Distributional Assessment of Emerging Technologies: A framework for analysis[1]

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Introduction

The debate over rising global inequality is intense. The new U.S. Treasury Secretary has acknowledged the challenge of growing household income inequality in the U.S. (Trumbull 2006), and the same situation is widespread across OECD countries. Galbraith and his colleagues have examined inequality in manufacturing wages within a large set of developed and developing countries over four years and demonstrate a widespread upward trend (Galbraith and Lu 2001). At global level, the UN's report on the world social situation in 2005

> … sounds alarm over persistent and deepening inequality worldwide, focusing on the chasm between the formal and informal economies, the widening gap between skilled and unskilled workers, the growing disparities in health, education and opportunities for social, economic and political participation… (United Nations 2006).

Yet the trend in GNP inequality between countries is either up or down, depending on whether the size of countries is taken into account along with average incomes, and the best estimates of global inequality among individuals show very high inequality levels and a bifurcated distribution, but no clear upward or downward trend (Milanovic 2005).

Technology is often portrayed as deepening the trend towards inequality, even when it is not the main force creating it. For example, Castells (1996) portrays a new networked society that creates a few high-wage jobs and many low-wage ones. Ghose (2003) attributes the shift of manufacturing jobs out of the OECD economies to technology-related decreases in communication and transportation costs; and others in turn attribute the hollowing out of wage structures in OECD countries in part to that shift. Some economists accept a hypothesis called skill-biased technological change, the idea that IT-induced increasing demand for higher and higher skills levels is driving apart the wages of more and less educated workers within countries (Acemoglu 2002). But others are critical of the notion and attribute the trends to other factors (Krugman 2006, Galbraith 1998).

In the complex dynamics of inequality, science and technology policies play various roles (Cozzens, Bobb, and Bortagaray 2002). Diffusion of technologies, encouraged by policy in many countries, includes the IT-intensive upgrading that creates skill-biased wage differentials. *Innovation policies* that encourage the introduction of new products and processes claim to contribute to economic growth for particular regions or countries through the monopoly rents the innovations command, a process that some see as favoring countries that are already affluent. *Research policies*, which encourage the production of new knowledge, increasingly emphasize adjusting research agendas to the needs of innovating industries, and are thus more and more implicated over time in the inequalities that innovation produces. Yet because research policies are set in the public sphere, they are also often the object of attempts by disadvantaged groups to increase knowledge about solutions to their own problems. *Human resource policies*, which attempt to assure an adequate supply of scientists and engineers for an innovating economy, are caught in the tension between egalitarian domestic objectives and the need to compete for top talent on a global market.

When the analysis moves to the level of specific technologies, we see that potential distributional impacts vary a great deal from area to area and that complex relationships among policies contribute to those results. In agricultural biotechnology, for example, proponents argue that the new crops will reduce poverty and increase food security, while skeptics worry about the effects on small farmers and the dominance of agribusiness in setting the research agenda (Altieri and Rosset 1999, Pinstrup-Anderson and Cohen 2000, Senker 2000). In health biotechnology, the cost of access to therapies is a major concern and the policy arena is often, although not always, intellectual property (Resnick 1999). The literature on the Internet is full of discussions of digital divides, referring primarily to differences in levels of access (Baskaran and Muchie 2006), while the literature on the social impact of mobile phones features examples of wide access, expanding social networks, and opportunities for micro-entrepreneurship for the poor (InfoDev 2003, Yunus 1999).

This paper focuses on the distributional consequences of emerging technologies, a place where research and innovation policy meet. The paper combines hypotheses on the consequences of emerging technologies for inequalities into a framework that can be used to analyze specific situations. Our immediate goal is to think carefully enough about the connections between emerging technologies, public and private policies, and a variety of inequalities to be able to study those connections. Our ultimate goal is to develop options for decision makers in the private and public sectors to help emerging technologies reduce rather than increase inequalities.

The next section of the paper defines terms and outlines assumptions and concepts. The following four sections address the variables in the qualitative model we are trying to build:

- the dependent variable, *distributional consequences*;
- the independent variable, *technological projects*; and
- the mediating variables, *national characteristics* and *public interventions*.

