The Wealth of Networks

How Social Production Transforms Markets and Freedom

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Chapter 9 Justice and Development

How will the emergence of a substantial sector of nonmarket, commons-based production in the information economy affect questions of distribution and human well-being? The pessimistic answer is, very little. Hunger, disease, and deeply rooted racial, ethnic, or class stratification will not be solved by a more decentralized, nonproprietary information production system. Without clean water, basic literacy, moderately well-functioning governments, and universal practical adoption of the commitment to treat all human beings as fundamentally deserving of equal regard, the fancy Internet-based society will have little effect on the billions living in poverty or deprivation, either in the rich world, or, more urgently and deeply, in poor and middle-income economies. There is enough truth in this pessimistic answer to require us to tread lightly in embracing the belief that the shift to a networked information economy can indeed have meaningful effects in the domain of justice and human development.

Despite the caution required in overstating the role that the networked information economy can play in solving issues of justice, it is important to recognize that information, knowledge, and culture are core inputs into human welfare. Agricultural knowledge and biological innovation are central to food security. Medical innovation and access to its fruits are central to living a long and healthy life. Literacy and education are central to individual growth, to democratic self-governance, and to economic capabilities. Economic growth itself is critically dependent on innovation and information. For all these reasons, information policy has become a critical element of development policy and the question of how societies attain and distribute human welfare and well-being. Access to knowledge has become central to human development. The emergence of the networked information economy offers definable opportunities for improvement in the normative domain of justice, as it does for freedom, by comparison to what was achievable in the industrial information economy.

We can analyze the implications of the emergence of the networked information economy for justice or equality within two quite different frames. The first is liberal, and concerned primarily with some form of equality of opportunity. The second is social-democratic, or development oriented, and focused on universal provision of a substantial set of elements of human well-being. The availability of information from nonmarket sources and the range of opportunities to act within a nonproprietary production environment improve distribution in both these frameworks, but in different ways. Despite the differences, within both frameworks the effect crystallizes into one of access—access to opportunities for one's own action, and access to the outputs and inputs of the information economy. The industrial economy creates cost barriers and transactional-institutional barriers to both these domains. The networked information economy reduces both types of barriers, or creates alternative paths around them. It thereby equalizes, to some extent, both the opportunities to participate as an economic actor and the practical capacity to partake of the fruits of the increasingly information-based global economy.

The opportunities that the network information economy offers, however, often run counter to the central policy drive of both the United States and the European Union in the international trade and intellectual property systems. These two major powers have systematically pushed for ever-stronger proprietary protection and increasing reliance on strong patents, copyrights, and similar exclusive rights as the core information policy for growth and development. Chapter 2 explains why such a policy is suspect from a purely economic perspective concerned with optimizing innovation.

A system that relies too heavily on proprietary approaches to information production is not, however, merely inefficient. It is unjust. Proprietary rights are designed to elicit signals of people's willingness and ability to pay. In the presence of extreme distribution differences like those that characterize the global economy, the market is a poor measure of comparative welfare. A system that signals what innovations are most desirable and rations access to these innovations based on ability, as well as willingness, to pay, over-represents welfare gains of the wealthy and underrepresents welfare gains of the poor. Twenty thousand American teenagers can simply afford, and will be willing to pay, much more for acne medication than the more than a million Africans who die of malaria every year can afford to pay for a vaccine. A system that relies too heavily on proprietary models for managing information production and exchange is unjust because it is geared toward serving small welfare increases for people who can pay a lot for incremental improvements in welfare, and against providing large welfare increases for people who cannot pay for what they need.

LIBERAL THEORIES OF JUSTICE AND THE NETWORKED INFORMATION ECONOMY

Liberal theories of justice can be categorized according to how they characterize the sources of inequality in terms of luck, responsibility, and structure. By luck, I mean reasons for the poverty of an individual that are beyond his or her control, and that are part of that individual's lot in life unaffected by his or her choices or actions. By responsibility, I mean causes for the poverty of an individual that can be traced back to his or her actions or choices. By structure, I mean causes for the inequality of an individual that are beyond his or her control, but are traceable to institutions, economic organizations, or social relations that form a society's transactional framework and constrain the behavior of the individual or undermine the efficacy of his or her efforts at self-help.

