Americans consider institutional arrangements for

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delivery of public goods and services, they either begin with systematic economic reasoning or, more often, with less systematic assumptions filtered through the *laissez-faire nostrums* embedded deeply in US political culture (Lindblom, 2001). When Americans seek to determine the value of resources, goods and services, they reflexively look for price indices, eschewing more complex and indeterminate approaches.

The focus of our paper is on developing a practical analytical and rhetorical framework that confronts the manifest problems of economic valuing for science and technology activities. We argue that pervasive use of market valuation, market-failure assumptions and economic metaphors shapes the structure of science policy in undesirable ways. In particular, reliance on economic reasoning tends to shift the discourse about science policy away from political questions of "why?" and "to what end?" to economic questions of "how much?"

If we assume that everyone is made better off by investments in science then the only sensible policy question is "how much science can we afford?" Yet, if we assume that science's benefits and costs affect citizens in very different ways and to different degrees, and that those benefits and costs are in turn affected by the composition of society's science portfolio, then public value questions emerge as at least as important as economic ones.

Critiques of post-World War II US science policy have recognized in its operation the subservience of a broadly construed but difficult to measure public interest to more easily recognizable economic interests (for instance, Dickson, 1984; Winner, 1986; Kleinman, 1993; Cozzens and Woodhouse, 1995; Sarewitz, 1996; Greenberg, 2001). Indeed, a central dilemma of post-War science policy has been this: the value of science is commonly promoted in terms of concrete social outcomes (say, curing a disease), but the process by which the products of science permeate society are largely through the marketplace, and the tools for measuring value are largely economic.

Yet the tension between the public value embodied in promise of science and the market value realized through its commercialization is real and pervasive. For example, the doubling of the budget for the National Institutes of Health between 1998 and 2002 was justified by the promise of health benefits for Americans (for instance, FASEB, 2001), even as health care becomes increasingly unaffordable to increasing numbers of citizens, health disparities persist across socioeconomic and ethnic divides, and the public health returns on research investments remain difficult to document (for instance, Evans, *et al*, 1994; Wilkinson, 1996; Callahan, 1998; Smedley *et al*, 2002).

The most resilient justification for publicly funded science has been job creation and increased standards of living (for instance, Bush, 1945; Clinton and Gore, 1994; Lindsay, 2001). Yet GDP (gross domestic product) *per capita* is the coarsest possible proxy for quality of life; indeed the affluent-world experience of the past 30 shows that science- and technology-based economic growth is accompanied by increasing inequality in distribution of economic benefits, including increasing unemployment or underemployment, decreasing real wages, increasing wage inequality, and increasing wealth concentration within nations and between nations (for instance, Noble, 1995; Sen, 1997; UNDP, 1999; Castells, 1998; Galbraith and Berner, 2001; Arocena and Senker, 2003).

We might imagine that such tensions between public values and economic values in science policy would strengthen political motives to ensure that publicly funded science effectively served public values. Yet scholars in disciplines ranging from economics of technology to history of science have been documenting a 50-year increase in the influence of the marketplace on the agendas of public science.

To some extent this rising influence can be seen as an explicit transition in national priorities from Cold War competition with the USSR to economic competition with emerging economies such as Japan. Yet even during the Cold War, science policies justified in terms of national defense were tightly coupled to private-sector innovation processes (for instance, Mansfield, 1968; Noble, 1984; Leslie, 1993; Norburg and O'Neill, 1996).

More subtly still, the dynamics of science's role in economic growth seems to promote very strong coupling between public agendas and private motives. For example, technological frontiers (generally pursued in the private sector) have a strong influence on academic research by revealing new phenomena and problems for scientists to confront (for instance, Rosenberg, 1982, chapter 7; Narin and Olivastro, 1992; Rosenberg and Nelson, 1994; Pavitt, 1998).

There is nothing inherently wrong with the idea of science as catalyst for economic activity — a healthy economy is essential to the functioning of the modern state: our concern is with science's insufficiency in meeting public values

Also, a progressive increase in the ratio of private to public funding in the US, combined with changing intellectual property regimes, is continually strengthening the linkages between private-sector priorities and publicly funded science (for instance, Press and Washburn, 2000; Nelson, in press). In some sense this is not surprising. If several decades of scholarship in science and technology studies (STS) have demonstrated the co-evolution of science and society (for instance, see Jasanoff *et al*, 1995), then in modern liberal democracies the place where we would most expect to see this co-evolution expressed is in the economic realm.

There is nothing inherently wrong with the idea of science as catalyst for economic activity —a healthy economy is essential to the functioning of the modern state. Rather our concern is with science's insufficiency in meeting public values. As Ezrahi (1990, chapter 11) has provocatively argued, the gradual delegitimation of science as a source of authority leaves the economic role as the only one that no longer demands a defense. All that matters is economic growth.

It is therefore sufficient to know that, as Hull (1988, page 31) observed, science "works," and works quite well enough to contribute robustly to economic growth (for instance, Nelson *et al*, 1967; Rosenbloom and Spencer, 1996; Mowery and Rosenberg, 1989; Griliches, 1995; Denison, 1962). When it comes to economic value, the cultural or political construction of science is neither here nor there. Thus, the last bastion of "exceptionalism" for science may well be its role in economic growth (Bimber and Guston, 1995).

What is 'science policy?'

Throughout the paper we use the term 'science policy' in its broadest and most encompassing sense. Indeed, most 'science policies' are actually subsidiary to other policies, such as higher-education policy, defense policy, agricultural policy, energy policy, and space policy. For many purposes, distinguishing among these is vital, but not for our purposes. When we use 'science policy' we refer to all these efforts to bring technical knowledge to fruition and application.

We do not distinguish among basic research, applied research and development, nor among discovery, invention, and innovation. As important as these distinctions may be for some types of policy decision, our analysis is at the highest level of aggregation. We also note that these distinctions are far from clear in many situations.

We are concerned about the values of this enterprise, writ large. Since all acts of knowledge creation, use and distribution have the potential to have impact on people, all such acts are united in their normative implications if in no other way. Each element of the technical enterprise has implication for public value.

We also note that when we refer to 'science policy' we are *not* concerned with the hundreds of thousands of decisions and the hundreds (at least) of decision processes pertaining to specific research grants for individual scientists. We *are* concerned with the broad policies and policy processes that guide those micro-level behaviors, policies governing allocation of research funding, and institutional arrangements for the conduct and delivery of research. We are also concerned with the mental models and rhetorical constructs that help guide decision making throughout the R&D enterprise.

Public values and public failure

Social theory offers few alternative ways of thinking systematically about science policy. There is no social theory of scientific outcomes; there is no social choice theory for science. There *is* a market-failure model that tells us conditions under which government should 'intervene.' What is missing in most contemporary rationales for science policy, at least as manifested in actual public policy deliberations, is a sense of the specific ways science does and does not serve public values.

