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Inequity in the distribution of science and technology outcomes: a conceptual model

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Abstract We propose a conceptual model to encourage systematic analysis of social equity issues of science policy. The model considers the relationships among several attributes of science and technology goods and services including the incidence of its impact, degree of concentration, and whether its consumption generates capacity for the individual or groups or is "hedonic," that is, short term and diminishing rapidly in its effects. We discuss the implications of the model in terms of four quite different types of equity. We conclude by suggesting some respects in which the model could be employed to facilitate public policy and moral deliberations about the effects of science and technology.

Keywords Science and technology policy · Equity · Public values

Introduction

Science and technology (S&T) outcomes are among the most important means of achieving the fundamental collective goals of societies, including economic growth, national security, health, and life itself (Author reference excluded; Sarewitz 1993; Woodhouse and Sarewit 2007; Watson et al. 2003). In some developing nations, the preferred science and technology (S&T) policy strategy pertains to applications in basic agriculture (Harsch 2004; United Nations 2005; Singer and Daar 2001). In most cases, though, and especially for those nations seeking to join the economically affluent first world, the preferred S&T policy strategy resembles that of the industrially developed

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nations: namely, the use of S&T to stimulate innovation and economic growth (Acharya 2007; Goldenberg 1998).

There is a wealth of literature on science to address policy issues, including the need for rapid response to S&T advancement for societal benefits. The usual metaphor for S&T societal benefit is "engine for economic growth." Policy-makers, leaders, and researchers in nearly every nation use this all-purpose term (Branscomb 1992). Since an enormous amount of literature is devoted to one or another aspect of technology/innovation/production/economic growth (for reviews see Nelson 1981; Ruttan 2001; Smith 1990), we do not address these linkages in detail in this paper.

We are more concerned that market interest for S&T sometimes overpowers our ability to think systematically about science as the engine of *social* change. We find no social change theory of science equivalent to economic growth theories of science, nor do we find an adequate parlance. While the literature on the *outcomes* of S&T is vast, the literature on the *equitable distribution* of science and technology's benefits and costs remains scant (Author reference excluded; Cozzens 2007). This gap in formal knowledge seems especially compelling if one assumes, as we do, that S&T, for all its demonstrable ability to remediate the world's direst problems, nevertheless contributes in some unfortunate ways to inequities and social, racial, gender, and individual risks (Harding 2006; Mookherjee and Ray 2003).

Let us distinguish at the outset between "equity" and "equality." There are, of course, a great many definitions for each term, and some use the terms interchangeably. When we refer to equality, our focus is on the usual meaning of equal, as in an equal share to all. This is similar to Arrow's (1971) use of the term in economics and to Lucas' (1965) use in philosophy. The authors make the point that equality is not necessarily a cardinal value and that society would not be better off with perfect equality. We agree. When we use the term "equity," we are referring to a correspondence among basic life needs (e.g., Goldstein 1985; Moon and Dixon 1985; Reader 2006) and the allocation of resources in a manner to ensure that those basic life needs or publicly warranted values are available to all members of a society. This notion of an "equitable society" does not assume equal allocation or even optimal allocation of goods, services, and values. Rather, it assumes the provision of basic needs and allocation schemes based in part on public benefit rather than exclusively on economic efficiency and private entitlement (for similar usage see Pazner and Schmeidler 1978). In terms of public value failure, our concept of equitable assumes that there will be no hoarding or capturing of goods and services deemed to serve public values (Author reference excluded). Simply put, in our parlance, equity implies fairness in distribution of resources and the provision of basic needs (for a review of literature relating equity, equality, and fairness see Konow 2003).

Our usage, which assumes a fairness basis for equity, is not at odds with concepts long employed in philosophy (e.g., Raphael 1946) and sociology (Bollen and Jackman 1985); but in economics, equity is typically defined in terms of market equilibrium (e.g., Alesina and Angeletos 2005; Varian 1975), an approach unsatisfying to "have not" nations and to the disadvantaged within national populations. For societal issues, equity means justice where the equality of treatment or access to services results in better outcomes (Sen 1973, pp. 1–2; Lievrouw and Farb 2003, p. 502). Rarely do we consider the contributions of S&T to injustice, inequities, and related negative impacts (Author reference excluded).

We are concerned with the *routine* ways in which S&T provide inequities or skewed benefits and costs. In particular, we argue that inequitable outcomes are "built-in" to the very institutions of S&T policy. In this paper, we develop a simple conceptual model to explain why, even with the best of intentions, outcomes from S&T tend to be inequitably distributed within societies. We are concerned with framing the issues, with concepts of equity, and with factors endemic to S&T that seem to determine or influence distributional outcomes of S&T. The questions we examine in this paper include

(1) What are the types of equity that one can examine with respect to the outcomes of S&T?
(2) What types and levels of equity of benefit are possible and desirable?
(3) How do characteristics of S&T interact with equity dimensions to conduce social impacts? How might these impacts be conceptualized?