We can think of John Rawls's *Theory of Justice* as based on a notion that the poorest people are the poorest because of dumb luck. His proposal for a systematic way of defending and limiting redistribution is the "difference principle." A society should organize its redistribution efforts in order to make those who are least well-off as well-off as they can be. The theory of desert is that, because any of us could in principle be the victim of this dumb luck, we would all have agreed, if none of us had known where we would be on the distribution of bad luck, to minimize our exposure to really horrendous conditions. The practical implication is that while we might be bound to sacrifice some productivity to achieve redistribution, we cannot sacrifice too much. If we did that, we would most likely be hurting, rather than helping, the weakest and poorest. Libertarian theories of justice, most prominently represented by Robert Nozick's entitlement theory, on the other hand, tend to ignore bad luck or impoverishing structure. They focus solely on whether the particular holdings of a particular person at any given moment are unjustly obtained. If they are not, they may not justly be taken from the person who holds them. Explicitly, these theories ignore the poor. As a practical matter and by implication, they treat responsibility as the source of the success of the wealthy, and by negation, the plight of the poorest—leading them to be highly resistant to claims of redistribution.

The basic observation that an individual's economic condition is a function of his or her own actions does not necessarily resolve into a blanket rejection of redistribution, as we see in the work of other liberals. Ronald Dworkin's work on inequality offers a critique of Rawls's, in that it tries to include a component of responsibility alongside recognition of the role of luck. In his framework, if (1) resources were justly distributed and (2) bad luck in initial endowment were compensated through some insurance scheme, then poverty that resulted from bad choices, not bad luck, would not deserve help through redistribution. While Rawls's theory ignores personal responsibility, and in this regard, is less attractive from the perspective of a liberal theory that respects individual autonomy, it has the advantage of offering a much clearer metric for a just system. One can measure the welfare of the poorest under different redistribution rules in market economies. One can then see how much redistribution is too much, in the sense that welfare is reduced to the point that the poorest are actually worse off than they would be under a less-egalitarian system. You could compare the Soviet Union, West Germany, and the United States of the late 1960s–early 1970s, and draw conclusions. Dworkin's insurance scheme would require too fine an ability to measure the expected incapacitating effect of various low endowments—from wealth to intelligence to health—in a market economy, and to calibrate wealth endowments to equalize them, to offer a measuring rod for policy. It does, however, have the merit of distinguishing—for purposes of judging desert to benefit from society's redistribution efforts—between a child of privilege who fell into poverty through bad investments coupled with sloth and a person born into a poor family with severe mental defects. Bruce Ackerman's *Social Justice and the Liberal State* also provides a mechanism of differentiating the deserving from the undeserving, but adds policy tractability by including the dimension of structure to luck and responsibility. In addition to the dumb luck of how wealthy your parents are when you are born and what genetic endowment you are born with, there are also questions of the education system you grow up with and the transactional framework through which you live your life—which opportunities it affords, and which it cuts off or burdens. His proposals therefore seek to provide basic remedies for those failures, to the extent that they can, in fact, be remedied. One such proposal is Anne Alstott and Ackerman's idea of a government-funded personal endowment at birth, coupled with the freedom to squander it and suffer the consequential reduction in welfare.[1] He also emphasizes a more open and egalitarian transactional framework that would allow anyone access to opportunities to transact with others, rather than depending on, for example, unequal access to social links as a precondition to productive behavior.

The networked information economy improves justice from the perspective of every single one of these theories of justice. Imagine a good that improves the welfare of its users—it could be software, or an encyclopedia, or a product review. Now imagine a policy choice that could make production of that good on a nonmarket, peer-production basis too expensive to perform, or make it easy for an owner of an input to exclude competitors—both market-based and social-production based. For example, a government might decide to: recognize patents on software interfaces, so that it would be very expensive to buy the right to make your software work with someone else's; impose threshold formal education requirements on the authors of any encyclopedia available for school-age children to read, or impose very strict copyright requirements on using information contained in other sources (as opposed to only prohibiting copying their language) and impose high penalties for small omissions; or give the putative subjects of reviews very strong rights to charge for the privilege of reviewing a product—such as by expanding trademark rights to refer to the product, or prohibiting a reviewer to take apart a product without permission. The details do not matter. I offer them only to provide a sense of the commonplace kinds of choices that governments could make that would, as a practical matter, differentially burden nonmarket producers, whether nonprofit organizations or informal peer-production collaborations. Let us call a rule set that is looser from the perspective of access to existing information resources Rule Set A, and a rule set that imposes higher costs on access to information inputs Rule Set B. As explained in chapter 2, it is quite likely that adopting B would depress information production and innovation, even if it were intended to increase the production of information by, for example, strengthening copyright or patent. This is because the added incentives for some producers who produce with the aim of capturing the rents created by copyright or patents must be weighed against their costs. These include (a) the higher costs even for those producers and (b) the higher costs for all producers who do not rely on exclusive rights at all, but instead use either a nonproprietary market model—like service—or a nonmarket model, like nonprofits and individual authors, and that do not benefit in any way from the increased appropriation. However, let us make here a much weaker assumption—that an increase in the rules of exclusion will not affect overall production. Let us assume that there will be exactly enough increased production by producers who rely on a proprietary model to offset the losses of production in the nonproprietary sectors.

