Emerging Technologies and Social Cohesion: Policy Options from a Comparative Study

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Among the new expectations articulated for S&T policy is strengthening social cohesion and reducing inequality (Conceicao 2003; Freeman 2000). An overly narrow emphasis on innovation for economic growth and competitiveness in Europe is being complemented with calls for quality of life objectives for research policy (Cozzens, Kallerud et al., 2007). In many developing countries, inequality is a prominent problem, and goals for science and technology are geared to address it (for example, Persley 1999, Singer 2005).

Nonetheless, the research and innovation policy community knows little empirically about the effects of its instruments on social cohesion. On the one hand, those instruments may inadvertently reinforce or exacerbate existing inequalities; but there have been few studies of those effects. On the other hand, outside the domain of human resources, there is little empirical evidence on the effectiveness of S&T program designed to reduce inequalities.

This paper presents preliminary results from a cross-national, cross-technology study of the distributional effects of emerging technologies.[1] The research aims to

1. describe the dynamics that link emerging technologies to patterns of inequality;
2. identify the roles of public interventions in those dynamics; and
3. develop a framework that policy actors can use prospectively to analyze the distributional valence of a specific new technology in a particular national context.

Our central research question is how policy interventions affect distributional outcomes for the same technology under different national conditions.

Inequalities and Emerging Technologies

Inequality is an enduring feature of social systems but an intermittent topic of popular attention. Commentary on globalization is scattered with the claim that global inequality is on the rise (for example, Wade 2004, Stiglitz 2006). U.S. inequality re-emerged as a theme in public discourse when the new Secretary of the Treasury raised the question (Trumbull 2006).

Empirically, however, the picture is much more complex than the rhetoric would suggest. Milanovic (2006) has recently examined the global data carefully, and demonstrates that inequality between countries, in traditional economic measures like GDP per capita, is rising -- unless one weights by population, in which case it is falling. Estimated at the global level, economic inequality among households is fairly

[1] The European and African case studies were done as Work Package Four of ResIST, a project funded by the European Commission (see http://www.resist-research.net/home.aspx). The case studies in the Americas are funded as Project Resultar by the U.S. Nataional Science Foundation under Grant SES 072-6919. Our colleagues on the ResIST team are Mark Knell, Bernd Beckert, Sibylle Gaisser, Lisa Pace, Noel Zarb-Adami, Roland Brouwer, Mario Falcao, and Lidia Brito. All opinions, findings, conclusions and recommendations are those of the authors and do not necessarily reflect the view of the sponsors.

stable at about the level of the highest intra-country inequality measures – still much too high, but apparently not getting much higher very quickly.

The trend is much less ambiguous for inequality within countries, which does appear to be on the rise. Freeman (2000) observes that this form of inequality is a spreading pattern in OECD countries. Galbraith and Lu (2001) also convincingly illustrates the trend, decade by decade, with manufacturing data from a large number of countries. Economic growth does not necessarily eliminate inequality (Goodman 2006), and even a country that spectacularly reduces absolute poverty, as China has done in the last decades, can at the same time generate increasing income gaps (Benjamin et al. 2004).

Emerging technologies are a strategic research site for examining the interaction of inequalities between countries and inequalities within countries. [2] Conceptually, we define emerging technologies in this project as new and research-based, with potential broad impact. Operationally, we propose to study the actual distributional consequences of selected biotechnologies and information and communication technologies (ICTs). We then use these examples to develop a framework for thinking about the distributional consequences of other emerging technologies. The framework is tested in the latter stages of the project against what is known and projected about the distributional consequences of nanotechnologies.

Why study emerging technologies in this project? First, precisely because they are new, emerging technologies are the site of change and growth in both global and local economies. The techno-economic networks that support them are still young and malleable, but are projected to be more significant as time goes on. They therefore represent a good place for public interventions towards equality, if such interventions were needed. Second, because emerging technologies are research-based, they are more likely to be sold at high prices (as firms try to recoup research and development costs) and to demand high levels of skills in the production process. Both these characteristics give emerging technologies a higher potential than older technologies for increasing inequalities in access and employment.