Equity issues in science and technology

Policy debates with respect to S&T yield many reasons for attention to equity. Since access to science and technology information is unequal, then inequities occur in outcomes, especially for vulnerable groups such as women and racial and ethnic minorities (Woodhouse and Sarewit 2007).

We begin this analysis by endeavoring to provide an expanded view of "equity" as the concept relates to S&T. Before considering a conceptual model of S&T impacts, we need first to review accepted and related concepts of S&T equity and equality. That there are inequities in society is nothing new (Rousseau 1755); human beings are endlessly diverse, both in circumstances and aspirations (Sen 1992). That the power of S&T can overcome poverty and inequities by transferring knowledge from the rich to the poor has been the subject of many scholarly articles, especially in the development literature (for an overview, see Radošević 1999). Yet, despite a belief in the ability of S&T to remedy the most fundamental social problems, all too often the S&T "engine" fails and serves too few. Distributional inequities occur when the effects of science and technology are the result of inequalities in the distribution of science that people value (Cozzens 2007). Further, there are many new expectations for the role of S&T policy to reduce inequities in the quality of life worldwide (Woodhouse and Sarewit 2007).

We propose to examine three criteria of well-being that directly or indirectly affect the advancement of scientific knowledge and technological development. They are political equity, equity of opportunity, and basic needs fulfillment (see Table 1).

Political equity

As a democracy, America is founded on the principle that, no matter one's economic or social standing, everyone's vote counts. More generally, we hold strongly the ideal that as citizens we should have an equal say in the development of policies that affect our lives. With respect to domains of public life that rely on scientific or technological knowledge, upholding the value of political equality becomes a challenge. Some writers have maintained that ordinary citizens, lacking the requisite knowledge base to understand the complexity of scientific problems and solutions, should not be participants in technical decisions—even that such participation is dangerous because it will lead to poor decision-making (Levitt and Gross 1994). The contrary viewpoint is that it is this very perspective that results in the disenfranchisement of certain sectors of society when they are confronted with the unassailable power of scientific and technical elites (Sclove 1992). In the long run, such disenfranchisement results in state power becoming ever more linked to

Table 1 Equity concepts and linkages to S&T

Equity concepts	Instrumental values or links between equity and science and technology
Value statements	*Relevant literature and/or research in parentheses*
Political equity	Knowledge/technical capacities are necessary for engagement in political processes, specifically:
People affected by political decisions should have the opportunity to democratically participate in those decisions	Access and ability to use information technology may be needed to gather relevant information (Kellog and Mathur 2003)
	The "digital divide" (Lievrouw and Farb 2003)
	A basic understanding of scientific principles is necessary to interpret scientific and technical information (Fielder 1992; Epstein 2000; Plough and Krimsky 1990; Tesh 2000)
	Being counted/making one's voice heard may require access to knowledge or technology pathways, such as voting booths, participatory citizens' panels, and communications technologies (Kakabadse et al. 2003; Sclove 1992)
	Knowledge sharing and political empowerment may require access to and ability to utilize information and communication technologies (Epstein 2000)
	General discussion: (Kleinman 2000; Mossberger et al. 2003; Winner 1992)
Equity of opportunity	Knowledge/technical capacities are prerequisites for competitions in the marketplace, specifically:
People should have the opportunity to compete in the marketplace and reap rewards as a function of their ability and effort	Possessing adequate education to understand and be able to use workplace technologies (Solomon et al. 2002)
	Access to and ability to utilize information and communication technologies for social networking (Henwood et al. 2001; Schiller 1996; Thomas and Wyatt 2000; Warschauer 2003; Wresch 1996)
	Access to appropriate assistive technologies for the disabled (National Council on Disability 2001)
	General discussion: (Caswill and Shove 2000; Wyatt et al. 2000)
Basic needs	Knowledge/technical capacities are needed to insure people's basic needs are met, specifically:
There is a certain basic minimum that all members of society should be provided, regardless of merit	Appropriate agricultural technology to grow food and efficient and equitable systems to distribute it. (Altieri and Rosset 1999; Jordan 2002; Kimbrell 1998; Persley and Lantin 1999; Senker 2003; Shiva 1993 and 1999)
	Affordable health maintenance technologies (medicines, tests, therapies) and access to basic health information (nutrition, reproductive health, exercise) (Farmer 1999; Stepan 1978; Tesh 1998).
	Environmental health science and sanitation technologies to insure clean land, air, and water (Tesh 2000).

concentrations of industrial wealth (Winner 1992). Without checks and balances, the handing over of decision-making to technical experts and technical processes can lead to great imbalances of power (Wartofsky 1992, p. 34; also see Ellul 1967, 1992 for scathing remarks on technology's degrading influence on democracy).

Among others, Kleinman (2000) provides evidence that, at least in some cases, ordinary citizens are quite capable of intelligent participation in debates about science and technology. Nevertheless, it often takes something extra to facilitate this process. When decisions about science and technology affect people's lives, it seems all the more important to both understand the obstacles to citizen participation and to find ways to overcome them. As noted in Table 1, the opportunity to participate in political processes that concern scientific knowledge can be limited by people's scientific and educational background, by their access to and knowledge of technologies that allow them to gather and utilize the relevant knowledge, and by their access to technologies or social venues that will allow them to express or debate their political positions. These limitations do not fall equally on all segments of society: minorities, and people with low incomes and levels of education, are often at a distinct disadvantage, which can result in inequitable outcomes.