It is easy to see why a policy shift from A to B would be regressive from the perspective of theories like Rawls's or Ackerman's. Under Rule A, let us say that in this state of affairs, State A, there are five online encyclopedias. One of them is peer produced and freely available for anyone to use. Rule B is passed. In the new State B, there are still five encyclopedias. It has become too expensive to maintain the free encyclopedia, however, and more profitable to run commercial online encyclopedias. A new commercial encyclopedia has entered the market in competition with the four commercial encyclopedias that existed in State A, and the free encyclopedia folded. From the perspective of the difference principle, we can assume that the change has resulted in a stable overall welfare in the Kaldor-Hicks sense. (That is, overall welfare has increased enough so that, even though some people may be worse off, those who have been made better off are sufficiently better off that they could, in principle, compensate everyone who is worse off enough to make everyone either better off or no worse off than they were before.) There are still five encyclopedias. However, now they all charge a subscription fee. The poorest members of society are worse off, even if we posit that total social welfare has remained unchanged. In State A, they had access for free to an encyclopedia. They could use the information (or the software utility, if the example were software) without having to give up any other sources of welfare. In State B, they must choose between the same amount of encyclopedia usage as they had before, and less of some other source of welfare, or the same welfare from other sources, and no encyclopedia. If we assume, contrary to theory and empirical evidence from the innovation economics literature, that the move to State B systematically and predictably improves the incentives and investments of the commercial producers, that would still by itself not justify the policy shift from the perspective of the difference principle. One would have to sustain a much stricter claim: that the marginal improvement in the quality of the encyclopedias, and a decline in price from the added market competition that was not felt by the commercial producers when they were competing with the free, peer-produced version, would still make the poorest better off, even though they now must pay for any level of encyclopedia access, than they were when they had four commercial competitors with their prior levels of investment operating in a competitive landscape of four commercial and one free encyclopedia.

From the perspective of Ackerman's theory of justice, the advantages of the networked information economy are clearer yet. Ackerman characterizes some of the basic prerequisites for participating in a market economy as access to a transactional framework, to basic information, and to an adequate educational endowment. To the extent that any of the basic utilities required to participate in an information economy at all are available without sensitivity to price—that is, free to anyone—they are made available in a form that is substantially insulated from the happenstance of initial wealth endowments. In this sense at least, the development of a networked information economy overcomes some of the structural components of continued poverty—lack of access to information about market opportunities for production and cheaper consumption, about the quality of goods, or lack of communications capacity to people or places where one can act productively. While Dworkin's theory does not provide a similarly clear locus for mapping the effect of the networked information economy on justice, there is some advantage, and no loss, from this perspective, in having more of the information economy function on a nonmarket basis. As long as one recognizes bad luck as a partial reason for poverty, then having information resources available for free use is one mechanism of moderating the effects of bad luck in endowment, and lowers the need to compensate for those effects insofar as they translate to lack of access to information resources. This added access results from voluntary communication by the producers and a respect for their willingness to communicate what they produced freely.

While the benefits flow to individuals irrespective of whether their present state is due to luck or irresponsibility, it does not involve a forced redistribution from responsible individuals to irresponsible individuals.

From the perspective of liberal theories of justice, then, the emergence of the networked information economy is an unqualified improvement. Except under restrictive assumptions inconsistent with what we know as a matter of both theory and empirics about the economics of innovation and information production, the emergence of a substantial sector of information production and exchange that is based on social transactional frameworks, rather than on a proprietary exclusion business model, improves distribution in society. Its outputs are available freely to anyone, as basic inputs into their own actions—whether market-based or nonmarket-based. The facilities it produces improve the prospects of all who are connected to the Internet—whether they are seeking to use it as consumers or as producers. It softens some of the effects of resource inequality. It offers platforms for greater equality of opportunity to participate in market- and nonmarket-based enterprises. This characteristic is explored in much greater detail in the next segment of this chapter, but it is important to emphasize here that equality of opportunity to act in the face of unequal endowment is central to all liberal theories of justice. As a practical matter, these characteristics of the networked information economy make the widespread availability of Internet access a more salient objective of redistribution policy. They make policy debates, which are mostly discussed in today's political sphere in terms of innovation and growth, and sometimes in terms of freedom, also a matter of liberal justice.