Third, emerging technologies stand at the intersection of global and national distributive processes. The dominant pattern in emerging technologies has been that new technologies have been developed in North America, Europe, or North Asia (the “Triad” regions), then diffused to other parts of the world, either when a multinational firm decides to place a production facility there or when the technology becomes available for purchase. The benefits and costs that people in the creating, producing, and using countries experience as a result of this process vary greatly among countries and technologies, but the global pattern of inequality may seem well established. Technology-creating countries will always appear to be those starting the revolutions, and technology-using countries will always appear to be trying to catch up, when we consider only this pattern.

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[2] Any attempt to develop a crisply defined research agenda on inequality is challenged by the many dimensions of the phenomenon. At a very fundamental level, Sen (1992) points out that inequality is a multi-dimensional space, with different observers valuing different “focal inequalities,” from abstract property rights through basic human needs. Empirically, there are income inequalities between and within countries; vertical and horizontal inequalities within countries; inequalities in other areas like computer access (the “Digital Divide”), health outcomes (“health disparities”), and environmental conditions (“environmental injustice”). Inequality and inequity are different concepts -- one descriptive, one normative – although they are seldom carefully sorted out (see Cozzens 2007 for a discussion in S&T policy).

To create a different pattern, however, many non-Triad countries invest in their local capabilities in emerging technologies, not only to provide better absorptive capacity, but also as the basis for using the emerging technology to meet local needs and create local competitive advantage. Indeed, the Millennium Project task force on innovation (Juma and Lee 2005) recommended that every developing country invest in three "platform technology" areas, namely, biotechnology, ICTs, and nanotechnology. These investments might create a re-distributional pattern with significant implications for the relationships between technologies and inequalities.

Our study provides an opportunity to examine both of these patterns in action. We assume that reality is more complex than either the "dominating North" or "optimistic South" views, and we set out to describe the actual distributional dynamics generated by emerging technologies in various national contexts.

Initial Concepts

The basic logic of the data gathering and analysis is that *technological projects* affect *inequalities* in *valued items* through pathways that are technology-specific, mediated by *national conditions*, and shaped by *public interventions*. Before turning back to the specific technological projects the study is examining, let us pause over each of these other concepts.

The term *technology* above is shorthand for the concept of ***technological projects***, that is, organized efforts of a group or institution. While private industry is the main source of technological projects, public institutions or civil society groups may also put them into motion. The study is based on the assumption that technological projects are always inherently distributional, and that the distributional aspects of individual projects and portfolios of projects are open to choice.

Inequality is the unequal distribution of something people value. This project will not only consider inequality in incomes, the focus of the economic literature on the topic, but also inequalities in the distribution of the benefits and costs of technological projects. We explicitly include both vertical inequalities (the general distribution in a country, including rural-urban differences) and horizontal inequalities (differences by gender, ethnicity, or other culturally defined factors).

In this project, we focus on inequalities in three ***valued items***, each generated through a different relationship to the emerging technology: assets, employment, and benefits/costs. Since under our definition, emerging technologies are research-based, innovation plays a strong role in bringing them into being, when the other necessary forms of capital and organizational skill are present. This is the process of technology *creation*. New intellectual capital for one actor can destroy the value of the intellectual property of another as, for example, when synthetic fibers undermined natural fiber-based industries and devalued knowledge and skills many developing countries possessed. As we have seen in the literature, conflicts over intellectual property are a common feature of the process of incorporating an emerging technology into a national context. We therefore want to include examination of the distributional aspects of those issues in our study. The ownership of intellectual property will of course be treated in context as part of capital accumulation and business ownership.

Relatively few jobs are associated with the creation of technology, but many are generated when the technology goes into *production, marketing, and sales*.

Competition for manufacturing production jobs is fierce, and technology-creating countries do not always win. Jobs can be generated directly, through production or sales of the technology, indirectly through raising the productivity of another business, or indirectly as the wages of workers in the new or expanding industry are spent in the local economy (the multiplier effect). Production jobs in ICTs or pharmaceuticals can significantly affect small economies, as can successful commercial agriculture. However, the higher labor productivity of new production processes may mean that fewer jobs are generated through these processes than through other industries, and they may be accessible to a narrower segment of the population. Employment is thus a key variable to track in our analysis.