Let us briefly consider an instance in which non-scientific actors gained a significant foothold in political decision-making. Such is the case with gay AIDS activists, who between the late 1980s and the early 1990s were able to carve out a role for themselves as in determining directions for AIDS research, debating research methodologies, and allocating research funds (Epstein 2000). Their unprecedented success, which carved the way for other grassroots groups to demand similar privileges (Epstein 2000), was facilitated by the strong impact of a message of impending death as well as the fact that the AIDS activist community was at the time largely composed of well educated, middle-class white men, many of whom were doctors, scientists, or experts in related fields (Epstein 2000). Activist leaders gained positions of privilege and authority within the decision-making structure and in this case traversed the lay-expert divide, exploiting knowledge, and network connections for a common interest.

For contrast, we can consider the case of environmental justice to show how citizens with less education, money, and social standing fare in political debates. The US Environmental Protection Agency defines environmental justice as "[t]he fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies" (Kellog and Mathur 2003, p. 574). Here, we see clearly the social value for political equity embedded in institutional policy. According to Kellog and Mathur (2003), the first step to meaningful participation is access to information. Given that much of the information concerning air and water quality in various locations is available over the Internet—and indeed, that access to the information in other ways is being curtailed (Kellog and Mathur 2003), there is great potential for the creation of an "information underclass" that just does not have the ability to participate even in the decisions that may affect the health of their own neighborhoods.

Even if people are given access, there is still the question of how the information is managed and generated. Gaining access is not enough. The community must also be able to identify problems, assess data needs, identify data sources, sometimes even collect and analyze data to play a full role in the political process (Kellog and Mathur 2003). Alternatively, they need to gain the support of trained experts who can do these things. But access to expertise may be limited by lack of financial resources.

Given problems of small sample size and the local complexities, science may be of limited help in demonstrating environmental risk (Tesh 2000; see also Nelson 2003).

Plough and Krimsky (1990); see also Fielder 1992) describe the problem as a confrontation between "technical rationality" and "cultural rationality." While in some ways their model is overly simplistic, it does highlight some important barriers to poor communities' participation in the democratic process.

If individuals and groups can get over the hurdles to gaining the necessary information, they still have to make their voices heard. Again, technology presents a challenge. Kakabadse et al. (2003) present four models of "electronic democracy" and argue that there are very different outcomes in terms of citizen participation depending on the ways technology is employed in the democratic process. Differential access to communications technology may also affect a communities' ability to develop powerful political coalitions. In the case of AIDS activists, they were well networked and equipped with the latest technology. This is not always the case with other social advocacy groups.

There are putative solutions to political resources and political equity pertaining to S&T outcomes. For example, the Loka Institute, based in Claremont, California, works to embed political equity in the scientific process,[1] as do advocates of participatory action research and "science shops" (Wachelder 2003; Zaal and Leydesdorff 1987). Caswill and Shove (2000), as well as Schensul (2002) make the case for adopting an interactive methodology in the social sciences.

Equity of opportunity

While political equity speaks to a social commitment that people be given an equal opportunity to express themselves as citizens, the ideal of equity of opportunity speaks to the ability of individuals to express themselves and to pursue individual interests. Arguably, the predominant means of self-expression in the US is in the market, as producers or consumers. While we clearly do not subscribe to any notion of equality in allocating jobs, incomes, and consumer goods, we nevertheless hold a social ideal that individuals should compete for resources on a level playing field. Indeed, it is our allegiance to the ideal of equal opportunity that serves as a justification for many of society's inequitable outcomes. Institutions support the equality of opportunity ideal. For example, the Equal Employment Opportunity Commission seeks the ideal in the workplace and the Department of Housing and Urban Development's Office of Equal Opportunity seeks to assure fairness in the allocation of housing dollars.

Perhaps, the cornerstone of equal opportunity for Americans is the commitment to providing young people a quality education, regardless of their economic status. The challenge of providing equal opportunities is greater if we consider how individuals' past disparities affect the ability to attain education (Cook and Hegtvedt 1983). The concept of equity of opportunity is complex and any study should take into account the role of historical antecedents and other mitigating factors that can have subtle influences on the accessibility of various "opportunities" (Cook and Hegtvedt 1983).

In no instance, do antecedent disparities affect opportunity more than S&T pursuits. When combined with preexisting disparities in income, education, and social position, science and technology have the potential to greatly increase these disparities. The primary area that researchers have focused on with respect to equity of opportunity is the "digital divide." It is argued that the ability to access, adapt, and create knowledge using information technologies is essential for both economic advancement and social inclusion

[1] See their website at www.loka.org.