COMMONS-BASED STRATEGIES FOR HUMAN WELFARE AND DEVELOPMENT

There is a long social-democratic tradition of focusing not on theoretical conditions of equality in a liberal society, but on the actual well-being of human beings in a society. This conception of justice shares with liberal theories the acceptance of market economy as a fundamental component of free societies. However, its emphasis is not equality of opportunity or even some level of social insurance that still allows the slothful to fall, but on assuring a basic degree of well-being to everyone in society. Particularly in the European social democracies, the ambition has been to make that basic level quite high, but the basic framework of even American Social Security—

unless it is fundamentally changed in the coming years—has this characteristic. The literature on global poverty and its alleviation was initially independent of this concern, but as global communications and awareness increased, and as the conditions of life in most advanced market economies for most people improved, the lines between the concerns with domestic conditions and global poverty blurred. We have seen an increasing merging of the concerns into a concern for basic human well-being everywhere. It is represented in no individual's work more clearly than in that of Amartya Sen, who has focused on the centrality of development everywhere to the definition not only of justice, but of freedom as well.

The emerging salience of global development as the core concern of distributive justice is largely based on the sheer magnitude of the problems faced by much of the world's population.[2] In the world's largest democracy, 80 percent of the population—slightly more people than the entire population of the United States and the expanded European Union combined—lives on less than two dollars a day, 39 percent of adults are illiterate, and 47 percent of children under the age of five are underweight for their age. In Africa's wealthiest democracy, a child at birth has a 45 percent probability of dying before he or she reaches the age of forty. India and South Africa are far from being the worst-off countries. The scope of destitution around the globe exerts a moral pull on any acceptable discussion of justice. Intuitively, these problems seem too fundamental to be seriously affected by the networked information economy—what has *Wikipedia* got to do with the 49 percent of the population of Congo that lacks sustainable access to improved water sources? It is, indeed, important not to be overexuberant about the importance of information and communications policy in the context of global human development. But it is also important not to ignore the centrality of information to most of our more-advanced strategies for producing core components of welfare and development. To see this, we can begin by looking at the components of the Human Development Index (HDI).

The Human Development Report was initiated in 1990 as an effort to measure a broad set of components of what makes a life livable, and, ultimately, attractive. It was developed in contradistinction to indicators centered on economic output, like gross domestic product (GDP) or economic growth alone, in order to provide a more refined sense of what aspects of a nation's economy and society make it more or less livable. It allows a more nuanced approach toward improving the conditions of life everywhere. As

Sen pointed out, the people of China, Kerala in India, and Sri Lanka lead much longer and healthier lives than other countries, like Brazil or South Africa, which have a higher per capita income.[3] The Human Development Report measures a wide range of outcomes and characteristics of life. The major composite index it tracks is the Human Development Index. The HDI tries to capture the capacity of people to live long and healthy lives, to be knowledgeable, and to have material resources sufficient to provide a decent standard of living. It does so by combining three major components: life expectancy at birth, adult literacy and school enrollment, and GDP per capita. As Figure 9.1 illustrates, in the global information economy, each and every one of these measures is significantly, though not solely, a function of access to information, knowledge, and information-embedded goods and services. Life expectancy is affected by adequate nutrition and access to lifesaving medicines. Biotechnological innovation for agriculture, along with agronomic innovation in cultivation techniques and other, lower-tech modes of innovation, account for a high portion of improvements in the capacity of societies to feed themselves and in the availability of nutritious foods. Medicines depend on pharmaceutical research and access to its products, and health care depends on research and publication for the development and dissemination of information about best-care practices. Education is also heavily dependent, not surprisingly, on access to materials and facilities for teaching. This includes access to basic textbooks, libraries, computation and communications systems, and the presence of local academic centers. Finally, economic growth has been understood for more than half a century to be centrally driven by innovation. This is particularly true of latecomers, who can improve their own condition most rapidly by adopting best practices and advanced technology developed elsewhere, and then adapting to local conditions and adding their own from the new technological platform achieved in this way. All three of these components are, then, substantially affected by access to, and use of, information and knowledge. The basic premise of the claim that the emergence of the networked information economy can provide significant benefits to human development is that the manner in which we produce new information—and equally important, the institutional framework we use to manage the stock of existing information and knowledge around the world—can have significant impact on human development.