One of the difficulties of previous work in public values and the public interest (for instance, Flathman, 1966; Held, 1972; Cochran, 1974) is that these key concepts, important as they are, do not easily match with extant institutions and processes. The elegance of market solutions is that to achieve their result we, allegedly, need to do nothing other than restrain barriers to competition. The argument spills over easily into science: in a seminal paper, Michael Polanyi (1962) portrayed science as a self-regulating marketplace of ideas whose efficiency could not be improved, but could only be compromised, by outside intervention. Such economic metaphors have had a powerful impact on public discourse about science policy (see discussion in chapter 3 of Guston, 2000).

To enact public values, something more than philosophy and reticence is required. Thus, we examine not only the possible role of public values in science policy but also identify a set of criteria that can assist policy-makers in identifying public values issues in much the same way as they now use market-failure models to identify economic aspects of science policy. We provide an alternative schema, which we call the public-failure model (Bozeman, 2002). This model gives rise to criteria that can allow policy-makers to make rigorous judgments about the public value and distributional implications of science policy, in addition to questions of economic efficiency and economic growth.

The public-failure model depends on the notion that there are such things as 'public values,' just as the market-failure model derives from an idealized notion of a market, generally defined in terms of efficiency. The term public value has many meanings (for instance, Schubert, 1960; Sorauf, 1957; Fuller, 1964). What we mean by 'public values' are those that embody the prerogatives, normative standards, social supports, rights and procedural guarantees that a given society aspires to provide to all citizens.

This is not the same as a public good because public values are not goods, either tangible (dishwashers) or less tangible (for instance scientific information). Public values are not Platonic ideals, rather they vary across cultures and time, depending on the common values prized in the culture. Public values can be identified in empirical inquiry into the particular public values of particular cultures, but, even absent an empirical anchor, public value is a useful enabling concept, not unlike that of the perfectly competitive market.

A key assumption of our paper, and the public-failure model, is that market efficiency and public value are not closely correlated. Public failure can occur with market success, public failure and market failure can occur simultaneously, and in some happy circumstances, public success and market success can coincide.

To illustrate the disjunction between market efficiency and public value, we need only return to the case of AIDS drugs, an excellent illustration that market failure and public failure are not the end points of a single dimension. AIDS drugs represent a remarkable market success, where initial public investment in research under conditions of market failure led to private-sector development of effective pharmaceutical interventions that also generate considerable profit. However, the vast majority of HIV and AIDS sufferers worldwide do not have access to these expensive drugs.

It is possible, that is, to have governments intervene effectively through R&D to correct a market failure, and to have markets operate with great efficiency once the market failure has been addressed, and yet still have unconscionable failure of public values. The case of AIDs medicines is an illustration of the constricting moral and operational knots we tie ourselves in when we have no frameworks or criteria to compete with market efficiency as a guide to science policy and its concomitant social outcomes.

An introduction to public-failure theory

Policy-makers of every ideological stripe have long been comfortable with the idea that the private sector will never make sufficient investments in basic scientific research to generate the necessary knowledge to support robust innovation and economic growth. This market-failure argument has long been accepted as good sense (for instance, Bush, 1945), but since World War II it also been vindicated by economic scholarship (for instance, Nelson, 1959; Mansfield, 1980).

In this paper, we present an analytical and rhetorical counterbalance to the economic rationality that has so successfully justified and vindicated science policies for the past 50 years. Our approach, following Bozeman (2002), is to develop a framework that is conceptually symmetrical to the market-failure rationale used to justify government investment in science. We call this framework "public-failure theory."

'Public failure' occurs when neither the market nor public sector provides goods and services required to achieve core public values. A public-failure approach changes the discussion of public policy by making government (and public values) something other than a residual category or an issue of technical efficiency in pricing structures. With the public-failure model, the key policy question becomes: "Even if the market is efficient, is there nonetheless a failure to provide an essential public value?"

Using a market-failure model, government involvement is thus justified only when market processes fail and "prices lie — that is, when the prices of goods and services give false signals about their real value, confounding the communication between consumers and producers" (Donahue, 1991, page 18). The causes of such failure are oft-articulated and well-understood: externalities; steep transaction costs; distortion of information or inhibition of information flow about a good or service; and monopolistic behavior or other competitive failures. (For a precise definition of market failure, see Bannock *et al*, 1998, page 117.) A public-failure model eschews assumptions about the correspondence of efficient markets and desirable social outcomes and focuses instead on social values criteria.

With respect to science policy, economics is about the private value of public things. Despite the relative rigors of market-failure theory, no economic analysis can encompass the full range of policy choices facing society. Efficient pricing cannot solve all problems of public values, and indeed, there is a strong societal sense that, in some domains, economically optimal solutions are entirely inappropriate, for example, in creating a market for blood or organ donors. Some political actions explicitly eschew economic efficiency in favor of social equity, for example, the Americans with Disabilities Act. Yet economic approaches have been applied, often controversially, in domains that encompass public values, such as in the valuation of natural resources, the creation of markets for pollution-permit trading, and the design of science and technology programs.

Even if we accept the market-failure rationale on its own terms, it is unavoidably incomplete, for two rather obvious reasons. First, just because markets fail, it does not mean that government action can eliminate or avoid the causes of failure. For example, environmental externalities may signal market failure, but a government decision to respond to these externalities is not an *a priori* demonstration that doing so will lead to more social benefit. While the US government invested billions in collaboration with the big three automakers in the Partners for a New Generation of Vehicles program, Japanese automakers on their own produced a first generation of hybrid-electric automobiles that outstripped anything the Americans had to offer.

Second, the absence of market failure does not *a priori* imply public success, and therefore is not a sufficient reason to eschew government investment. That is, market value does not equal public value. The situation with AIDS drugs in the developing world is archetypal: the market has succeeded and millions wait to die.

As obvious as these arguments may be, they are insufficiently available for purposes of public policy making. The aim of public-failure theory is to provide an analytical framework that can be set alongside market failure as an alternative set of policy-making criteria. The notion of public failure derives from the reality that sometimes neither the market nor the public sector is providing goods and services necessary to achieve certain core public values.

A public-failure approach to policy making changes the terms of debate by making government (and public values) something other than a subsidiary issue of efficiency in market performance. The key question in market-failure rhetoric is: "are prices distorted due to a failure of communication between consumers and producers?" The key question in public failure goes an essential step further: "regardless of market efficiency, is there nonetheless a failure to provide an essential public value?"

We recognize, of course, that 'prices' are more tangible, or at least quantifiable, than 'public values' as a unit of analysis. However, there is very little, if any, fundamental disagreement in the United States about the existence of a fairly comprehensive set of core public values, especially those embodied in the nation's founding documents, such as the right to subsistence, the rule by consent of the governed, freedom of speech and religious practice, and *habeas corpus*. This basis is more than sufficient for us to proceed, because public-failure theory is not a decision-making tool (*à la* cost–benefit analysis), but rather a framework (*à la* market failure) to promote rigorous deliberation about the relation between economic value and public value.