(Warschauer 2003). The evidence is substantial that both abilities and access are inequitably distributed (Schiller 1996; Warschauer 2003; Wresch 1996; Thomas and Wyatt 2000). From the literature, two aspects of the digital divide arise as warranting further exploration. The first aspect derives from research which indicates that it is not only access to information and communications technologies that matter, but whether or not one possesses the ability to use the technology for activities that will further one's social or economic standing. Several researchers argue that even when access is relatively equal, disparities in ability results in a clear dividing line between the haves and the have-nots (Mossberger et al. 2003; Thomas and Wyatt 2000). This points to a deeper cause: disparities in education levels between students of different income levels and of different races. As documented by Jonathon Kozol (1991), dollar expenditures on education per child can vary drastically between poorer and wealthier communities, and often along race lines as well:

> There is a certain grim aesthetic in the almost perfect upward scaling of expenditures from the poorest of the poor to the richest of the rich within the New York City area: $5,590 for the children of the Bronx and Harlem, $6,340 for the non-white kids of Roosevelt, $6,400 for the black kids of Mount Vernon, $7,400 for the slightly better-off community of Younkers, over $11,000 for the very lucky children of Manhasset, Jericho and Great Neck (Kozol 1991, pp. 122–23).

Solomon et al. (2002) explore the issue of "digital equity" at all levels in the educational system, from funding decisions to classroom techniques. Some argue that as technology gets cheaper and people catch up to technology, the digital divide will disappear. Others argue that the gap may actually be increasing as informational disparities reinforce and strengthen preexisting structural inequalities (Lievrouw and Farb 2003). Of particular relevance, here are the ways in which commercialization of information technologies may function to increase gaps in access and ability, and disenfranchise different groups within society (Schiller 1996).

Basic needs fulfillment

The notion of equity that underlies America's welfare and Social Security programs is the idea that all members of a given society should be provided with a "social minimum" set at a level to meet an individual's basic needs (Morris 1979; Meeker and Elliot 1987; Scott et al. 2001). Of course, S&T has the potential to satisfy basic needs, for example through agricultural technology or water purification; likewise, S&T has the capacity to threaten basic needs, for example through pollution of the water supply, or, in the most drastic scenario, nuclear annihilation.

In many instances, the relationships between technical and social equity are often difficult to sort out. For example, agricultural biotechnology has clearly reduced hunger, due to its potential to produce more food on less acreage of land, with less inputs of fertilizer (Rauch 2003). Nevertheless, there is a strong and growing body of literature that suggests that food shortages are rarely the result of inadequate production, but of inadequate distribution systems (Altieri and Rosset 1999; Jordan 2002; Kimbrell 1998; Poynter and De Miranda 2000; Shiva 1993, 1999). While reducing some world hunger, capital heavy agricultural biotechnology is not a solution to all social ills. For example, it favors large-scale export farming over small-scale subsistence farming, thus decreasing the ability of the world's poorest people to provide for themselves and their families. Expanding this argument, we can see a pattern related to equity developing: advanced technology is advocated as a way to meet people's basic needs, but the way the resulting technology is applied functions to reinforce or increase disparities.

A key question that emerges then is how to determine when technology is the problem, the solution, both, or neither with respect to cure of social inequities. In medicine, there is ample evidence that the greatest advances are in areas where the commercial market is strong. By definition, these are not the areas that serve the poor (Woodhouse and Sarewit 2007). The fact that S&T plays out in the market and that, consequently, the affluent benefit does not imply damage, but rather a maldistribution of benefits.

A simple model of S&T impacts

Having argued that equity has multiple concepts relevant to S&T, we move to developing a simple conceptual model to categorize and perhaps better understand S&T impacts. In a later section, we connect this conceptual model to the equity typology provided above. The purpose of our paper is to present a model to test S&T outcomes on social outcomes, ultimately providing propositions that could inform public policy and public debate.

Our simple model of S&T impacts, presented in Fig. 1, includes two dimensions, one pertaining to the *distribution of impacts* (with "social impacts" at one pole and "individual impacts" at the other pole) and the second pertaining to the *potency of impacts* (with "capacity impact" at one pole and "hedonic impact" at the other.

Distribution of impacts: social or individual

Following the figure, we can identify two categories of "S&T Incidence of Impact," individual and social. "Individual Impact" implies that effects of S&T, in any given case, are confined to one person. In "Social Impact," the impacts are distributed and, thus, one can consider the equity of the distribution of impacts. An interesting issue, one not

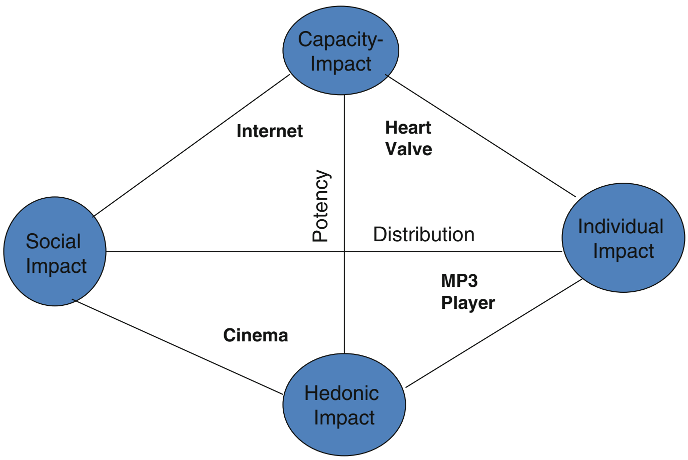

Fig. 1 S&T social impact model

accommodated by the model, is whether any S&T impact is entirely confined to one person. We will return to that question below.