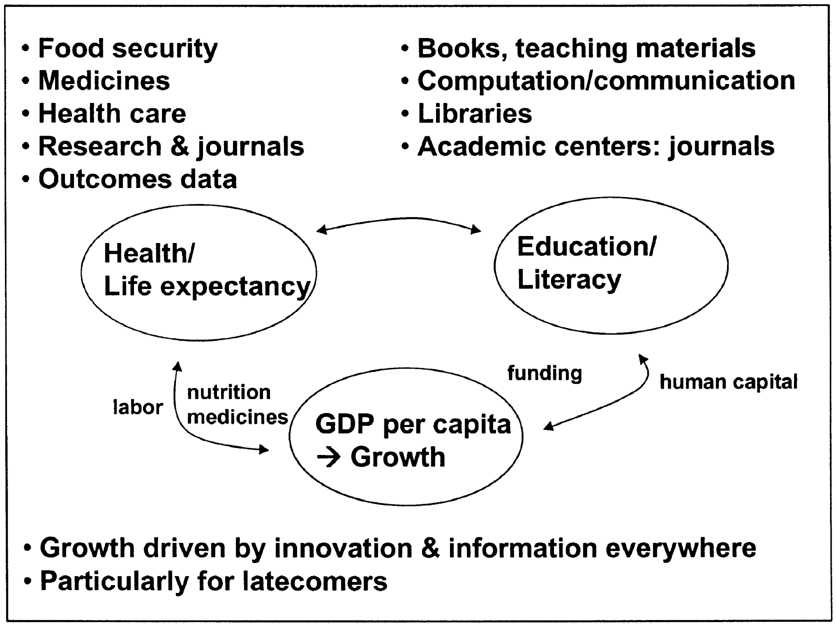

Figure 9.1: HDI and Information

INFORMATION-EMBEDDED GOODS AND TOOLS, INFORMATION, AND KNOWLEDGE

One can usefully idealize three types of information-based advantages that developed economies have, and that would need to be available to developing and less-developed economies if one's goal were the improvement in conditions in those economies and the opportunities for innovation in them. These include information-embedded material resources—consumption goods and production tools—information, and knowledge.

Information-Embedded Goods. These are goods that are not themselves information, but that are better, more plentiful, or cheaper because of some technological advance embedded in them or associated with their production. Pharmaceuticals and agricultural goods are the most obvious examples in the areas of health and food security, respectively. While there are other constraints on access to innovative products in these areas—regulatory and political in nature—a perennial barrier is cost. And a perennial barrier to competition that could reduce the cost is the presence of exclusive rights, mostly in the form of patents, but also in the form of internationally recognized breeders' rights and regulatory data exclusivity. In the areas of computation and communication, hardware and software are the primary domains of concern. With hardware, there have been some efforts toward developing cheaper equipment—like the simputer and the Jhai computer efforts to develop inexpensive computers. Because of the relatively commoditized state of most components of these systems, however, marginal cost, rather than exclusive rights, has been the primary barrier to access. The solution, if one has emerged, has been aggregation of demand—a networked computer for a village, rather than an individual. For software, the initial solution was piracy. More recently, we have seen an increased use of free software instead. The former cannot genuinely be described as a "solution," and is being eliminated gradually by trade policy efforts. The latter—adoption of free software to obtain state-of-the-art software—forms the primary template for the class of commons-based solutions to development that I explore in this chapter.

Information-Embedded Tools. One level deeper than the actual useful material things one would need to enhance welfare are tools necessary for innovation itself. In the areas of agricultural biotechnology and medicines, these include enabling technologies for advanced research, as well as access to materials and existing compounds for experimentation. Access to these is perhaps the most widely understood to present problems in the patent system of the developed world, as much as it is for the developing world—an awareness that has mostly crystallized under Michael Heller's felicitous phrase "anti-commons," or Carl Shapiro's "patent thicket." The intuition, whose analytic basis is explained in chapter 2, is that innovation is encumbered more than it is encouraged when basic tools for innovation are proprietary, where the property system gives owners of these tools proprietary rights to control innovation that relies on their tools, and where any given new innovation requires the consent of, and payment to, many such owners. This problem is not unique to the developing world. Nonetheless, because of the relatively small dollar value of the market for medicines that treat diseases that affect only poorer countries or of crop varieties optimized for those countries, the cost hurdle weighs more heavily on the public or nonprofit efforts to achieve food security and health in poor and middle-income countries. These nonmarket-based research efforts into diseases and crops of concern purely to these areas are not constructed to appropriate gains from exclusive rights to research tools, but only bear their costs on downstream innovation.