Technologies are ultimately designed to deliver benefits in health, food, environment, etc. through *use*. These benefits are technology-specific, as are the costs that might be generated in a specific national context. For example, the benefit from insulin would be better control of blood sugar and improved quality of life for diabetics, but if the insulin is only available to affluent consumers, these benefits could increase health disparities. To receive benefits, people must have access to the technology, through private purchase or public procurement, so in each case study we will characterize access with the best information available.

The distributional effects of technological projects are mediated through a variety of ***national conditions***, which are seldom discussed in the literature on technological impacts. As a starting point in analyzing the effects of these conditions, we describe our case study countries in terms of national income level, poverty, general human capital in the form of educational attainment and specialized training of the nation's citizens, and technological capability. The last is a complex concept, only imperfectly captured in the many current indicators and indexes related to it, and we are looking for its presence beyond the indicators in our cases. These are the kinds of general factors that we expect to be associated with common patterns across technologies within countries, and we are adding others as they emerge in the analysis.

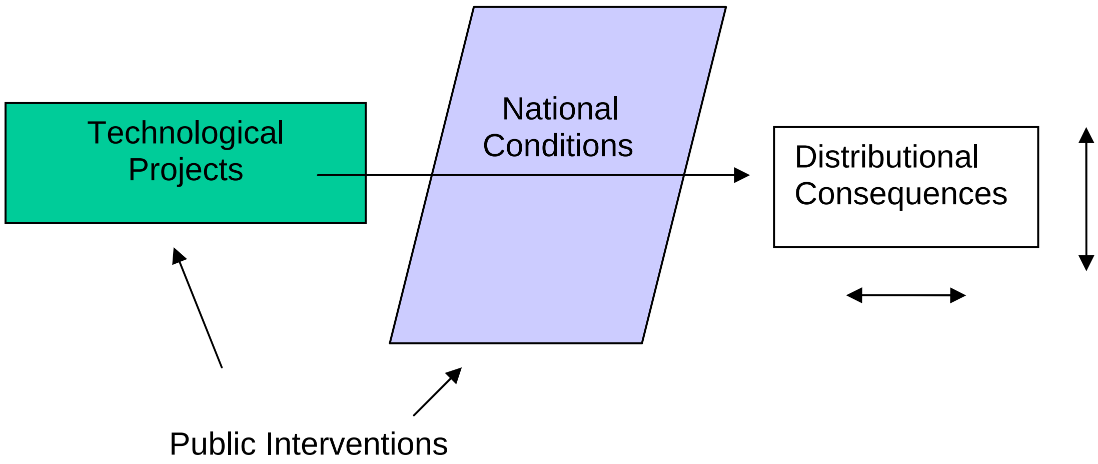
Finally, given its policy audience, the study characterizes the policy instruments available to S&T decision makers to influence distributional consequences. We refer to these generically as ***public interventions,*** because they constitute a mix of policies, programs, and other kinds of actions. These interventions may either act to shape the technological projects themselves, for example through inputs from public research programs or incentives to firms, or by affecting national conditions, for example, through investments in education to build human capital. Likewise, the absence of public intervention can influence technological projects profoundly, for example, the inability to establish a regulatory environment that creates trust. Our comparative design is particularly helpful in allowing us to identify such gaps.

Our initial consultations with policy audiences about the project[3] have produced an initial list of candidate areas for public intervention, including regulatory policies (e.g., biosafety regulations that affect whether small or large farmers are more likely to benefit from planting a new crop); ownership provisions, for example, loose or tight intellectual property protection; shaping employment options through labor regulations; targeting specific technologies for faster development through public research; public procurement policies that provide markets for particular technologies, for example, health service purchases of recombinant insulin; and policies that

[3] Project ResIST began with world regional consultations with policymakers in Africa, Latin America, and Europe.

develop human capital through specific training or general educational opportunities. Our case study results are allowing us to refine this list.

Figure One. Basic Model



Choice of Technologies

We chose to study these issues through case studies because of the complexity of the relationships we are studying and the importance of context. As a team, we are very familiar with the available quantitative indicators, and therefore skeptical that they reflect the complexity of the dynamics we want to study. Our qualitative approach is allowing us to put quantitative information in context, and at the same time to describe and compare factors that could not be included in a statistical analysis.