Distribution of S&T impacts: individual versus social

Making distinctions between individual and social impact is sometimes quite difficult. Perhaps, the best way to make the point is to provide simple examples. If we observe an individual wearing a set of headphones attached to an IPod or some other MP3 player, we can infer that the impact of the technology's use is on the individual. In most instances, others would not know whether the IPod was actually operating and, even if one noticed an "on" light, it would not be possible to know whether music was playing or the device was simply in the "on" position.

This example is as close as one gets of a pure type individual impact of a technology's use. But even this example illustrates the complications of conceptualizing use and impact in S&T. First, as anyone who rides urban subways knows, MP3 players and other music devices are often played at such a high volume that those nearby can hear every note. That is, even in the direct and immediate act of using the technology, the user can easily generate impacts on others. To take the distinction to a next level, one could argue that even when the IPod player is played at a low level, so low that no one else can hear it, and even when the IPod listener does not hum, dance, or engage in other potentially annoying behaviors, there is *still* potential for spillovers from the use of the technology. Another subway rider might well feel that his or her sense of community and well-being is diminished if fellow commuters are so engaged in their IPod listening that the most meager communication (e.g., "excuse me, I am exiting at this stop") is impeded. Other implications are more technical, such as the propensity to share music, the reliance of some such devices on open source software, and the many more social interconnections that occur when our device is not a limited use IPod but a much broader use, socially embedded IPhone or Blackberry. Moreover, even considering simple cases, it is nearly impossible to think of instances in which the consumption and impacts of S&T goods are entirely exclusive to the individual.

Despite these complexities, they need not be of great concern to the objective of conceptualizing S&T for the purpose of understanding distributional impacts. In examining the public goods characteristics of physical and social commodities, economists long ago showed us that there are few goods that are either purely public or purely private but that does not mean that the conceptualization is without merit (see for example Goldin 1977; Mueller 1976). We can all understand that an individual listening to an IPod, the social context of the act notwithstanding has a different sort of impact than, say, the subway transportation system itself. In the first case, the interaction between the individual and the technology is primary (even if in a social context) and, once the technology is purchased and batteries are inserted, depends upon little else: only the music the individual has previously downloaded or purchased. In the second case, the use of the subway depends upon a series of operators, attendants, and energy providers who work cooperatively and will not function for long in the absence of a series of support structures including safety inspectors, fare collectors, and such. On the individual-social dimension, the IPod is at one extreme and the subway system at the other. The fact that there is a social context to the IPod, depending as it does on production and upon content for its use, implies that it is not a pure and autonomous technology; perhaps, none is purely private. But it is not difficult to see that the social dependence and private consumption dynamics are quite different than in the intensive technology (Thompson 1967) of the subway.

Patently, the most concentrated S&T impact is when its impact is on just one individual. However, if the impacts of S&T are distributed beyond the individual, then we can ask the extent to which impacts are concentrated (or dispersed) across an aggregation, such as a social or demographic group, a nation, or even humankind. This leads, in turn, to other questions bearing on the equity of S&T impacts. To illustrate a question that arises when we consider the degree of dispersion from distributed benefits: "who benefits from the building of a new coal-fired electrical power plant?" The answer to the question depends upon the definition of benefit, but if what we mean by benefit is cheaper consumer electricity rates then the dispersion concentration question is amenable to an easy answer. We can identify particular individuals whose electricity rates decline as a result of the new plant coming online. The distributional (and equity) issues pertaining to social costs or "disbenefits" are much more complicated. Thus, we might ask, "Who bears the brunt of the air pollution resulting from a new coal-fired electrical power plant?"

From this example, one can envision an increasingly complex set of distributional issues bearing on the equity of S&T outcomes. Thus, one might ask about the *magnitude* of impacts in relation to distribution; if we identify those who suffer negative externalities from pollution, it is quite likely some suffer more than others. If we have knowledge of who sustains benefits and costs, we can presumably calculate the *incidence* of these benefits and costs within particular aggregations, perhaps plotting the incidence by geographic location or demographic attributes.

Potency of S&T impact: capacity versus hedonic

The issue of impact potency relates to the ability of technology to enable multiple uses or applications. At one extreme is a pure hedonic impact in which an S&T output is fully consumable by the individual and its use stimulates no new applications or capabilities. To return to the previous example, listening to music on an IPod player would in most instances represent a pure hedonic impact. That is, the use of the technology is consumed fully in the enjoyment of the music. Even if the IPod has a dock and several people are listening, the potency remains hedonic because the impact is fully consumed and generates no new uses or applications.