Information. The distinction between information and knowledge is a tricky one. I use "information" here colloquially, to refer to raw data, scientific reports of the output of scientific discovery, news, and factual reports. I use "knowledge" to refer to the set of cultural practices and capacities necessary for processing the information into either new statements in the information exchange, or more important in our context, for practical use of the information in appropriate ways to produce more desirable actions or outcomes from action. Three types of information that are clearly important for purposes of development are scientific publications, scientific and economic data, and news and factual reports. Scientific publication has seen a tremendous cost escalation, widely perceived to have reached crisis proportions even by the terms of the best-endowed university libraries in the wealthiest countries. Over the course of the 1990s, some estimates saw a 260 percent increase in the prices of scientific publications, and libraries were reported choosing between journal subscription and monograph purchases.[4] In response to this crisis, and in reliance on what were perceived to be the publication cost-reduction opportunities for Internet publication, some scientists—led by Nobel laureate and then head of the National Institutes of Health Harold Varmus—began to agitate for a scientist-based publication system.[5] The debates were, and continue to be, heated in this area. However, currently we are beginning to see the emergence of scientist-run and -driven publication systems that distribute their papers for free online, either within a traditional peer-review system like the Public Library of Science (PLoS), or within tightly knit disciplines like theoretical physics, with only post-publication peer review and revision, as in the case of the Los Alamos Archive, or ArXiv.org. Together with free software and peer production on the Internet, the PLoS and ArXiv.org models offer insights into the basic shape of the class of commons-based, nonproprietary production solutions to problems of information production and exchange unhampered by intellectual property.

Scientific and economic data present a parallel conceptual problem, but in a different legal setting. In the case of both types of data, much of it is produced by government agencies. In the United States, however, raw data is in the public domain, and while initial access may require payment of the cost of distribution, reworking of the data as a tool in information production and innovation—and its redistribution by those who acquired access initially—is considered to be in the public domain. In Europe, this has not been the case since the 1996 Database Directive, which created a property-like right in raw data in an effort to improve the standing of European database producers. Efforts to pass similar legislation in the United States have been mounted and stalled in practically every Congress since the mid-1990s. These laws continue to be introduced, driven by the lobby of the largest owners of nongovernment databases, and irrespective of the fact that for almost a decade, Europe's database industry has grown only slowly in the presence of a right, while the U.S. database industry has flourished without an exclusive rights regime.

News, market reports, and other factual reporting seem to have escaped the problems of barriers to access. Here it is most likely that the value-appropriation model simply does not depend on exclusive rights. Market data is generated as a by-product of the market function itself. Tiny time delays are sufficient to generate a paying subscriber base, while leaving the price trends necessary for, say, farmers to decide at what prices to sell their grain in the local market, freely available.[6] As I suggested in chapter 2, the advertising-supported press has never been copyright dependent, but has instead depended on timely updating of news to capture attention, and then attach that attention to advertising. This has not changed, but the speed of the update cycle has increased and, more important, distribution has become global, so that obtaining most information is now trivial to anyone with access to an Internet connection. While this continues to raise issues with deployment of communications hardware and the knowledge of how to use it, these issues can be, and are being, approached through aggregation of demand in either public or private forms. These types of information do not themselves appear to exhibit significant barriers to access once network connectivity is provided.

Knowledge. In this context, I refer mostly to two types of concern. The first is the possibility of the transfer of implicit knowledge, which resists codification into what would here be treated as "information"—for example, training manuals. The primary mechanism for transfer of knowledge of this type is learning by doing, and knowledge transfer of this form cannot happen except through opportunities for local practice of the knowledge. The second type of knowledge transfer of concern here is formal instruction in an education context (as compared with dissemination of codified outputs for selfteaching). Here, there is a genuine limit on the capacity of the networked information economy to improve access to knowledge. Individual, face-to-face instruction does not scale across participants, time, and distance. However, some components of education, at all levels, are nonetheless susceptible to improvement with the increase in nonmarket and radically decentralized production processes. The MIT Open Courseware initiative is instructive as to how the universities of advanced economies can attempt to make at least their teaching materials and manuals freely available to teachers throughout the world, thereby leaving the pedagogy in local hands but providing more of the basic inputs into the teaching process on a global scale. More important perhaps is the possibility that teachers and educators can collaborate, both locally and globally, on an open platform model like *Wikipedia*, to coauthor learning objects, teaching modules, and, more ambitiously, textbooks that could then be widely accessed by local teachers