Public-failure criteria

Public failure occurs when core public values are not reflected in social relations. Bozeman (2002) elucidates criteria for identifying public-values failure, criteria that to some extent mirror market-failure criteria, but that focus on public values rather than efficiency of market transactions. In applying this framework to science policy, we identify six public-failure criteria:

- inadequate values articulation
- imperfect monopolies
- scarcity of providers
- short time horizons
- non-substitutability of resources
- benefit hoarding

While we do not claim this set of public value criteria to be canonical, it provides a starting point to enhance discourse and decisions for the allocation of responsibilities between public and private sectors, and for shaping allocations within the public sector. Table 1 (adapted from Bozeman, 2002) provides diagnostic criteria of the public-failure model, illustrated by examples specific to science policy. In the next section, we discuss in greater detail specific illustrations of each criteria, to show the applicability of public-failure theory to real-world science-policy dilemmas.

Cases in public failure and science policy

Case 1. Public failure in values articulation and aggregation: priority setting in science

Public failure can occur when expression of public values is stifled or distorted. For example, if campaign financing procedures lead to conspicuous conflict between public values (as elicited, say, through polling) and the values of elected officials, then there is a potential for public failure. This type of conflict may provide an incentive for private investment in lobbying that is rational by economic standards yet counter to the larger public interest — as when efforts by the insurance industry and its allies to prevent health-care reform have overcome a broader public desire for a more affordable and equitable health-care delivery system.

In science policy, a pervasive cause of values articulation public failures is an absence of mechanisms that allow non-scientists to have a significant say about public investments and priorities in most areas of science. The reasons for this failure are clear: How can a non-scientist be expected to make a sensible choice between, say, funding two distinct areas of health research, for instance, research aimed at understanding the contribution of polycystic ovarian syndrome, versus research on understanding the impact of bovine hormone in milk on breast cancer?

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It would take a great deal of effort even for most scientists to have an informed opinion about the largely unknowable trade-off between two important lines of applied medical research. Moreover, politicians (and the general public) are as likely as scientists to understand their own preferences for, say, favorable outcomes in breast cancer research vs favorable outcomes in astronomy or in polar sciences or in mental health. This is not an overestimation of the ability of the 'median voter' to understand science trade-offs but, rather, a perhaps more realistic (and pessimistic) estimate of the relative ability of experts to make high-level values choices (for discussions of basic questions involved in scientific choice, see, for instance, Fuller, 2000).

Science policy-makers have evinced some concern about the balance between scientific values (for instance, what constitutes 'good' science?) and social values (for instance, how is the public good being advanced?). In response to Congressional prodding, the National Science Foundation (NSF) has sought to use the peer-review process to enhance the societal value of its research portfolio. In addition to standard criteria of scientific merit, NSF added in 1997 the criterion of social benefit to its peer review process.

NSF then commissioned the National Academy of Public Administration (NAPA) to evaluate how well this effort to incorporate public values into peer review was working. NAPA (2001) reported back that the changes, as implemented, were unlikely to have much positive effect. Problems with NSF's approach ranged from a lack of "quantitative measures and performance indicators to track the objectives of the new merit review criteria" (page 7), to skepticism or even outright opposition on the part of reviewers to the inclusion of social impact criteria to begin with. NAPA went on to recommend a variety of actions that NSF could take to correct these problems, such as improving "the conceptual clarity of the objectives of the new criteria" (page 8), and ensuring "genuine attention to the goals of the new criteria throughout the entire review cycle" (page 9).

Yet neither the NSF social impacts criteria nor the NAPA report addressed the underlying source of public failure. Nobody denies that the scientific community has great skill in assessing technical quality of research, but who has vested it with special training, skill, or legitimacy in assessing the social value of research? Moreover, there is no particular reason to believe that the social priorities

Table 1. Public failure and public policy: a general diagnostic model

Public failure	Failure definition	Science policy illustration
Mechanisms for values articulation and aggregation	Political processes and social cohesion insufficient to ensure effective communication and processing of public values	Peer review, the favored means of making decisions of individual-level projects, is appropriated for decisions about huge scientific programs, resulting in the displacement of social goals for more easily resolved technical goals
Imperfect monopolies	Private provision of goods and services permitted even though Government monopoly deemed in the public interest	When public authorities abrogate their responsibility for overseeing public safety in clinical trials for medical research, there is potential for violation of public trust and public value
Scarcity of providers	Despite the recognition of a public value and agreement on the public provision of goods and services, they are not provided because of the unavailability of providers	The premature privatization of the Landsat program shows that a scarcity of providers can create a public failure potentially remediable by Government action
Short time horizon	A short-term time horizon is employed when a longer-term view shows that a set of actions is counter to public value	Policy for energy R&D, by considering the short term, fails to fully capture the costs of global climate change on future generations
Substitutability vs conservation of resources	Policies focus substitutability (or indemnification) even in cases when there is no satisfactory substitute	'No-net-loss' policies fail to take into account the non-substitutability of many natural organisms ranging from wetlands protection to prohibiting the sale of human organs on the open market
Benefit hoarding	Public commodities and services have been captured by individuals or groups, limiting distribution to the population	A prime technical success of genetic engineering, the 'terminator gene,' proves an excellent means of enhancing the efficiency of agricultural markets, to the detriment of millions of subsistence farmers throughout the world

of scientists are representative of society. Indeed, surveys of scientists' political opinions and values suggest there are often large differences between scientists and the general public (for instance, Bauer *et al*, 2000; Plutzer *et al*, 1998; Barke and Jenkins-Smith, 1993), though scientists are closer to other elite groups such as journalists.

Just as with other professions and demographic groups, scientists' values probably resemble those of persons who have socioeconomic attributes and life experiences similar to their own. Also, citizens have not voted for scientists or in any way designated them as the 'official' articulators or judges of public value. Finally, the public value of science is rarely ascertainable at the individual project level, where peer review most often operates.

Public values operate at a level where science policy receives very little attention: cross-science comparisons, and the opportunity costs associated with resource allocation decisions. It is also at this level of broad preferences where the general public, or at least the attentive public, may plausibly contribute (for instance, Carnegie Commission), but the structure of US science policy provides little opportunity to do so. Congress, because of its jurisdictional structure, is generally unwilling to make either cross-science choices or systematic choices among the public values that science serves. Likewise, the science bureaucracy works within scientific fields, disciplines or objectives, rarely among them.

Scientists themselves have even less incentive for the internecine warfare that would arise with a more systematic assessment of the values associated with a diverse set of desired scientific outcomes, thus militating against even expert-driven processes of choosing among disciplines (for instance, as originally suggested by Weinberg (1963), and revisited by Fuller (2000)). This is a built-in public failure affording limited opportunity for values articulation (see Kitcher (2001) for a formal argument about enhancing the public role in articulating public values for science).

When the putatively 'value neutral' science policy funding machine is temporarily thrown off kilter, it is generally because an issue emerges that grips the public imagination, or a highly motivated special interest group, to such a degree that public value issues simply cannot be ignored. The most recent case in point is the stem cell controversy, which provides an excellent proof that it is not the complexity of scientific issues that forestalls public participation and public values articulation. The scientific issues in the various stem cell debates are technical and esoteric, but the values issues are so fundamental and compelling that research cannot proceed apace (for instance, Fukuyama, 2002).