We chose technologies for case studies in light of our exploration of the literature and the conceptual framework of the study. One criterion was newness; we ruled out much older information and communication technologies like telephones and computers. Another criterion was relevance across the range of countries in the study. We would gain much less insight studying technologies that were only relevant in affluent countries. We tried to respond to opportunities arising from our team's experience and connections, and we attempted to balance the set in terms of the technological projects of large corporations versus smaller challengers.

In the ICT area, we focus first on *mobile telephones*. They are nearly ubiquitous: we have been able to study the mobile phone business in every country included in the study. The specific inventions that go into each mobile handset have origins in a number of different countries, and production is done on a distributed global basis. Furthermore, this technology is still evolving, with the emergence of third generation (3G) standards that are outside mainstream use in most countries (except Japan and South Korea). There are a number of creative uses of the technology, including by female entrepreneurs ("mobile phone ladies") in poor communities receiving microfinance. Because telephone service is a public utility, we expected to see a variety of public interventions in our cases. Indeed our preliminary review of national ICT policies in Africa, Asia, and the OECD countries, based on 62 policy documents available in English, showed wide variation in approaches, with nearly a third mentioning social inclusion or redistribution as one goal of the policy.

To provide a counter-balance to the corporation-centered story of the mobile phone industry, we will also explore the open source software movement. Even in the poorest country of our group, Mozambique, small businesses are growing up based on customization of open source software. The open source movement represents an alternative, democratized form of innovation (von Hippel 2005), and has raised policy issues like the current debate on whether the European Union should use Linux exclusively as its operating system (Thurston 2007).

In biotechnology, we divided our choice of cases into agricultural and health areas, which are quite distinct in industrial connections, production processes, and users. A good list exists of the genetically-modified crops in production worldwide and the countries that plant them. We were surprised to find that we could study a common genetically-modified crop planted in most of the countries of the study (James 2005) Again, we chose a technology that has received less attention in the past. The literature on social impacts of GM crops has focused on soy and Bt cotton. GM maize, our case study technology, is in production in several countries in Europe as well as widely in the Americas and in South Africa.

There are, however, only 21 countries in the world that plant genetically-modified crops, including only one in Africa (James 2005). To limit our study of agricultural biotechnology to these crops would keep us from exploring why biotechnological capability is so high on the agendas of S&T policymakers in a much broader set of countries. We therefore decided also to include case studies of the application of a much older biotechnology technique, tissue culture (TC). Again, Mozambique provided a vivid example that helped us choose this focus: While the technique is about 30 years old in the North, tissue culture of plants has only been possible in Mozambique in the past year, through a new facility constructed with funds from the U.S. Agency for International Development. Following through on the lesson learned from this story, we included analysis of a locally-important crop that is reproduced through tissue culture in several countries in the study. The most likely candidate in Costa Rica was bananas, where almost all banana plants are grown in a laboratory, with 50% of the production by multinationals and the other 50% by 35 independent farmers. The focal crop across some other countries is potatoes, one of the fastest-growing food crops in the world.

Finally, we wanted a technology example from health biotechnology. Of the 256 biotechnology-based drugs approved by the U.S. Food and Drug Administration,[4] only a few fall in areas where the World Health Organization has identified "essential medicines," important for developing countries.[5] A considerable and sometimes charged literature already exists on one such category, the drugs for HIV/AIDS (see for example Dodier 2005, Homedes 2006, Galvao 2005, Baghadi 2005). We have chosen a quieter case for our analysis. Recombinant insulin was the very first biotechnology-based drug approved by the U.S. Food and Drug Administration (Walsh 2005), and thus has the longest history of distributional consequences to trace.

[4] Approved Biotechnology Drugs – Biotechnology Industry Organization http://www.bio.org/speeches/pubs/er/approveddrugs.asp Accessed Jan.02, 2007

[5] WHO Model List of Essential Medicines http://whqlibdoc.who.int/hq/2005/a87017_eng.pdf The WHO Essential Medicines list comprises the most efficacious, safe, cost-effective medicines for priority conditions.