INDUSTRIAL ORGANIZATION OF HDI-RELATED INFORMATION INDUSTRIES

The production of information and knowledge is very different from the production of steel or automobiles. Chapter 2 explains in some detail that information production has always included substantial reliance on nonmarket actors and on nonmarket, nonproprietary settings as core modalities of production. In software, for example, we saw that Mickey and romantic maximizer-type producers, who rely on exclusive rights directly, have accounted for a stable 36–37 percent of market-based revenues for software developers, while the remainder was focused on both supply-side and demand-side improvements in the capacity to offer software services. This number actually overstates the importance of software publishing, because it does not at all count free software development except when it is monetized by an IBM or a Red Hat, leaving tremendous value unaccounted for. A very large portion of the investments and research in any of the information production fields important to human development occur within the category that I have broadly described as "Joe Einstein." These include both those places formally designated for the pursuit of information and knowledge in themselves, like universities, and those that operate in the social sphere, but produce information and knowledge as a more or less central part of their existence—like churches or political parties. Moreover, individuals acting as social beings have played a central role in our information production and exchange system. In order to provide a more sector-specific analysis of how commons-based, as opposed to proprietary, strategies can contribute to development, I offer here a more detailed breakdown specifically of software, scientific publication, agriculture, and biomedical innovation than is provided in chapter 2. Table 9.1 presents a higher-resolution statement of the major actors in these fields, within both the market and the nonmarket sectors, from which we can then begin to analyze the path toward, and the sustainability of, more significant commons-based production of the necessities of human development.

Table 9.1 identifies the relative role of each of the types of main actors in information and knowledge production across the major sectors relevant to contemporary policy debates. It is most important to extract from this table the diversity of business models and roles not only in each industry, but also among industries. This diversity means that different types of actors can have different relative roles: nonprofits as opposed to individuals, universities as opposed to government, or nonproprietary market actors—that is, market actors whose business model is service based or otherwise does not depend on exclusive appropriation of information—as compared to nonmarket actors. The following segments look at each of these sectors more specifically, and describe the ways in which commons-based strategies are already, or could be, used to improve the access to information, knowledge, and the information-embedded goods and tools for human development. However, even a cursory look at the table shows that the current production landscape of software is particularly well suited to having a greater role for commons-based production. For example, exclusive proprietary producers account for only one-third of software-related revenues, even within the market. The remainder is covered by various services and relationships that are compatible with nonproprietary treatment of the software itself. Individuals and nonprofit associations also have played a very large role, and continue to do so, not only in free software development, but in the development of standards as well. As we look at each sector, we see that they differ in their incumbent industrial landscape, and these differences mean that each sector may be more or less amenable to commons-based strategies, and, even if in principle amenable, may present harder or easier transition problems.

Table 9.1: Map of Players and Roles in Major Relevant Sectors

Actor Sector	Government	Universities, Libraries, etc.	IP-Based Industry	Non-IP-Based Industry	NGOs/ Nonprofits	Individuals
Software	Research funding, defense, procurement	Basic research and design; components "incubate" much else	Software publishing (1/3 annual revenue)	Software services, customization (~2/3 annual revenue)	FSF; Apache; W3C; IETF	Free/open-source software
Scientific publication	Research funding	University presses; salaries; promotion and tenure	Elsevier Science; professional associations	Biomed Central	PLoS; ArXiv	Working papers; Web-based self-publishing
Agricultural Biotech	Grants and government labs; NARS	Basic research; tech transfer (24% of patenting activity)	Monsanto, DuPont, Syngenta (~74% of patents)	No obvious equivalent	CAMBIA BIOS CGIAR	Farmers
Biomed/ Health	Grants and government labs	Basic research; tech transfer (~50%?)	Big Pharma; Biotech (~50%?)	Generics	OneWorld Health	None

TOWARD ADOPTING COMMONS-BASED STRATEGIES FOR DEVELOPMENT

The mainstream understanding of intellectual property by its dominant policy-making institutions—the Patent Office and U.S. trade representative in the United States, the Commission in the European Union, and the World Intellectual Property Organization (WIPO) and Trade-Related Aspects of Intellectual Property (TRIPS) systems internationally—is that strong protection is good, and stronger protection is better. In development and trade policy, this translates into a belief that the primary mechanism for knowledge transfer and development in a global information economy is for all nations, developing as well as developed, to ratchet up their intellectual property law standards to fit the most protective regimes adopted in the United States and Europe. As a practical political matter, the congruence between the United States and the European Union in this area means that this basic understanding is expressed in the international trade system, in the World Trade Organization (WTO) and its TRIPS agreement, and in international intellectual property treaties, through the WIPO. The next few segments present an alternative view. Intellectual property as an institution is substantially more ambiguous in its effects on information production than the steady drive toward expansive rights would suggest. The full argument is in chapter 2.