Each of the last three sections introduces hypotheses about the influence of the independent variable on the dependent variable as affected by the mediating ones. The final section draws the proposed hypotheses into an intervention model with greater equality as the goal.

Terms, concepts, assumptions

The term **"emerging technology"** is seldom defined in the literature. In a recent project (Cozzens et al. 2005), we mined the literature for common elements in the use of the term, and found that four characteristics form the core of the concept. An emerging technology is *new*, *science-based*, *expanding rapidly*, and *showing significant market potential*. The affluent countries of the world compete with each other for market position in relation to these technologies; and experts recommend that countries in the developing world build and maintain capacity in the skills required for emerging technologies, so that they are not left out of global technological change (Task Force 2005). Many countries of the world are already focusing their efforts on building these capabilities in the areas the U.N. report names: biotechnology, information and communication technologies (ICTs), and nanotechnology. Our research in this area will examine the experiences with ICTS and with biotechnologies (specifically health and agricultural biotechnologies, the main applications) in order to develop a framework for thinking about distributional consequences of nanotechnologies.

What attracts these countries to emerging technologies also attracts our attention as analysts. To articulate technological choices that affect distributional consequences, there is no better place to look than new technologies that are still open to shaping. The science base of emerging technologies means that public sector choices may be closely tied to the new technological capabilities. The characteristics of rapid expansion and significant market potential mean that if we can design ways to use emerging technologies to increase equality, we can have a significant influence. Finally, emerging technologies are the ones most likely to increase inequalities, for several reasons. First, the science base also means that production and perhaps distribution processes are likely to demand the high levels of skills that are thought to increase wage inequality. Second, by definition, emerging technologies are among those that are likely to command monopoly rents and thus perhaps be marketed at high costs, potentially increasing inequalities in access and distributing benefits unevenly.

By **distributional consequences**, we mean the effects of the technologies on inequalities in the distribution of things people value. As we discuss in the next section, inequalities can appear in many aspects of well being: income, health, education, social capital, cultural expression, or political power. There are inequalities in well-being between countries as well as within countries. In this part of our work, we focus first on the relationships between emerging technologies and inequalities within countries, turning to the implications of those findings for inequalities between countries only at the end of our analysis. Within countries, we are interested in both vertical and horizontal inequalities. Vertical inequalities are differences in the distribution of wages, income, or other valued items that vary by income level, such as health (Wilkinson 1996). Horizontal inequalities are differences in the distribution of valued items that occur between culturally-defined groups, such as genders, ethnicities, and regions. Inequality in well-being in a society appears in both dimensions, and the distributional consequences of emerging technologies appear in both dimensions as well.

We operate with the assumption that emerging technologies are primarily developed, produced, and marketed by the private sector. A country can be the site of **invention, production, or consumption** of the technology, or any combination. Impacts, including distributional consequences, may come through any of these routes. Invention and development are often associated with ownership of intellectual property and the accumulation of wealth. Production, sales, and distribution of technologies create jobs, for instance, those created in the electronics industry or to provide mobile phone services in developing economies. Business consumption, however, if it "increases productivity," can eliminate jobs. Mass consumption can improve well-being, for example, when biotechnology crops lower food prices for the urban poor. All these activities take place in the private sector.

But **public investments and decisions** stimulate and shape technology in the private sector in important ways. Because emerging technologies draw on a science base, public research efforts are often an important element of the environment that stimulates and supports firms to develop them, and those efforts can be directed to technologies that benefit the poor in particular. Public policies may provide incentives for research and development in private firms, or complementary investments for the location of production facilities. These policies can have distributional consequences, such as when intellectual property policies set the rules for accumulation of wealth by some at the expense of others, or investments that affect location decisions of firms benefit urban rather than rural citizens. Government consumption may improve public services, including health and education, which help the poor be increasing their capacity to participate in the market. Regulations may play a stimulating role, as in the application of biotechnology in environmentally friendly production processes. Some of the industries that are central to the use of emerging technologies are public utilities, as in the case of ICTs and the telecommunications industry. In short, emerging technologies operate in environments in which public and private sectors are both important actors, with influences combined in complex ways.