It is an important drug, becoming more important by the year as the global epidemic of diabetes expands (World Health Organization 2003). As with mobile phones, we have been able to study the use of recombinant insulin in every country in the study. While it was developed first in the United States and two U.S. firms still produce it, the largest producer is now Novo Nordisk, a Danish firm, which markets recombinant insulin in 179 countries. Social responsibility is a hallmark of Novo Nordisk, which is well known for working with non-governmental organizations, and operates with a "triple bottom line," that is, financial, environmental, and social sustainability. The case thus provides a chance to contrast business styles and philosophies.

Choice of Countries

ResIST has confined its efforts to three world regions, Europe, Africa, and Latin America/Caribbean, making the judgment that available resources did not permit the inclusion of Asia in its empirical studies, as important as developments there are. Resultar followed the lead of our partner project in this. The ResIST participants studied selected target technologies in their own countries: Germany, Malta, and Mozambique, and followed GM maize into the Czech Republic. The Resultar team has complemented their efforts with a range of case studies in the Americas. In the end, the set includes four "developed" countries and four "developing ones," with a range of national income levels within each group.

Table One: Countries

	Argentina	Canada	Costa Rica	Jamaica	United States	Germany	Malta	Mozam-bique
Population[6]	38.7m	32.3m	4.3m	2.7m	296.5m	82.5m	404,000	19.8m
GNI/capita[7]	$4,470	$32,600	$4,590	$3,480	$43,740	$34,580	$13,590	$310
Technolo--gical Achieve-ment[8]	.381	.589	.358		.733	.583	na	.066

Methods

Our method is comparative case study. Each case is a technology-country pair, as indicated in the table below. We have gathered information for each case using a common protocol, drawing information from published sources and interviews. We are in the process of coding the reports on each case in NVivo, a qualitative analysis software tool, using a common set of categories: national conditions, technological project, public policy sphere (including public interventions), distributional consequences in assets, employment, benefits and costs. Using this analysis, various team members are producing integrative chapters for each technology. The team leaders are in the process of synthesizing findings across the technologies. Team members are also identifying policy implications within the national contexts they have studied.

[6] World Bank, World Development Indicators, data for 2005
[7] Gross National Income per capita, World Bank, World Development Indicators, data for 2005
[8] United Nations, Human Development Report 2001.

Table Two: Case Study Matrix

	AR	CA	CR	Ger	Jam	Mal	MZ	US
Mobile phones (8)	XX	XX	XX	XX	XX	XX	XX	XX
Open source (6)	XX	XX	XX	XX		XX	X	XX
rDNA Insulin (7)	XX	XX	XX	XX EU	XX	X	XX	XX
GM maize (5)	XX	XX	XX			XX CZ		XX
Tissue cultured crop (4)	XX	X	XX		XX		XX	X

Preliminary Summary Results

In reporting preliminary results of the study, we need to stress that at the time of this writing, write-ups for the cells in Table Two have only recently been produced and shared across the team, and the detailed analysis is in its early stages. What we present here are therefore preliminary observations that might be revised later.

One of the main lessons learned from the cases concerns diversity. On the one hand, the specific distributional consequences of the technologies are quite different and are clearly strongly influenced by all the factors displayed in the model: how the technological project was shaped by its champions; national conditions, in particular skills and poverty; and public interventions. On the other hand, the public interventions in each technology were relatively standard. And the overall distributional patterns followed some general patterns that we were able to see much more clearly from the comparison than we could have from individual cases.

Technological Projects. Although we had a focus for each technology in the study, we still needed to search in each case for the technological project itself – something that some actor or set of actors (the “champion”) was trying to make happen. Among our five targets, it is clear that the technique or capability is not the only influence shaping the project. Instead, the way the technique is packaged – with what services, priced, in what way, with what accessories – is of the essence. Mobile phones are a product-service combination, and in this case, it turned out that the pricing for the service itself was a crucial factor in extending the market: pre-paid plans are widely seen as the way low income consumers have been to afford cellular access. Open source software is the technological project of an evangelical movement of programmers, along with some corporate giants who are interested in a way to compete with the proprietary software manufacturers. The business model is new: the product is free, but in its business forms, the service that adapts it and keeps it running are not. BT maize is one product designed to be used with another, a pesticide, and recombinant insulin is also marketed along with, although not designed for, a set of supplies for testing blood sugar and administering the drug itself.