By contrast, many technologies are enabling and build capacity in that they permit the performance of additional tasks or pursue other technological applications and, in that sense, the technology application is not fully consumed by any single impact. A good example is a computer. By using a computer the individual can, among other things, make online purchases, manage personal finances, communicate with friends and strangers, play computer games, engage in Internet banking, study a foreign language, and apply online for admission to universities. This is, then, a classic enabling technology. The social policies derived from this distinction seem clear enough. As far as we know, there are no public policies aimed at ensuring wider distribution of MP3 players, but there are many aimed at providing computers or computer access. The social benefit from access to computers may be considerable while, in most cases, the social benefit accruing from MP3 access is much less. But the capacity value of these technologies, and most developing, widely dispersed technologies, changes and in some cases changes rapidly.

The IPod, or any MP3 player, provides an excellent illustration of the ways in which the capacity impacts of technologies evolve with the technology itself. Early generation MP3 players were simple devices for playing music. But the technology has developed and so has its capacity. Many courses of instruction, including ones for college credit, are now provided via podcasts. The emergence of smartphones has likewise been instructive. Mobile phones have in a short time evolved from a relatively simple (at least from a use standpoint) technology for telephonic communication to an all-purpose technology with applications ranging from accounting, to emergency management, to dietary planning, just to name a few of the more than 100,000 (and still counting) officially recognized applications (O'Brien 2009).

The implications of S&T potency are not clear-cut. Most S&T impacts are neither purely hedonic nor purely capacity enabling, at least not inherently. Thus, in the case of the MP3 player, the music student may use the player to help build familiarity with music he or she intends to perform and, in that sense, it is enabling. Similarly, if one uses computers *only* for electronic games, then the application is hedonic. Many technology uses are both hedonic and capacity building in their impacts, and it is the particular mix (i.e., more hedonic, less hedonic, more capacity, or less) that is of interest. Thus, the Internet can be capacity enabling in a great many respects but it can also be a source of small pleasures of playing online solitaire or just Internet surfing for its own sake. In a single impact or use of S&T, it can *simultaneously* be hedonic and capacity enabling. Thus, an elderly computer user can play computer-based word games for the sheer fun of it while, at the same time, believing that this same act builds (or retains) capacity by helping stem the onset of Alzheimer's.

Relationship of S&T impact and distribution

Let us consider the dimensions of distribution and impact type together. Figure 1 above shows the possibility of locating particular technologies on a grid composed of the intersecting dimensions pertaining to the use of S&T. The particular location of technologies is, of course, highly contestable, but the examples are nonetheless suggestive. The Internet seems to us best described as *Social/Capacity (SC)* technology. It is social in the sense that its very existence requires "mediating technology" (Thompson 1967), the linkage of users and providers. It is not *necessarily* a capacity technology—"surfing" for its own sake is common—but it is *often* a capacity-building tool. We consider the heart valve as *Individual/Capacity (IC)* technology because its applications are clearly on the individual (heart valves are neither shared nor used simultaneously by two or more persons) and it is certainly enabling inasmuch as the very life of the individual (and all activities of life) may critically depend upon it.

In Fig. 1, the MP3 player is viewed as *Individual/Hedonic (HI)* because most of its impacts accrue to individual users and typically the impact entails short-term consumption rather than longer-term capacity enabling impacts. Similarly, the cinema is a *Social/Hedonic (SI)* technology because its impacts are generally consumed simultaneously by many but with just a single application of the movie. If the movie is watched, as most are, for entertainment value, then it is hedonic in the sense that it confers no longer-term capacity, except, perhaps, enhancing one's ability to provide clever conversation.

Perhaps, the most complex among our complex examples is the case of the personal computer (PC). We have placed the PC at the intersection of the two dimensions because the technology lends itself to such a diversity of applications and impacts. One can engage in thousands of solitary uses, but one can likewise engage in many uses that require interaction with others. One can use personal computers for the most advanced educational and creative applications, but one can also use the PC for sundry entertainment or aesthetic applications. It is the ultimate chimera technology and, thus, we term it a *Mixed Use/Mixed Impact* technology.

Implications of a simple model of S&T impacts

If the model of S&T impacts contributes to discourse about the nature of technology and its application, then we have (if we may be self-referential) generated an "enabling" tool. We feel that the typology may be of some use in generating propositions about S&T impacts, propositions potentially relevant to policy deliberations about S&T investments and impacts. For example, the typology can be used to show why some technology types may prove better public investments than others and, relatedly, how the value of technologies change over time and circumstance. Thus, the mobile phone has evolved from an S&T commodity whose chief user value was simply convenient mobile communication to a device that is essentially a "computer in the pocket." It has gone from great economic importance and significant but limited social importance to even greater economic importance and diverse and rich social utility. Yet, despite this evolution, the extent to which the technology, now much more powerful, remains largely Individual/Hedonic in its impacts makes it a weak candidate for public value (Author reference excluded) or public investment. By contrast, the Internet provides a much more compelling case for public value and public investment. Indeed, just recently the government of Finland appears to have taken the step of elevating Internet access to a legitimated, fundamental human right (Cross 2009).