We assume that different technologies have different distributional consequences and that they are malleable, with characteristics determined in the interaction between developers, investors, markets, and regulators. To avoid reifying the characteristics of technologies in our analysis, we will use the term **technological projects** rather than technologies in our analysis. *Our first general hypothesis is that technological projects are always inherently distributional, and that the distributional aspects of individual projects and portfolios of projects are open to choice.* We seek to characterize the early stages of technological projects to begin to project those differences and illuminate **development choices** with distributional consequences. Our research is thus part of the overall effort in constructive technology assessment (Rip 1995, Smits 1995), processes that open broader input on technologies at early stages of development rather than blocking or opposing them once marketing and sales begin.

Our second general hypothesis is that the same technological project under different policy conditions will have different distributional consequences, that is, **public interventions** can influence how the benefits and costs of the technological project are shared. Science and technology policies are characterized by a variety of distributional ethics (Cozzens 2006b). We distinguish in this paper among four general distributional approaches in science and technology policies:

- ***utilitarian approaches***, which focus on using science and technology to increase economic growth without specific attention to assuring that the benefits of growth are distributed widely;
- ***pro-poor approaches***, targeted to reducing poverty or the conditions associated with poverty, for example, by developing AIDS drugs;
- ***equalizing approaches***, aimed at reducing vertical inequalities, for example, by generating middle-income jobs; and
- ***egalitarian approaches***, aimed at reducing horizontal inequalities, for example, by leveling the playing field for historically disadvantaged groups.

Following Lowi, we will refer to the last three together as *re-distributional approaches*.

Although the utilitarian approach is dominant in science and technology policies in the North, some re-distributional policies and programs can be found in OECD countries. But our experience suggests that S&T policies in the developing world, where inequality is often sharper and poverty deeper, are much more likely to include re-distributional elements. Note that in the context of science and technology policies, all the approaches aim to "grow the pie," in the American phrase. They are all pro-science and pro-innovation. The difference among them is in how they want the new growth distributed. The utilitarian approach is silent on the distribution of the benefits of growth. The others are designed to distribute the benefits of growth in ways that produce a more equal future society.

Our third general hypothesis concerns national contexts. *In different national contexts, we hypothesize that the same technological project will have different distributional consequences, even under similar policy circumstances.* Thus both development choices and public interventions must take variations in **national contexts** into account if they want to achieve re-distributional effects. For example, national contexts vary in their industrial structures, urbanization, educational levels, economic inequality, ethnic fractionalization, and governance. Cozzens (2006a) argues that the same S&T policy, such as high-technology economic development or intellectual property regulations, will have different consequences in different national contexts because of these differences.

Our longer-term research program is aimed at understanding the connections among these factors: technological projects, contexts, policies, and consequences. The remainder of this paper attempts to develop specific hypotheses about the connections.

Consequences

Having sketched in the broad outlines, we are now prepared to focus in more detail on characterizing the elements of the framework, beginning with the dependent variable, distributional consequences, defined above. We have deliberately chosen this phrase over the more commonly-used term <u>impact</u>. The field of science and technology studies has largely abandoned the use of the word <u>impact</u> with regard to technology because it carries implications of reified technologies and one-way causation – implications we have tried explicitly to avoid. Policy and evaluation studies, on the other hand, use the term <u>impact</u> in a very technical sense, as the end of a (one-way, causal) chain that moves through inputs, activities, outputs, and outcomes to impacts (see Cozzens 1997 for one form of this "logic model"). Significantly, outcomes are generally taken to be within the sphere of influence of government policies and programs in this model, but impacts are beyond that sphere of influence, taking place in a wider world of complex interactions which policies and programs enter but do not control. Outcomes are therefore the intended consequences of policies and programs, and impacts include the unintended consequences. In this scheme, it is easy to place inequalities in the category of unintended consequences of science and technology policies and leave them to other policies to deal with it. This is the essence of the utilitarian approach (Cozzens 2006b).