When the conduct of research requires one to consider such issues as "what constitutes a human being?", the momentum of the science policy funding machine slows down and the role of public values is brought to the fore. The results of the stem cell controversy highlight the dearth of institutions and analytical frameworks available for values articulation and analysis.

Case 2. Public failure and 'imperfect monopolies': clinical trials

Whereas private-sector monopoly is an indication of market failure, in some cases the inability of a government activity to protect its monopoly may lead to erosion of a public value. For example, foreign policy is a legitimate government monopoly, and any competition from unauthorized envoys could damage the broader public interest.

Regulation of private-sector activities to protect public welfare is a widely accepted role of government, although the appropriate degree of regulation is often highly contentious. In the area of clinical trials to determine the efficacy of pharmaceuticals and other medical interventions, the government has granted research institutions and scientists considerable autonomy. This autonomy is justified by faith in the self-policing capacity of the scientific community, especially as embodied in its claim to objectivity — or at least disinterest — through the scientific method, and to quality control through peer review.

The protection of humans in scientific experiments is a well-established public value, enshrined in international law through the Nuremburg Code and Helsinki Declaration (Woodward, 1999), and nationally through such codified principles as informed prior consent. All experiments involving humans that are funded, in whole or part, with federal dollars, are overseen by Institutional Review Boards — decentralized, self-policing oversight bodies aimed at "protecting the rights and welfare of human subjects of research" (CFR (Code of Federal Regulations, 1993) Title 45, Part 46.103) and ensuring that "[r]isks to the subjects are reasonable in relation to anticipated benefits" (CFR 45: 46.111). Such experiments include tests and trials to demonstrate the efficacy of new drugs, therapies, and procedures, both as part of the process of gaining government approval for general use, and as a means of informing physicians about the relative value of available options.

In September 1999, 18-year-old Jesse Gelsinger died while undergoing gene therapy for a rare liver disease. Gene therapy had long been touted as a potentially miraculous emerging line of treatment for a wide variety of serious genetic disorders, but its promise had remained unfulfilled, and Gelsinger's death made national news. Early reporting on his death suggested only that something had gone terribly wrong in the experiment, but that all appropriate processes and procedures had been followed to ensure that risk was minimized and his participation was fully consensual (Wade, 1999).

Deeper investigations revealed irregularities. The consent forms that Gelsinger signed misrepresented the dosages that were to be administered, and did not include information about animal deaths from similar treatments. Evidence of high toxicity and adverse side effects in earlier experiments was ignored. The doctor in charge of the experiments, and the university he worked for, had a financial stake in the company that would have produced the new gene therapy (Nelson and Weiss, 1999).

Before Gelsinger's death grabbed the headlines, academic studies of clinical trials had been painting a more dispassionate, less publicized picture of public failure. A number of studies revealed that clinical trials directly or indirectly supported by pharmaceutical companies often yielded more favorable assessments of new therapies than trials that were not tied to the private sector in any way. In one analysis, only 5% of company-sponsored studies on anticancer drugs yielded unfavorable assessments, while, for studies sponsored by non-profits, the unfavorable rate was 38% (Friedberg *et al*, 1999).

An investigation of calcium-channel antagonists, a class of drug used to treat cardiovascular disease, demonstrated "a strong association between authors' published positions on the safety of calcium-channel antagonists and their financial relationships with pharmaceutical manufacturers" (Stelfox *et al*, 1998, page 101). An analysis of published symposia proceedings showed that "[a]rticles with drug company support are more likely than articles without drug company support to have outcomes favoring the drug of interest" (Cho and Bero, 1996, page 485).

Few have argued that such results demonstrate scientific fraud. More likely, "[c]lose and remunerative collaboration with a company naturally creates goodwill [that] can subtly influence scientific judgment in ways that may be difficult to discern" (Angell, 2000, page 1517). Some scientists have publicly claimed that they are not subject to such influences. James Wilson, the researcher in charge of the Gelsinger trial, said: "To suggest that I acted or was influenced by money is really offensive to me … You've got to be on the cutting edge and take risks if you're going to stay on top [scientifically]" (Nelson and Weiss, 1999, page A1)

While such claims to immunity from human weakness may or may not ring true, researchers' ties to industry by definition create a conflict of interest, which, if not revealed to patients in trials, undermines the principle of informed consent, and, if not apparent to peer reviewers and publishers of research articles, can obscure the implications of research results. Bodenheimer (2000) catalogued a variety of ways in which a drug test can be carried out to favor one result or another without rendering the data itself invalid. For example, "[i]f a drug is tested in a healthier population … than the population that will actually receive the drug, a trial may find that the drug relieves symptoms and creates fewer adverse effects than will actually be the case" (Bodenheimer, 2000, page 1541).

In terms of public-failure theory, a particularly troublesome attribute of this problem lies in the difficulty of actually documenting the threat to public values. The Gelsinger story was atypical in that the connection between the conflict of interest and the public consequence — Gelsinger's death — was obvious (even if not demonstrably causal). However, when published studies comparing one drug to another influence a physician to prescribe one drug rather than another, the very existence of the public failure may be difficult to ascertain, and the public-failure consequences highly diffused. It is, indeed, a testimony to the transparency of the biomedical and medical–legal research enterprises that this problem did emerge.

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Federal regulations for oversight of human subjects research do not explicitly require Institutional Review Boards to consider conflict of interest in the approval process (CFR 45:46), although the Food and Drug Administration, for example, requires that applications for drug approval must be accompanied by disclosure of investigator conflicts in all research supporting the application. The final report of the now-defunct National Bioethics Advisory Commission (2000) recommended that the Government develop specific guidelines for defining and regulating conflict of interest in human-subjects research, and that conflict of interest should be disclosed to research participants as part of the prior consent process. Enforcement of these recommendations would help to reestablish the Government monopoly over protecting human subjects of medical research, and thus help to reverse a case of public failure in science (see Goldner (2000) for a comprehensive discussion of conflict of interest in biomedical research).

Case 3. Public failure due to scarcity of providers: geographic information

Protection of a core public value may depend on the presence of a sufficient number of providers of that value. If market signals are insufficient to attract the necessary number of providers, and if the government fails to step in, then public failure may occur. Few would disagree that the number of high quality public school[1] teachers is less than optimal, due to many factors including relatively low salaries and other disincentives. This may be counted a public failure. When certain government activities are deregulated, provider scarcity may follow. For example, when airline deregulation leads to decreased services for rural areas, significant portions of the population may be adversely affected. The market may be operating efficiently, but public failure has occurred.

The federal Government has long been recognized as the appropriate source of support for developing and disseminating data on the geographic and physiographic characteristics of the nation. The Lewis and Clark expedition was a famous early example of a Government research project aimed at garnering geographic information, and surveying and mapping activities were early mainstays of federal support for science prior to World War I (for instance, Dupree, 1986).

In recent decades, the importance of geographically referenced, or geospatial, data has increased rapidly. This growth has been fueled by new technologies, from remote sensing and geographic positioning satellites to sophisticated computer graphics software, and also by societal demand for new capabilities to monitor and address complex challenges, ranging from environmental protection to emergency management.