But each technology is not completely malleable; each carries certain requirements of technical skills and infrastructural conditions that limit the creativity of technological champions. Micro propagation, for example, has to be done in a clean facility. This creates a floor on the level of investment that must be made for the technology to be available and thus limits the possibility for the industry to lower the cost of the product far enough for small farmers to afford it in some of the countries we studied.

National conditions play a different role than we pictured when we started the project. Distributional consequences are not mediated by averages, like those given above for the case study countries, but rather by specific conditions for particular individuals, firms, or company. For example, for a firm to be able to use open source software, it is not the average level of programming skills for the country that is important but rather the firm's own in-house expertise. Likewise, while the low average income per capita in Mozambique indicates that it is a country where many, many people are very poor, individuals with good incomes in the capital city can afford the costs of a mobile phone or driving to South Africa to buy insulin. In order to really understand distributional dynamics around technologies, we need first and foremost to be able to picture the global distribution of household incomes, and then consider the portion of that distribution represented in a particular country. Some of the relevant conditions, however, are created by national governments, for example, an electricity infrastructure to underpin rural mobile networks. (If those conditions are specific to the technology, then we include them under "public interventions" rather than "national conditions.")

Public interventions, a somewhat broader concept than pubic policies and programs but closely related, are key variables in our analysis. All the technologies we studied had originally been fed by results produced in public research and development. Recombinant insulin, for example, would not have been possible were it not for breakthroughs in basic science made in universities with public funding in the United States. Our discussion will eventually take into account how the choice of research topics in public R&D helped make these particular technological projects possible, rather than others. This is certainly an important part of the public policy context for the projects. Likewise, intellectual property provisions play important roles in several of our technology stories. We will discuss those roles in greater detail in the section of this paper on assets.

However, our distinctive contribution is tracing the distributional consequences of the technologies as they have been commercialized or applied. Here, we find five main categories of interventions that appear in the cases: public procurement; public utility oversight; anti-trust actions; health and safety regulations; and environmental protection. The first three are mildly to strongly re-distributiive, while the latter two affect access negatively because while reducing overall risk they also raise costs. Let us say a few words about each.

Clearly, if an emerging technology represents an irreplaceable capacity to solve a basic problem, governments are likely to intervene to make sure that capability is available to everyone in some form. Among our cases, recombinant insulin exemplifies this phenomenon (with some exceptions, as noted below). Insurance schemes or health services provide access to basic medicines for most people in most places, and when they cannot afford to do so, NGO coalitions are likely to intervene to ameliorate the situation, as they did with AIDS medication. Interestingly, public provision also plays a role in tissue culture and micro propagation, where provision of quality planting material to farmers is seen in some contexts as a public responsbility. Most consumer goods fall outside this "essential" category, so we would not expect governments to subsidize or purchase mobile phones for poor individuals; but interestingly, governments have started to acquire for their populations the new inexpensive laptop computers, some of which are equipped with open source software.

Public utilities are also closely regulated because of the perception that they provide basic services that should be accessible to all citizens. Public utility oversight therefore plays a re-distributive role in some countries in the mobile phone example. Telecommunications regulators are concerned with keeping services “affordable” and encouraging tariff structures that extend service broadly rather than concentrating it only among the affluent or in urban areas that are easier to serve. These principles are historically rooted in oversight of land line telephones. They are clearly de-concentrating or re-distributive.

Telecommunications regulators have sometimes allowed “natural monopolies” in land line service, but are more concerned with creating or maintaining competition in the mobile phone sector. The higher level of competition in the sector appears to contribute strongly to the push in the sector to provide service in smaller increments to lower-income consumers. The characteristics of the technology also contribute: the ease of installing capacity and the negligible incremental costs of serving additional consumers within a geographic area.

Anti-trust regulation also plays a role in the distributive effects of open source software. Open source software breaks one source of monopoly created by proprietary software companies, namely, ownership of and secrecy around source code. Opening up source code creates small and medium-scale business opportunities for support firms and others that want to develop applications, and thus distributes business opportunity more broadly than the five software giants (four American and one German) would do on their own. At the same time, however, the requirement for a high level of complementary programming skills to be able to absorb and maintain open source software has led to the irony that large firms are more likely than small firms actually to use it – a negative distributional effect.