For consideration with respect to public policy, the heart valve provides an interesting S&T Impact type and our model illustrates an important implication of the technology: namely, that policies based purely on political economy rationale are insufficient to the challenge of understanding and deploying S&T (see Author reference excluded). Given the current state of health disparities and the primary components of health care reform initiatives, we can expect that poorer people are less likely to have heart valves than richer people. Given that the heart valve is among a set of "ultimate" enabling technologies (i.e., those required for sustaining life), the arguments for public provision are strong *even though the heart valve is also a pure private good*. The fact that user pricing of the heart valve involves little inefficiency and that providers can fully appropriate the profits from the sale of heart valves is not a sufficient argument to stem government "intervention" (Portner 2001). Focusing on the distributional impacts of S&T often provides a quite different set of policy heuristics than one derives from focusing exclusively on issues of production and pricing efficiency.

Intersection of distribution with equity

Figure 2 provides a view of an expanded S&T Social Impact model, one taking into consideration the potency and the distribution dimensions, and also the equity dimensions developed in the previous section.

Implicit in the S&T social impacts models is that pure equality of S&T impact distribution, even when possible, is not always desirable. As before, we distinguish between equality (equal distribution) and equity (distribution taking into account basic needs and fairness). An obvious example: society seems not to fret that breast cancer remediation

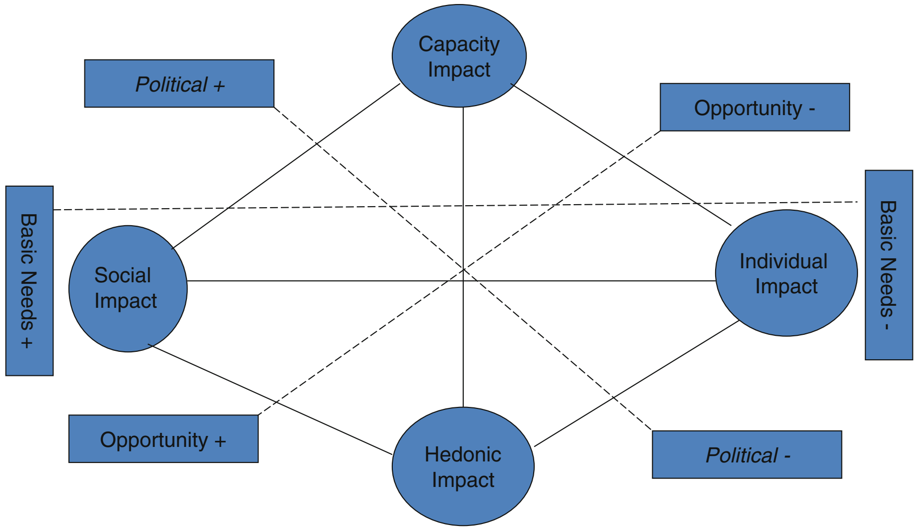

Fig. 2 Expanded S&T social impact model

S&T is disproportionately (i.e., unequally) directed to women. Men get breast cancer and, when they do, it is more likely to be fatal (Giordano et al. 2002), but the incidence is so low that the disproportionate allocation of resources to women seems to address a more common basic need and to be more fair (i.e., equitable). The 1,500 US cases of breast cancer experienced each year on average by US males pale against the nearly 200,000 cases diagnosed in women each year (American Cancer Society 2008). In this case, allocating S&T resources *equally* between men and women would—by our definition—be *inequitable.*

Let us consider the relation of equity to relative deprivation. In many instances, relative deprivation is coincident with wealth and income, but in some cases, it is not. Economically advantaged people of African descent nonetheless suffer relative deprivation with respect to incidence of sickle cell anemia. Similarly, the genetic roulette that determines who has such diseases as cancer has little to do with wealth and income. In some cases, the normative distributional issues become quickly complicated. A case in point: in the US white women are someone more likely than women of African descent to have breast cancer, but black women are more likely to die from it. The group most likely to die from breast cancer, once contracted, is white men; but, as we note above, their incidence is just a small fraction of the incidence for women. Policy question: what does this interaction of prevalence versus severity imply for policies aimed at redressing S&T distributional inequities?

Conclusions: S&T equity reformulated

Doubtless, the benefits and costs of US S&T are not equitably distributed. The root causes of the inequitable distribution are deeply etched in the grain of US history and political culture (Author reference excluded) as well as the norms and practices of S&T production and dissemination.

The conundrum seems to be this: given that full equality (i.e., equal allocation) is neither possible nor in some instances desirable, how do we (citizens and policy-makers) best ensure a more equitable (i.e., fair and accounting for basic needs) set of outcomes from S&T? Most current policies seem implicitly to cling to the long-standing "trickle down" ethos, assuming, or perhaps hoping, that ultimately S&T will benefit all. Allocation issues often get pushed to the end of the policy agenda or do not appear on the agenda at all. There is perhaps fear that we risk killing the golden goose by overtly directing S&T and, in our ignorance, doing irreparable harm to the vitality and autonomy of science.