At the same time, private-sector involvement in both the collection and use of geospatial data has increased, leading to a number of dilemmas regarding the appropriate allocation of public and private activities. Considerable attention has been focused on the need to ensure that this increasing private-sector role does not result in erosion of public access to information and products that are recognized as public goods.

The revolution in geographic information began with NASA's launching of the first civilian remote sensing satellite — Landsat 1 — in 1972. Efforts to gradually privatize the Landsat program were initiated in 1979 by the Carter administration. Two years later, the Reagan administration began advocating a more rapid shift to privatization, which in turn led to legislation in 1984 (P.L. 98-365) that privatized the sale of Landsat data, and encouraged private-sector development of future satellites.

These actions took place despite studies indicating that privatization was not yet economically sustainable. Indeed, for the next five years, the Landsat program was in a state of constant fiscal crisis. By the early 1990s, with the operational satellites (Landsats 4 and 5) beyond their design life, and no concrete plans for replacing them either with public or private satellites, the very existence of the Landsat program was in jeopardy (NASA, 1998; NRC, 1991).

In 1992, Congress took action to ensure the continued provision of satellite-based geospatial data. In doing so, it explicitly noted that the privatization effort interfered with the provision of public goods: "The cost of Landsat data has impeded the use of such data for scientific purposes, such as for global environmental change research, as well as for other public-sector applications" (H.R. 6133). A new law was enacted (P.L. 102-555) to ensure the continuity of the Landsat program, but also to ensure that publicly supported scientists and others who depend on satellite imagery for non-commercial uses would have access both to archived data and to newly acquired data — access that had been compromised by high prices during the privatization effort.

The near debacle created by the premature privatization of Landsat demonstrates how a scarcity of providers can deprive society of a public good upon which it depends, and how such public failure can be corrected by appropriate government action. In this case, the obvious failure of a putative market solution — privatizing Landsat — made it easy to recognize the public failure. That is, public failure and market failure existed hand-in-hand.

The more interesting and problematic case, however, occurs when the markets are functioning well, but the provision of the public good is not automatically preserved. Recent development of geospatial data policy exemplifies an awareness of this tension, and is in fact something of a success story: a case where policy intervention ensures that market success is combined with the support of public values.

As we have discussed, overcoming public failure depends on general agreement about the desirability of a particular public value, and indeed the idea of geospatial data as a public good is well accepted. For example, a study by the National Academy of Public Administration states that "[m]any believe that [geospatial] data should be made widely available at no cost or at reasonable cost to the user, and that this will satisfy an almost infinite variety of governmental, commercial, and societal needs" (NAPA, 1998, page 2).

One National Research Council (NRC) committee asserted that "it is in the public interest for government to play a leading and facilitating role in coordinating the development of spatial data and to make those data available for public use and exchange" (NRC, 1995, page 1). Another NRC committee made the even more specific claim "that it is in the public interest and a federal responsibility for the … development of an interdisciplinary, multidatabase architecture that will allow disparate databases to become nondestructively interoperable in a common geospatial context" (NRC, 2001, page 77).

While such language cannot easily be derived from the Constitution, it can nonetheless be justified by "countless applications (for instance, facility management, real estate transactions, taxation, land-use planning, transportation, emergency services, environmental assessment and monitoring, and research)" (NRC, 1993, page 2), and the consequent public benefits that access to geospatial data can confer.

The major obstacle to ensuring such benefits has become the coordination of rapidly expanding private- and public-sector capabilities in acquiring, processing, and disseminating a wide variety of geographic information. The transition from analog ('paper') maps and photos to digital databases has enabled a thriving private-sector effort to apply spatial data to a diversity of public and private needs. In particular, the rise of 'geographic information systems' (GIS) has created the capability of bringing together very different types of data to support decision making. The challenge of assuring that data, software, and hardware capabilities arising from a multitude of providers did not create a sort of geographic information tower of Babel even led to the formation, in 1994, of a non-profit organization, the Open GIS Consortium, "to address the lack of interoperability among systems that process georeferenced data" (Open GIS Consortium, 1999, page 2).

The situation had rapidly changed from one of a scarcity of providers of a single type of data — satellite imagery — to a scarcity of providers of an integrated product. The point is worth emphasizing because it illustrates the subtlety and power of public-failure theory: in the first case, the public failure of provider scarcity correlated with market failure; in the second, the correlation was with market success. A new need rapidly arose: to ensure "a common spatial data foundation organized according to widely accepted layers and scales (or resolution) that is available for the entire area of geographic coverage … to which other geospatial data can be easily referenced" (NAPA, 1998).

For example, if a municipality needed to develop geospatial data to support ecosystem management, it might require spatially referenced data about the location of wetlands and other sensitive areas, about demographic and land-use trends, groundwater chemistry, surface water flow, sources of pollution, distribution of animal and plant species, power lines and pipelines, and of course traditional physiographic data. For these data to be useful, they must be combined as part of a single geospatial database, which means they must be available in compatible formats and coverage, and usable with one software package, on one computer. Such compatibility was not arising from private-sector providers acting individually to maximize profit and capture market share.

The need for Government intervention has been broadly accepted and recognized in both the public and private sectors. In 1994, President Clinton issued Executive Order 12906, "Coordinating geographic data acquisition and access: the national spatial data infrastructure [NSDI]" (page 17671), to establish:

1) a Federal Geographic Data Committee to coordinate the development of the NSDI;
2) a national geospatial electronic data clearinghouse that would encompass all data collected by the public sector;
3) a process for developing standards to ensure compatibility among public, private, and non-profit sector sources of geospatial data; and
4) a framework of basic geospatial data — "data you can trust" — for a variety of applications that would be available for all.

The framework represented a clear embodiment of public action to protect a public good: "basic geographic data in a common format and an accessible environment that anyone can use and to which anyone can contribute … a nationwide community for data sharing" (Federal Geographic Data Committee, 2001).

Case 4. Public failures and short time horizons: energy R&D

Human beings pay attention to unborn generations, but they do not do so out of economic rationality. Pricing will not account for consequences that are expected to emerge in the distant future. Thus, there is clearly a public role in guaranteeing the long-term perspective even if there is no short-term market failure.

This type of problem has emerged most conspicuously in the area of environmental protection. For example, the price of gasoline in the past did not reflect the public health costs associated with high levels of lead in the air; currently gas prices do not account for the long-term global environmental costs associated with climate change. In the case of lead, Government action created a public success — mandatory introduction of lead-free gasolines — in the absence of market signals. For climate change, the necessary regulatory and R&D investments have yet to be made, so here we see both public failure and market failure arising from short time horizons.

The market-failure paradigm has provided a politically robust rationale for long-term investment in research where no foreseeable application exists. Oddly enough, the paradigm has been less successful as a justification for public research investment where the long-term application is clear, but the short-term incentives for private-sector involvement are weak. This irony reflects the apparent repugnance in market-failure dogma to choose 'winners and losers,' or at least to significantly alter the balance between current winners and losers. The consequences are starkly illustrated in the case of energy R&D.