Are distributional consequences beyond the control or even influence of science and technology policies and programs? That is a key question to be answered empirically as our research proceeds. What is clear is that the literatures on ICTs and biotechnologies discuss quite a wide range of potential distributional consequences. At this stage of the research, we are simply gathering those for further analysis, grouping them into vertical and horizontal effects, and noting whether they are associated with invention, production, or consumption of the new technology, the three main roles we indicated a country might play with regard to an emerging technology. The matrix might be pictured as follows:

Consequences of Technology X…

	In this dimension →	
Associated with ↓	Vertical	Horizontal
Invention		
Production		
Consumption		

Economic consequences are the ones most commonly discussed under the rubric of "inequality." Invention generates intellectual property which is in turn associated with wealth. Individuals who made their fortunes in the ICT industry often feature on the lists used to illustrate vertical economic disparities. The pharmaceutical industry, where health biotechnology plays its largest role, would probably reveal similar patterns based on similar dynamics, but seems to receive less attention in the literature. In agricultural biotechnology, however, we find competing dynamics: on the one hand, an agro-food industry gathering wealth through knowledge ownership, and on the other, a strong public research system with a tradition of producing new strains and varieties as public goods. The international agricultural research institutions, for example, have an explicitly pro-poor research policy, and are investing in expertise in intellectual property in order to protect their global public goods from being appropriated privately.

Galbraith and Hale (2004) have vividly illustrated one form of horizontal inequality as reflected in the accumulation of wealth in certain regions of the U.S. during the ICT industry boom of the late 1990s, when a few counties[3] pulled far away from most of the country on this measure. Likewise the regional accumulation of research and development activity, which implies high-wage jobs and their attendant multiplier effects, receives attention in the literature. Gender and ethnicity, other horizontal categories, receive almost no attention in relation to invention, research, or development in any of the emerging technologies.

The pattern is similar with regard to economic consequences associated with production activities in ICTs and biotechnologies. Countries vie to be the location of production jobs in both areas, with the general recognition that these are high quality jobs in relation to the local environment. It is hard to tell whether jobs generated in pharmaceutical manufacturing are related to modern biotechnology, but ICT production jobs have been the engine of economic growth in a number of the world's fastest expanding economies, like Ireland and Korea. The available information on multiplier effects of both these industries is good – that is, they tend to generate a fair number of other good jobs in their local economies, thus potentially having good effects in the

[3] units below the level of states in the US

vertical dimension. The horizontal dimension may be problematic, however. Even in affluent countries, some regions benefit and others tend to be left behind in high-technology production. Gender and ethnic disparities in access to high-technology jobs seem likely, but have barely been studied.[4]

Again in agricultural biotechnology, the picture is much different. Farmers are the producers, and the agricultural biotechnology seeds and strains produced by private industry are thought to be more expensive than traditional ones and therefore (perhaps) out of the reach of poor farmers. Nothing in the literature suggests that the agro-food industry is sensitive to gender or ethnic differences in production jobs in the sector. Public sector R&D organizations in agriculture, however, are quite likely to be aware of and sometimes responsive to these issues. In this case, regional differences play out in a different way: increasing productivity may eliminate jobs in the country-side, possibly increasing poverty there, but lower food prices for the urban poor (a consequence related to household consumption rather than production).

It is consumption-related consequences that get the most attention in the literature on distributional consequences of both ICTs and health biotechnologies. With ICTs, business consumption clearly gets major attention, in the form of study of the incorporation of ICTs into business processes in a wide array of other industries. Use of these technologies is widely assumed to be essential to increasing productivity and competitiveness on both local and global markets, so the utilitarian approach is virtually always to expect positive results from this “diffusion” of technology. In addition, falling costs of communication may make new industries available in some areas, such as the business services provided from the U.S. Midwest and from India. However, an increase in productivity can mean that people are put out of jobs in older industries, with effects that will vary according to national conditions (see later section). Incorporation of ICTs into business processes is associated with the skill premium phenomenon, mentioned earlier in this paper -- a negative vertical distributional effect that appears in some developed economies but is apparently swamped by other economic benefits in poorer economies that are able to grow quickly through ICT opportunities. Micro-enterprise opportunities in poor neighborhoods have also been generated by the availability of mobile phones.

In the ICT area, there is a huge literature on the Digital Divide, a phrase commonly used to refer to inequalities in access to a particular technology, for example, personal computers, Internet connections, or mobile phones. ICT access varies by income level (a vertical inequality) as well as by gender, ethnicity, and urban/rural residence. All these differences get attention in the literature, in the marketing strategies of ICT firms, and in the regulatory considerations of the public utility boards, since those boards set price regulations that affect the distribution. Likewise in the health biotechnology, high-technology drugs, diagnostics, and therapies are assumed to be higher cost and therefore reduce the range of people who can benefit from them. If higher and higher quality health care is accessible to fewer and fewer people, inequality in health care is rising.