The other sets of public interventions that we have encountered in the cases are health, safety, and environmental regulations. Recombinant insulin needed to be approved by the U.S. FDA, then re-approved in other countries, in order to be available for use. GM maize likewise needed to be cleared for planting, under regulations that vary from full approval in the U.S. and Canada to limited approval in Europe to outright prohibition in Costa Rica and Mozambique. The environmental regulations in Europe are an interesting example of how these kinds of regulations raise costs and therefore have a concentrating rather than dispersing effect. Farmers in the Czech Republic, our example country for GM maize in Europe, are only likely to find GM maize useful if they are in an area that makes their crops susceptible to European Corn Borer. If they need to use the GM variety, they not only face the higher costs of the seed, but also the higher costs of meeting European regulations for planting, such as leaving zones around their field to prevent cross-fertilization. Small farms on the edge financially are not as likely to be able to absorb these costs as larger operations. Similarly, the regulatory approval process raises production costs for drug manufacturers – costs that they pass on to consumers in the form of higher prices. Those prices in turn make it harder for poor people and poor countries to get access to the benefits of the drug.

Distributional consequences: assets. The science base of the emerging technologies we have studied leads, in three out of five technologies, to a strong role for IP in creating a business opportunity. In the mobile case, a welter of IP holdings tend to be cross-licensed within the industry, and the advantage of being a country that is home to a technology creator is seen in the role the Blackberry patents are playing in Canada in keeping some manufacturing there. The original patent on recombinant insulin was licensed to firms that are still the main competitors in the field, and Monsanto protects its intellectual property in GM maize with an aggressive legal campaign. In all these cases, IP protection has the tendency of concentrating assets and business opportunities. In contrast, in two of the studies IP is either not important (tissue culture) or used to disperse the business opportunities (open source, which enforces open IP).

In these two cases, however, there were other barriers to entry for new businesses. In the open source example, an individual or company must have a high level of technical skills to get into the business. Skills are also quite important in tissue culture, plus the significant capital investment already mentioned for a clean facility. IP is therefore not the only aspect of emerging technologies that tends to concentrate business activity rather than spreading it. Likewise, the cases reveal a number of other strategies that large firms are using to hold onto monopoly rents that have their IP at the core, such as Monsanto's acquisition of local seed companies and related services.

The science base of the emerging technologies also implies that micro-enterprise is an unlikely beneficiary of the new development, and in three out of five stories, this hypothesis is confirmed. Software piracy is small business, and like open source undermines the concentrating effects of the proprietary software business. And in the mobile phone story, micro-enterprise is a prominent feature, from local businesses that sell minutes on cell phones to those who do not own them to the ubiquitous pre-paid card venders in Mozambique. Both these examples involve micro-enterprises based on re-selling small quantities of something that another company has manufactured.

Distributional consequences: employment. We were a bit surprised to find some manufacturing jobs associated with our five technologies located in the affluent countries in the study. These were high-skill jobs in the pharmaceutical industry, which are not numerous but pay quite well. At the other end of the spectrum are the sales jobs associated with emerging technologies that are shaped to reach a mass or even bottom of the pyramid market. Sometimes the new product does not produce new jobs, but is rather absorbed into an existing production process. New jobs in the new industries thus do not always displace older jobs, but may in fact retain them. The most obvious loss of jobs associated with the technological changes we studied were the losses in landline telephones. In the farm sector, although micro propagation as an expensive input tended to help small farms fold and larger farms grow, the larger farms were employing people in different kinds of jobs, so no clear downward trend in employment was visible. The employment issue associated with ownership was the unhappy circumstance that multi-national enterprises were able to move jobs into and also out of a national economy. This was obviously disruptive nationally and can contribute to unemployment and poverty. But from a global viewpoint, the practice probably has a dispersing rather than concentrating effect.

Distributional consequences: benefits and costs. All the technological projects we studied provided benefits, so the diffusion of the technology itself is one important indicator of the distribution of those benefits. As expected, price is an important determinant of diffusion or penetration rate, but we were interested to find that it was definitely not the only one. The most dramatic illustration of another factor determining patterns of use is in the open source example. By definition, the product itself is free; but this simply means that other factors shape the distributional patterns.