The energy crises of the 1970s demonstrated that the long-term US dependence on foreign sources of oil could have far-reaching economic and political consequences. More recently, the growing awareness of the connections between fossil fuel use and global climate change have created an additional long-term rationale to switch to other types of less-polluting energy technologies. In the face of these two realities, trends in both public and private investment in energy R&D are quite amazing: they have declined by almost two-thirds, in real dollars, since the late 1970s (Dooley, 1999, Figure 4).

The reasons for this lack of investment are clear: over short time horizons, the market has been working quite well. In particular, and contrary to general expectations, oil prices have been fairly stable as a result of aggressive exploration, enhanced extraction technologies, open global markets, and the willingness of the US to intervene militarily to protect access to oil supplies. In market-failure thinking, continued low energy prices justify neither aggressive public funding of energy R&D, nor Government regulatory action to promote efficiency, which could stimulate private-sector R&D. Absent the price pressures of oil embargoes, there has been little motive to innovate. Annual energy technology patents, for example, have been declining since the 1980s (Margolis and Kammen, 1999).

Reduced commitment to research seems to be reflected in both energy production and consumption trends. In 1970, fossil fuels accounted for 93% of all US energy production. This proportion declined 5% over the next five years (during the first energy crisis) but only 8% more over the succeeding 15 years. (Energy Information Administration, 2000). On the consumption end, energy intensity (energy use per unit of economic output) declined 2.4% per year in the 1980s; in the 1990s, the average annual decline was only 1.5% (Energy Information Administration, 2001).

Given the ongoing volatility of politics in the Middle East, and the increasing evidence that carbon emissions influence the behavior of the global climate, it is difficult not to see the declining public investment in research on alternative energy sources and more efficient energy technologies as deeply problematic. This declining investment documents a continued failure to overcome the short-term thinking in Government energy R&D policy that is made possible by a well-functioning market that continues to deliver stable energy supplies and low prices.

Case 5. Over-reliance on substitutability of resources: organ sales as a medical public failure

Market mechanisms may indemnify against the loss of particular resources, or offer substitutes for lost resources. While such mechanisms may be efficient from a market perspective, they may also represent public failure. An obvious example is the calculation that automobile manufacturers might use when determining how safe to make a vehicle. Part of this calculation includes the price of adequate indemnification against law suits for wrongful death.

Given the volatility of politics in the Middle East, and the evidence that carbon emissions influence global climate, the declining public investment in research on alternative energy sources and more efficient energy technologies is deeply problematic

While such trade-offs are unavoidable (a totally safe car would be either unaffordable, or immobile), they may still represent public failure, for example, if the manufacturer determines that the costs of fixing a known problem exceed the expected legal costs, as occurred when Ford failed to correct the exploding gas tanks in its Pinto model (Tietz, 1993). The idea that life is explicitly substitutable offends sensibilities of most non-economists, and may often imply public failure.

A related example comes from environmental policy. ‘No-net-loss’ policies allow for developers who fill in existing wetlands to construct artificial wetlands as a substitute. However, ecological research suggests that artificial wetlands tend not to have the same species diversity or ecological value as the natural ones that they replace (Kaiser, 2001). Similarly, when old-growth forests are clear-cut and replaced by planting of monoculture forests, the ecological value of the original forest has not been retained, even if the economic value, as measured by board-feet of lumber, is maintained.

In market-failure-based policies, public-value failures are most often a result of the substitution of money for a tangible or natural resource. One especially interesting case implicating science policies and pertaining to medical practice is money-for-body-parts transactions. In the United States, trafficking in human organs is illegal — a clear signal that public values should take precedence over market efficiency. Elsewhere in the world, evidence of a market in human organs to supply rapidly advancing capabilities in medical science continues to crop up. An active market in kidneys and corneas has been documented in India (Kumar, 1994), and an organ market is also thought to exist in the Philippines (*Medical Industry Today*, 1998).

Such transactions degrade humans, victimize the poor, and invariably occur under some type of economic or political duress; they exemplify public failure. Yet, from a market standpoint, money-for-body-parts transactions may be viewed as efficient, with money being an acceptable substitute for personal health. From a consumer sovereignty standpoint this logic is unimpeachable. As one Harvard economist writes: “If a desperately ill individual who would die without a kidney is able to buy one from a healthy individual, both are made better off. Why … stand in the way of market transactions that will not only make those who engage in them happier but also save lives?” (Shavell, 1999, page 22)

Perhaps whether or not one keeps one’s corneas is really a matter of one’s view about the substitutability of health for other assets. Nevertheless, in a world where millions live in abject poverty, the notion of consumer sovereignty and of rational choice of one good for another seems less about markets than about massive public-values failure.

Case 6. Public failure and benefit hoarding: terminator technology

In the marketplace, externalities may distort prices and thus skew costs or benefits toward particular consumers. For example, the costs of cleaning up pollution are rarely included in the price of the polluting good. Thus, those who produce and consume that good may benefit preferentially. Analogously, if the benefits of a public policy meant to aid a large group are captured preferentially by a much smaller group, public failure may be occurring.

Recent attention to the 'digital divide' may illustrate such a failure. Disparities in health care may be another example. Development of the internet and many medical technologies was made possible by public support of the necessary R&D. If only certain segments of the population are benefiting from this investment, then benefit hoarding may be taking place.

In the early 1980s, following a decade of disappointing economic performance, US policy-makers were anxious to find ways to stimulate economic growth. One area of action focused on creating incentives to transfer the results of Government-funded research to the private sector as a stimulus to technological innovation, and resulted in such laws as the Stephenson-Wydler Act of 1980, the Bayh-Dole Act of 1980, and the Federal Technology Transfer Act of 1986.

The Technology Transfer Act legalized public–private research partnerships, called 'CRADAs (cooperative research and development agreements), meant to stimulate collaboration between Government and corporate laboratories. The 'Findings' that articulate the rationale for the Act include brief mention of "social well-being," "increased public services" and "public purposes," but in fact focus almost entirely on economic arguments, for example: "Increased industrial and technological innovation would reduce trade deficits, stabilize the dollar, increase productivity gains, increase employment, and stabilize prices" (15 USC Sec. 3701). While these are all laudatory goals, they make no mention of possible social impacts that could undermine public values.

On 3 March 1998, the US Patent Office granted a patent jointly to the US Department of Agriculture's (USDA) Agricultural Research Service and the Delta and Pine Land Co, a breeder of cotton and soybeans, entitled "Control of Plant Gene Expression." This patent arose from joint work funded through a CRADA, and embodied the type of technology transfer envisioned by legislators more than a decade earlier.