In our view, this is a false choice. Even if some accounts of the S&T enterprise raise dire warnings of social tinkering, the fact remains that policy-makers and political leaders do this all the time. For example, if one looks at the largest science establishment in the US, the National Institutes of Health, one finds that planning statements such as *Healthy People* 2010 (USDHHS 2010) not only provide explicit objectives and priorities for S&T but also recognize straightforwardly the distribution issues entailed. NIH takes it as an objective to serve disadvantaged populations, often specifying particular populations with respect to particular objectives. In some instances, these distributional issues relate to differential disease impacts, but in others, they are more a matter of historical differences in access to medical care and medical technology or redresses of apparent disparities occurring due to inequity in clinical trials. The extent to which distributional objectives are achieved is unclear (for example, despite explicit objectives, little progress has been made in reducing breast cancer mortality rates among black women) but the possibility of having distributional issues drive policy is clear enough.

In previous decades, US S&T policy made clear choices about distributional issues, even if the choices were not always well articulated in policy documents. Consider the following distributional choices made by S&T policy-makers, some in past years, some continuing today:

1. The predominance of white males in clinical trials (a de facto distributional choice);
2. Minimal funds devoted to "diseases of the poor," including tuberculosis and malaria, as compared to diseases affecting a fraction of the people (but ones who vote and have strong associational interest groups);
3. Increasing funds allocated to high end, enormously expensive medical technology that can only be afforded by those with excellent private insurance;
4. Placement of garbage burning incineration plants in low-income neighborhoods;
5. R&D tax credits (for profitable, "high technology" business).

Thus, there is no reluctance to make S&T policy decisions that have a strong distributional component. But S&T policy analysis and evaluation generally focus less on these distributional issues, partly because the analytical tools available for evaluating S&T are, for the most part, rooted in economics and oriented to analysis of production and pricing efficiencies rather than distributional issues. By developing new ways of thinking about distributional impacts, and relating aspects of S&T to its deployment, perhaps, it will at some point be easier to bring distributional S&T policy issues into the light—even at the point, decisions and choices are being made.

Models of S&T impacts distribution can, potentially, be of use to policy-makers who have need for conceptual tools to assist in moving from near exclusive analysis of production and pricing for S&T to distribution questions. But even if such crude models as we present here help frame issues, they are no substitute for testable propositions about impacts distribution and maldistribution. We have taken pains to demonstrate that equity issues are more complex than they seem at first blush and that inequality is not invariably undesirable. But it is important to emphasize that unequal distribution is not the same as *inequity* and, moreover, that inequity certainly is not random. Generally speaking, it is the poor and the disenfranchised that suffer inequity with respect to both the costs and benefits of science. In some cases, this seems to relate to the structural inequalities in the economy, but there are many other factors at work as well. For example, discrimination based on gender, race, national origin, and sexual preference often does not track purely economic lines but can be an important element of inequity.

The most important research agenda for analysis of distributional impacts of S&T pertains to the *causes* of inequity. Whereas distribution is neutral, inequity pertains to abridgement of basic needs, opportunity, health, and political access and voice. Of the many different potential causes of inequity, the ones that merit particular attention are those stemming from the internal characteristics of science and technology as an institution. If there are structural inequalities in the economy that affect the distribution and absorption of S&T impacts, then the remedies are likely economic and political. However, causes owing to structures, processes, and institutions of S&T may be even more pernicious and may be more difficult to identify and to address. For example:

- Do peer review and the emphasis on the quality of research mitigate the focus on social benefit and the distribution of benefits?
- Do the social structures and the social capital deployed by scientists and engineers systematically militate against the recruitment and advancement of minorities and women?
- Compared to civilian technology, does a focus on defense and national security technology, and the "dual use" technologies that accrue, tend to provide less benefit to the disadvantaged?
- What are the impacts of labor saving technologies on jobs usually occupied by the poor?
- Does the increasing interdependence of technology systems mean that once the disadvantaged are shut in one domain that they are necessarily shut out of another?
- Do advances in linkage technologies (e.g., banking and financial services) further disempower the poor?
- Do technologies, including medical technologies, allow the rich to wall themselves from the poor and thereby reduce attention to issues that once affected the general public?
- What is the relationship between the often substandard elementary and secondary education available to the disadvantaged and the ability to recruit scientific talent from their ranks?
- Do the reward systems of the S&T community reward publication more than impact and intellectual impact more than social and economic impact? If so, does this give rise to inequity?

None of these questions have easy answers, but one need not be an enemy of science to think they are worthy of more attention than they receive. In the US, as elsewhere, a capitalistic economy is set up precisely to insure inequality and sometimes this inequality results in structural inequities. But inequity is not an aspiration for science and technology. Most Americans seem to cling to the notion that science and technology are enablers, lifting the quality of life of all citizens—not exacerbating gaps among citizens and not creating further disadvantage. By developing better knowledge about the distribution of S&T impacts, perhaps, we can take steps to insure that S&T comes closer to our expectations.

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