Other consequences. In comparison with this list of potential economic tilting forces, the matrices for other sets of consequences are sparsely populated, and a wider set

[4] A co-author of this paper, Sonia Gatchair, is writing a dissertation that addresses this issue for the U.S.

of effects appears in the literature on ICTs than on the two biotechnology areas. Health consequences are clearly implicated in relation to health biotechnology in the vertical dimension through the intervening variable of price of access to new drugs and techniques: the rich are likely to get healthier and the poor not likely to benefit. ICTs, however, are projected to increase the efficiency of publicly-provided services in general, including health services, a change that would benefit the poor. In relation to agricultural biotechnology, while the environmental benefits of the new varieties are often touted, the human connection is seldom noted. Agricultural workers are more likely to benefit from the lower use of pesticide than managers, and rural communities more likely to benefit than urban ones, a welcome reverse of the distributional consequences in many other areas. In the ICT area, telemedicine is also projected to make better medical care accessible in more remote areas, another possible re-distributional effect in the horizontal dimension.

Similarly, ICTs are projected to decrease urban/rural divides in access to education and to offer the possibility of increased social capital to poor communities. The latter effect is projected where the poor gain broader access to telephone service at lower unit costs and therefore are able to stay in touch with friends and family more effectively. (Scholars have noted that this phenomenon can also lead to an economic effect – money sent from richer relatives elsewhere.) However, if the Digital Divides are steep, these very dynamics would increase rather than decrease social exclusion. Distributional issues connected to cultural capital also appear in the literature on ICTs. If the content of new media is entirely controlled by dominant ethnic groups, for example, then the ethnic identity of small groups may be threatened. Thus there is an emphasis on developing local or ethnically-controlled content for the Internet as a way of preventing increasing cultural inequalities. Finally, ICTs are also seen as a factor in shifting inequalities in political capital or power. E-government is projected to increase transparency and levels of interaction between government and citizens, and the Internet in the hands of civil society has been shown to be a powerful tool for garnering international support, as in the case of the Zapatista uprising in Mexico. The latter dynamics interact with both horizontal and vertical inequalities.

We thus find that our “dependent variable,” distributional consequences, is actually a set of variables, with some serving as antecedent conditions for others. In addition, we can already see that distributional consequences are connected in complex and different ways to different technological projects, the topic to which we turn next.

Technological projects

Technologies are not born spontaneously, nor are they developed, produced, or diffused without an organized effort on the part of a company, either private or public. We refer to those efforts as technological projects. Volumes have been written on ICTs and biotechnologies as technological projects, and our task in this project is not to summarize those volumes but to suggest some testable hypotheses on the connections between the ways the technological projects were pursued and their distributional effects. We still have much work to do to achieve that objective, and can only share initial thoughts here.

Firms develop their technological projects with markets in mind, and our main hypotheses at this time link projects with consequences through markets. Much of the literature on technological impacts assumes that because private industry is developing technology in order to make a profit, it is most likely to develop goods for affluent markets. As a broad pattern, this is undoubtedly correct, but firms know that if they can produce useful products at lower prices their potential markets are larger and they can therefore generate significant profits there. It is also of interest that in two out of the three technological projects we are focusing on include significant “free-ware” or “public goods” elements present (the examples are the Internet and agricultural biotechnology).

Envisioning a market and developing a product to appeal to that market, we suggest, are the key distributional decisions that technological developers make. Our hypotheses in this area are therefore:

1. Distributional consequences are taken into account in technological projects primarily in the form of targeting markets, not in terms of employment or human development objectives.
2. Therefore, very few technological projects, especially in emerging technologies, are pro-poor, equalizing, or egalitarian in concept, although they may be in effect.

The third hypothesis relates our central focus on markets with one of the options available for public intervention.

3. Public markets play a large role in stimulating redistributive projects.

Above, we identified our first general hypothesis -- that technological projects are always inherently distributional, and that the distributional aspects of individual projects and portfolios of projects are open to choice. Markets are only one of these choices. Would it be possible to interest firms in making individual projects or portfolios of projects that are also re-distributive? Firms certainly have a stake in operating in a socially sustainable world. The next section discusses some steps that government might take in that direction.