The patent covered a process, called the Technology Protection System (TPS), that would allow seeds to be genetically engineered so that they did not give rise to fertile offspring. The intention was to protect the technological innovation embodied in new varieties of seeds (for example, resistance to drought or herbicides), by ensuring that farmers could not plant second-generation seeds produced by the first generation crop. Rather, they would have to buy new seeds for each planting. In the words of the USDA (ARS, 2001), the new technology "would protect investments made in breeding or genetically engineering these crops. It would do this by reducing potential sales losses from unauthorized reproduction and sale of seed." This economic argument was causally linked to a social-benefits argument via standard market logic (ARS, 2001):

> "The knowledge that the seed companies could potentially recoup their investment through sales will provide a stronger incentive for the companies to develop new, more useful varieties that the market demands. Today's emerging scientific approaches to crop breeding — especially genetic engineering — could be crucial to meeting future world food needs, conserving soil and water, conserving genetic resources, reducing negative environmental effects of farming, and spurring farm and other economic growth. TPS technology will contribute to these outcomes by encouraging development of new crop varieties with increased nutrition to benefit consumers and with stronger resistance to drought, disease and insects to benefit farmers for example."

TPS technology does appear to hold considerable interest for plant-breeding companies, and TPS patents continue to be granted in the US and abroad (ETC Group, 2002). In essence, TPS makes protection of intellectual property a biological process, rather than a legal one. At present, seed companies must count on the honest farmers to honor intellectual property by not 'brown-bagging' second-generation seeds, or the companies must resort to policing of farms to enforce their intellectual property. Indeed, in pursuing the latter course, Monsanto suffered a public relations disaster when they sued a Saskatchewan rape-seed farmer for patent infringement (for instance, Margoshes, 1999).

TPS is a testimony to amazing progress in genetic engineering. The process described in the original patent involves enormously complex, integrated manipulation of transgenic components that are inserted into the DNA of the plant to be protected. A plant gene "normally activated late in seed development" must be fused with a "promoter to the coding sequence for a protein that will kill an embryo going through the last stages of development" and then coupled to a mechanism to repress the promoter until it is treated with a specific chemical (Crouch, 1998).

Less than two years after the TPS patent was granted, M S Swaminathan, one of the founders of the Green Revolution and an advocate of biotechnology in the service of global agriculture, declared that if TPS was widely adopted, "[s]mall farmers will then experience genetic enslavement since their agricultural destiny will be in the hands of a few companies" (Swaminathan, 1999). The Consultative Group on International Agricultural Research (CGIAR, the organization that provided much of the science for the Green Revolution) banned TPS from their research agenda (Service, 1998) and Monsanto, which was attempting to acquire Delta and Pine Land Company (co-holder of the original patent), pledged, under pressure from public interest groups and philanthropic foundations, "not to commercialize sterile seed technologies" (Shapiro, 1990).

The Rural Advancement Foundation (RAFI, later renamed ETC Group), which mobilized opposition to TPS, coined the phrase "terminator technology" and asserted that the "seed-sterilizing technology threatens to eliminate the age-old right of farmers to save seed from their harvest and it jeopardizes the food security of 1.4 billion people — resource poor farmers in the South — who depend on farm-saved seed" (ETC Group, 1998). RAFI also argued that TPS would further contribute to diminution of global agricultural genetic diversity, especially for plant varieties of importance to developing countries.

The argument against TPS is multifaceted (our summary is drawn from: Visser *et al*, 2001; Eaton *et al*, 2002; Service, 1998; ETC Group, 1998; 1999). At the heart of the issue is the practice by many farmers, especially (but not only) in the developing world, to continually seek better plant varieties for local growing conditions, through careful selection of kept seed, as well as purchase of new varieties from both private and public seed distributors.

TPS was alleged to threaten this process in many interconnected ways. First, it would allow commercial breeders to capture markets for crops that are not amenable to hybridization, including wheat, rice, and cotton. (Commercial breeders do not focus on such crops precisely because they cannot control farmers' use of kept seed. Hybrid seed, on the other hand, tends not to express its engineered attributes homogeneously in the second generation, and thus offers some inherent protection of intellectual property.)

This commercialization of seed varieties in turn would inevitably reduce the available commercial sources of such seed because of advantages conferred to larger breeders and seed purchasers by economies of scale. Local plant breeders' access to new genetic materials would thus become increasingly restricted, and their ability to select for improved seed varieties would be impaired.

Secondly, because commercial plant breeders would be aiming their products at the most profitable markets — those of the rich countries — they would be unlikely to engineer plant varieties to meet the needs of poorer farmers, as has been the case generally with hybrid products. At the same time, publicly funded plant breeding organizations, such as CGIAR, might be blocked from using engineered traits developed by private breeders unless they also accepted TPS. Such trends would exacerbate agricultural technology gaps between rich and poor.

Thirdly, because poor farmers would find it increasingly difficult to acquire seed without terminator technology, their exposure to year-to-year food-supply disruption as a result of economic, political, climatic, or other factors would increase. Finally, genetic diversity of agricultural varieties would decline, because the largest source of such diversity is the seed-production activities of farmers themselves. Large breeding companies tend to reduce, not increase, genetic diversity.

In defense of TPS, USDA focuses on market arguments (ARS, 2001):

> "[L]oss of cost savings from brown-bagging [kept seed] also must be weighed against the productivity gains to the farmer from having superior new varieties that could increase crop values such as yield and quality, input cost reductions such as for fertilizers and pesticides, and reduced losses such as those due to pests or adverse soils and weather."

Such arguments assume a level playing field, where the attributes of new, engineered seed varieties will be those needed by small farmers and poor farmers, where such farmers will be able to afford the new varieties, and where they will, therefore, no longer be dependent on their own seed selection skills to optimize crops for particular local growing conditions. Even should such an optimistic scenario transpire, it ignores the effects of reduced genetic diversity on the resilience of agricultural systems worldwide.

Terminator technologies thus create a possibility for corporations to gain control of a process — seed selection — and a product — plant varieties — that have been in the hands of farmers for millennia. The effect is a private hoarding of what had been a public good — the plant-genetic commons. This effect is less troubling in the context of affluent nations, where agriculture has become increasingly industrialized, than for poor ones, where small farmers continue

Terminator technologies create a possibility for corporations to gain control of a process — seed selection — and a product — plant varieties — that have been in the hands of farmers for millennia: the effect is a private hoarding of what had been a public good

to depend upon kept seed and selective breeding for crop improvement and adaptation, and for food security from year-to-year.

A particularly conspicuous element of this story is that the original research was partly funded by public money and conducted at a public research laboratory. As such, it is an exemplar of the way that market values displace public values in justifying public funding of science and technology.

Science policy and the 'public value grid'

Among other implications of these examples and the criteria they illustrate is that public failure and market failure are *not* single poles on a dimension or even two orthogonal dimensions. Instead, it is best to view the two as axes of a grid, as in Figure 1, which provides a depiction of the ways in which science policies can have very different economic and public values outcomes.

The notion of setting market values against other values not easily encompassed by market framework is not new. For example, Page (1977) suggested contrasting dimensions of market efficiency and conservation of resources. Norton and Toman (1997) speak of "two tiers," one an efficiency criterion, the other a conservation criterion. Figure 1 provides a highly simplified depiction of public failure and market failure, illustrating the possibility of a virtually infinite range of outcomes among the extremes of complete public failure, complete public success, complete market failure, complete market success. One obvious point is that market failure and public failure need not be correlated at all.

Figure 1 is broadly illustrative. We might easily quibble with the exact location of the policies depicted. Another obvious limitation is that such broad categories as "academic research policy" are little more than stand-in symbols for many diverse science (and other) policies. However, the lack of precision should not undercut the chief point.