For the business applications, large firms were more likely than small ones to use open source software, primarily because a firm needs in-house expertise to absorb and maintain the product when it does not come bundled with support from a proprietary software company. On the consumer side, open source software provides no benefits if you do not have a computer, so having enough money to acquire the computer itself becomes the limiting factor.

Likewise, the common idea that products will initially be expensive but that prices will drop as a mass market emerges does not characterize all the cases. Tissue cultured banana plantings were free for a while in Jamaica, in a program subsidized by the European Union. When the subsidy stopped, large farmers were able to import material but the small farmers simply went back to previous methods. The high capital and labor costs of micro propagation put a minimum price on the planting material that did not allow it to reach the market at the bottom of this agricultural pyramid.

The complementary assets of skill and infrastructure then serve as important secondary factors shaping distribution. Complementary assets can even turn benefits into risks and costs for emerging technologies. Our example is recombinant insulin. Doctors in Mozambique do not always prescribe insulin in medical situations where doctors in Europe or the U.S. would, because their patients are so poor that their lives cannot sustain the regimen of the treatment. Under the circumstances of these patients, insulin can actually be a life-threatening drug; the risks of taking it would be greater than the benefits.

The Technological Transition. We are beginning to tie these various observations together with a new concept, a structural feature of the global economy that we will call the technological transition.[9] One set of diffusion and adoption dynamics is characteristic above the transition point and another set below. Predictable shifts in dynamics therefore occur for any given technology at the point of transition. We suspect that the transition point is probably closely associated with the global absolute poverty line, but that point is still under investigation. Regardless of where the actual transition appears, it comes along with differences in income distributions that below the transition point will be a disproportionate number of women and members of disadvantaged religious and ethnic groups.

Above the transition point, champions can choose among luxury or mass markets for the products they create from the technological opportunity. Basic infrastructure can be taken for granted and champions must compete for the portion of a market created by the variety they offer. Technological choices involve relatively small costs in relation to income, and consumers have the resources and leisure to shop around.

Below the technological transition point, the product may be irrelevant (open source software for people without electricity let alone computers) or downright dangerous (insulin in an urban slum). If the product reaches poor consumers at all, it is likely to be either in second-hand form (like the hand-me-down mobile phones common in Maputo) or broken down into small lots that cost more per unit (again, the higher rates per minute for pre-paid versus contract mobile phone access illustrate). They thus pay

[9] This is an analogy to a concept in public health of the epidemiological transition: that one set of diseases characterizes countries with incomes up to a certain level, after which certain infrastructural conditions have been met and a different set of diseases emerges against the background of generally good public health. The first set is the “diseases of poverty” and the second set “the diseases of affluence.”

a larger share of their income to have access to the benefit, and the whole issue of benefits becomes more acute because the opportunity costs are relatively higher. The important questions then do not have to do with access per se, but rather with whether access might actually be counter-productive.

Summary and Policy Implications

If these observations about the distributional dynamics of emerging technologies are accurate, what can national policymakers do to increase the actual benefits of emerging technologies to all their citizens? Some very common generic advice would seem to fit this situation: Raise general education levels (spreading the necessary skills further). Eliminate absolute poverty. Make sure that new employment opportunities are open to both men and women and all groups in society, as well as paying equitable wages. There is no special advice from this study on how to achieve these goals but our work does reinforce some basic principles of good economic and human development.

Our examination of public interventions also reinforces the common idea that public procurement can make the benefits of emerging technologies widely accessible. But it points to a less obvious re-distributional intervention as well, namely regulatory attention to affordability and enforcement of competition. These elements in a regulatory environment at least sometimes shape technological projects towards mass or bottom of the pyramid markets.

Finally, the findings suggest attention to targeted investments in high-level expertise where it can shape access for a broad set of citizens to some high-priority item. Pockets of expertise can make a difference, as the tissue culture laboratory in Maputo is making a difference. These investments are not elitist but rather strategic. Likewise, local expertise can focus on coming up with technological variants that work in a wider range of environments, including those at the bottom of the income scale.

In summary, however, the findings suggest caution with regard to emerging technologies. Diffusion is not an appropriate goal in and of itself; instead, distributional justice requires a more thoughtful approach that takes into account the realities of lives of those below the technological transition point.

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