Public interventions

Our second general hypothesis is that the same technological project under different policy conditions will have different distributional consequences, that is, that public interventions can influence how the benefits and costs of the technological project are shared.

Many countries have redistributive policy goals at a general level, but policies at the operational level do not always reflect these goals. Thus for example, the most recent update of Jamaica’s S&T Policy sees S&T as playing a role in the reduction of poverty and unemployment (S&T Policy, 2005). The reduction of poverty is high on the S&T Policy agenda since it is anticipated that “S&T will increase the gap between the rich and the poor if these tools are not specifically used to target the needs of the underprivileged to improve their productive base, democracy and the overall quality of life” (S&T Policy, 2005, p. 10). “Mechanisms to take S&T to rural and deprived urban communities to reduce poverty….will receive specials attention”. The use of biotechnology and building biotechnological competence as well as ICTs are considered instrumental in achieving goals of the overall S&T policy. S&T policies are expected to work along with the social and behavioral sciences to guide the use of knowledge to acquire a better quality of life for the Jamaican people.

Jamaica's National Biotechnology Policy is still in the draft stages. Although it is framed as policy for socio-economic development, in its current draft, it does not explicitly address the issue of unevenness in access, use or benefits of biotechnology in either health or agriculture. The assumptions on the benefits of the use of biotechnology appear to be utilitarian, with the expectation that if current policy objectives are met then not only will the wider society benefit but so will the disadvantaged.

Likewise, the Ministry of Health's Annual Report (2001) explicitly mentions the goals of equity, access and quality in the delivery of services to improve health. A strategic objective is to promote integrated development of all children and improve the social circumstance of children, particularly those at risk (Ministry of Health Annual Report, 2001). In its 2004, *Healthy Lifestyle Policy* document, the Ministry identifies chronic disease conditions as the major causes of death and disability in Jamaica in contrast to 50 years ago when the major causes were communicable and infectious diseases (Ministry of Health, 2004). However, this document does not deal with distributional differences related to the incidence, remediation or effectiveness of proposed programs or the role of biotechnology.

In the ICT area, we have begun an analysis of national ICT policies in Africa, Asia, and the OECD countries. Out of 62 with policy documents readily available in English, 18 mention promoting inclusion as a policy goal. This goal trails well behind increasing diffusion and use, however, which appears in 50 documents, as well as promoting ICT policy and business environments (which appear in 22 and 20 documents respectively).

But S&T policies are being used in re-distributive ways. Research policies, for example (see Sutz 2003), are often the object of attention of organized civil society groups, some of them with egalitarian goals. The research agenda of the CGIAR, the funding body for the international agricultural research institutes, is explicitly pro-poor. In the United States, the Women's Health Initiative and the Office of Research on Minority Health are examples of significant research efforts taken up in response to such pressures. By expanding the knowledge base for commercial efforts in particular directions, such programs provide incentives for particular development choices in industry. Innovation policies can be directed towards poor regions, addressing another horizontal inequality, and could be equalizing by explicitly considering the kinds of jobs that are likely to be generated in the industries targeted, as well as taking jobs into account in the activities of manufacturing extension services. Human resource policies are often explicitly egalitarian, paying special attention to opening careers in science and engineering to historically disadvantaged groups, as with the institution-building programs of the National Research Foundation in South Africa. Finally, regulatory policies, including the actions of public utility regulating boards, can be redistributive. In the telecommunications industry, for example, regulators have a strong control over pricing and thus affect rural access and access in poor communities.

There is no literature, however, on how effective these approaches are in actually reducing inequalities in either vertical or horizontal dimensions. Our key hypothesis with regard to this set of intervening variables is therefore simply that

4. Technological projects shaped by pro-poor, equalizing, and egalitarian public interventions will have more positive distributional consequences than those that move forward under utilitarian approaches.

The hypothesis needs empirical testing.

National contexts

In different national contexts, we hypothesized earlier, the same technological project will have different distributional consequences, even under similar policy circumstances. Both technological projects and public interventions must take variations in national contexts into account if they want to achieve re-distributional effects. The general point is obvious, but the specific relationships have not been explored empirically. Which aspects of national context are most relevant to the distributional consequences of technological projects?