Take the case of Internet technology development. We might argue, for example, that the history of Internet technology development provides a happy example of a public values success and, at the same time, a market success. While the Internet, much as any ubiquitous social phenomenon, has not been a success in every possible respect (witness controversies about privacy, pornography, intellectual property, and 'spam'), most would, on balance, assess the commercialization of the Internet as both a market and public values success.

Similarly, R&D policy for pharmaceuticals could be viewed as a considerable market success but in many respects a public failure. In neither instance is it a 'pure' success or failure and, thus, not at the extreme end of either pole.

One point worth noting is that over time policies move in 'normative space,' repositioning themselves in Figure 1. Thus, at the beginning of Internet technology development, the best description would be 'modest public values success combined with market failure.' That is, in 1992, the Internet (not yet called that) served some significant if limited public values in linking scientists and a few other users. However, at that time, the Internet was a nearly perfect market failure in the sense that no commercial value had yet been harvested, nobody was in a position exclusively to appropriate its benefits, and no price mechanisms were in place.

The public-failure grid provides a simple analytical tool for thinking about the public values and economic values served by science policies. We need not be 'right' in the positioning of policies to find such deliberation useful. Likewise, we need not entertain each public failure (and each market failure) diagnostic criterion to employ the grid and to obtain its value as a common sense check on deliberations about the values served by science policies.

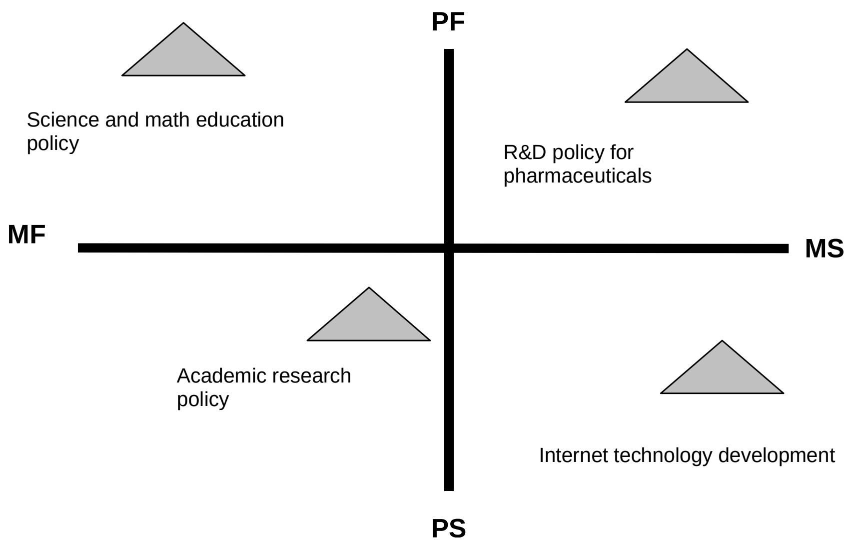

Figure 1. Public failure grid and science policy examples

Public failure theory

For the past 50 years, questions of choice have been central to science policy discourse. In a world of finite resources, how shall we choose among various portfolios of scientific investments and research strategies, and who shall do the choosing? The famed Bush–Kilgore debates of the late 1940s, which sought in part to establish the degree to which publicly funded science should be linked to specific social goals (Kevles, 1987), set the stage for an initial phase of intellectual debate that took as its starting point the assumption that science needed to be insulated from the vulgarities of democracy, and proceeded to ask how, then, choices might be made to serve the best interests of society (for instance, Polanyi, 1962; Weinberg, 1963; Brooks, 1968, chapters 1 and 2).

Yet the texture and depth of thinking about choice in science policy has had remarkably little impact on the actual science policy process, which remains, above all, a competition for incremental budget increases. Each year, science policy, as so much of the rest of federal policy, becomes riveted on the federal budget and, specifically, the amount of money available for science. There is great deliberation about the actual amount, the rate of growth, the percentage of the budget, the amount for science as opposed to other outlay categories, and the amount (and percentage and rate of growth) for particular agencies and particular programs within agencies, as compiled annually by the American Association for the Advancement of Science (for instance, Intersociety Working Group, 2003), and biennially by the National Science Board (for instance, NSB, 2002).

Every year, even during periods of considerable growth in spending, there are at least a few 'funding crises' identified and these become grist for op eds (a page of special features usually opposite the editorial page of a newspaper), sound bites, lobbying, and anguish. (The latest example is the concerns voiced on behalf of the National Institutes of Health (NIH), whose budget doubled between 1998 and 2002, and must now suffer a reversion to rates of increase typical of its prior history of robust growth (Weiss, 2003).)

The fact is, few people (and more likely no people) have the breadth of understanding to even begin to provide a valid account of what will happen as a result of a 5% decrease or increase in, say, biochemistry funding. Yet, in the world where science policy decisions are actually made, science funding acts as a proxy for public value; more of the former is assumed to yield more of the latter. Policy documents (for instance, Carnegie Commission on Science, Technology, and Government, 1992; Institute of Medicine, 1998) and scholarship (for instance, Petersen, 1984; Kitcher, 2001) have made the case for greater diversity of voices in science policy priority-setting, a recommendation that we would support, yet one that does little to address the more complex question of how successfully a given line of research may actually connect to advancing public values. It is telling that successful efforts to influence the internal conduct of science to achieve particular societal outcomes are relatively rare, and have mostly been driven by highly motivated and politically empowered groups focused on changing the norms of clinical health research (for instance, Lerner, 2001; Epstein, 1996).

We suggest that, while democratizing choice is important, it is insufficient for enhancing the public value of science. Indeed, in one very real sense, choice in science policy has been highly democratized. In the words of the late Congressman George E Brown, Jr (1999), perhaps the most thoughtful of all practitioners of the politics of science: "Congress does have a rational priority-setting system. Unfortunately it is largely zip-code based: Anything close to my district or state is better than something farther away. Individual colleges and universities and many federal labs know this system well and have used it to their advantage for decades."

The problem is that what really counts when it comes to the public values flowing from science policy is not so much budgetary level of effort as the institutional, cultural, political, and economic contexts in which science is produced and applied. So why, in the face of decades of critical STS scholarship about these complex contextual relations, does the formula that equates more-money-for-science with more-public-value assert itself with undiminished vigor? We suggest this is a consequence of two factors: first, the bipartisan power of economic thinking, bolstered by evidence of the key role for science in economic growth, and rationalized by the market-failure model for government intervention; and, second, the absence of analytical and rhetorical tools that can match the simplicity and potency of economic argumentation.

Here we have presented simple criteria that can be used to test claims that more science equals more public value. If values are not well articulated or aggregated; if public monopolies are imperfect; if providers are scarce; if time horizons are short; if resources are viewed as substitutable; if benefits can be captured by small groups; then the translation of science investments into public values may well be compromised, regardless of how well the market is operating, or how much money the science receives.

Note

1. In the US, public schools are free, tax-supported schools controlled by a local government authority.

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