Cozzens (2006b) explores some possibilities, and we base our hypotheses here in part on her analysis, which compares hypothetically the distributional effects of high-technology development in Finland, the United States, and South Africa. First, she argues, the high-skill, high-wage jobs that high-technology development produces will be accessible to more people in a well-educated population, that is, one in which many people have the necessary skills. Finland would be such a society; the United States not so much so; and South Africa far from the situation. Thus the first hypothesis is that

5. Technological projects subject to similar public interventions will have more positive distributional consequences in societies with high average levels of education and low inequality in educational achievement.

Cozzens further argues that multiplier effects – the other businesses helped and jobs generated by the growth of one industry – will be stronger in contexts in which there are already complementary industries. Local services may be relatively common, but if the other kinds of inputs to high-technology firms have to be imported rather than acquired locally, the benefits of the new industry will be correspondingly constrained. This effect should be strongest when the new industry is first being introduced, and may disappear over time if complementary firms are established. This latter development, however, will also be interdependent with skills levels and other national conditions.

6. Technological projects subject to similar public interventions, especially in their early stages, will have more positive distributional consequences in societies with stronger complementary industries.

Cozzens also points to general redistributive policies as an element of national context affecting the results from S&T-specific redistributive policies. If utilitarian S&T policies encourage the accumulation of wealth, but that wealth is taxed to provide public benefits in areas like health and education, all the good things that should flow from high-technology development will be more accessible to more people. Thus,

7. Technological projects subject to similar public interventions will have more positive distributional consequences in societies with strong general re-distributive policies.

Also in the area of general policy, governance conditions (Kaufmann et al. 2005) are likely to influence the effectiveness of S&T policies generally, including re-distributive ones. Low levels of violence, government stability, and government effectiveness can all be expected to be positive influences. A "business-friendly" regulatory environment, on the other hand, might signal lack of protection for disadvantaged groups, and may make it harder to achieve positive re-distributive results. Therefore

8. Technological projects subject to similar public interventions will have more positive distributional consequences in societies with high levels of human rights protection, low levels of violence, and stable and effective government.
9. Technological projects subject to similar public interventions will have less positive distributional consequences in societies with strong "business friendly" policies.

Finally, the country's initial levels of horizontal inequality must be taken into account. The greater the internal divisions in the country, particularly when they are culturally entrenched, the more limited the group to which the benefits of high technology can spread. Therefore

10. Technological projects subject to similar public interventions will have less positive distributional consequences in societies with larger gender divides, greater ethnic fragmentation, and bigger differences in wealth between regions.

The model

As stated in the introduction, our immediate goal in this paper was to think carefully enough about the connections between emerging technologies, public and private policies, and a variety of inequalities to be able to study those connections. Our ultimate goal is to develop options for decision makers in the private and public sectors to help emerging technologies reduce rather than increase inequalities.

None of our hypotheses has yet been tested, so it is too early to draw policy conclusions from the framework. Much will be learned about the model's relationships from actually exploring the hypotheses. The hypotheses themselves suggest two strong directions that public interventions should take. On the one hand, S&T policymakers in developing country environments probably need to join in the efforts in their countries to address certain conditions outside science and technology, if they want their own policies to be effective. Supporting the upgrading of education for both boys and girls and for all ethnic groups should be part of the S&T policy agenda, not a competitor to it. Choosing high technology investments in areas where complementary industries exist or can grow also makes sense. Any efforts to bridge urban/rural, gender, and ethnic divides within science and engineering are likely to contribute to positive conditions.

On the other hand, public intervention's primary audience must be the private sector, which holds most of the keys to technological projects that reduce rather than increase inequalities. The public and private sectors may need to engage in a dialog over markets. Mass markets, particularly for basic goods, can increase well-being for the poor, directly and indirectly. Firms should thus consider them carefully as part of their technology portfolios, and governments should provide all the incentives they can, including public procurement, to foster the development of those markets.

Science and technology policy practitioners live with a vision of their profession as making the world better. A world that is made better for only a few does not square with that vision. But ameliorating poverty, reducing economic inequality, and achieving equity across regions, genders, and ethnic groups will not happen without the efforts of every field of public endeavor. Science and technology need to put their shoulders to the wheel.

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