Intellectual property is particularly harmful to net information importers. In our present world trade system, these are the poor and middle-income nations. Like all users of information protected by exclusive rights, these nations are required by strong intellectual property rights to pay more than the marginal cost of the information at the time that they buy it. In the standard argument, this is intended to give producers incentives to create information that users want. Given the relative poverty of these countries, however, practically none of the intellectual-property-dependent producers develop products specifically with returns from poor or even middle-income markets in mind. The pharmaceutical industry receives about 5 percent of its global revenues from low- and middle-income countries. That is why we have so little investment in drugs for diseases that affect only those parts of the world. It is why most agricultural research that has focused on agriculture in poorer areas of the world has been public sector and nonprofit. Under these conditions, the above-marginal-cost prices paid in these poorer countries are purely regressive redistribution. The information, knowledge, and information-embedded goods paid for would have been developed in expectation of rich world rents alone. The prospects of rents from poorer countries do not affect their development. They do not affect either the rate or the direction of research and development. They simply place some of the rents that pay for technology development in the rich countries on consumers in poor and middle-income countries. The morality of this redistribution from the world's poor to the world's rich has never been confronted or defended in the European or American public spheres. It simply goes unnoticed. When crises in access to information-embedded goods do appear—such as in the AIDS/HIV access to medicines crisis—these are seldom tied to our basic institutional choice. In our trade policies, Americans and Europeans push for ever-stronger protection. We thereby systematically benefit those who own much of the stock of usable human knowledge. We do so at the direct expense of those who need access to knowledge in order to feed themselves and heal their sick.

The practical politics of the international intellectual property and trade regime make it very difficult to reverse the trend toward ever-increasing exclusive property protections. The economic returns to exclusive proprietary rights in information are highly concentrated in the hands of those who own such rights. The costs are widely diffuse in the populations of both the developing and developed world. The basic inefficiency of excessive property protection is difficult to understand by comparison to the intuitive, but mistaken, Economics 101 belief that property is good, more property is better, and intellectual property must be the same. The result is that pressures on the governments that represent exporters of intellectual property rights permissions—in particular, the United States and the European Union—come in this area mostly from the owners, and they continuously push for ever-stronger rights. Monopoly is a good thing to have if you can get it. Its value for rent extraction is no less valuable for a database or patent-based company than it is for the dictator's nephew in a banana republic. However, its value to these supplicants does not make it any more efficient or desirable.

The political landscape is, however, gradually beginning to change. Since the turn of the twenty-first century, and particularly in the wake of the urgency with which the HIV/AIDS crisis in Africa has infused the debate over access to medicines, there has been a growing public interest advocacy movement focused on the intellectual property trade regime. This movement is, however, confronted with a highly playable system. A victory for developing world access in one round in the TRIPS context always leaves other places to construct mechanisms for exclusivity. Bilateral trade negotiations are one domain that is beginning to play an important role. In these, the United States or the European Union can force a rice- or cotton-exporting country to concede a commitment to strong intellectual property protection in exchange for favorable treatment for their core export. The intellectual property exporting nations can then go to WIPO, and push for new treaties based on the emerging international practice of bilateral agreements. This, in turn, would cycle back and be generalized and enforced through the trade regimes. Another approach is for the exporting nations to change their own laws, and then drive higher standards elsewhere in the name of "harmonization." Because the international trade and intellectual property system is highly "playable" and manipulable in these ways, systematic resistance to the expansion of intellectual property laws is difficult.

The promise of the commons-based strategies explored in the remainder of this chapter is that they can be implemented without changes in law—either national or international. They are paths that the emerging networked information economy has opened to individuals, nonprofits, and public-sector organizations that want to help in improving human development in the poorer regions of the world to take action on their own. As with decentralized speech for democratic discourse, and collaborative production by individuals of the information environment they occupy as autonomous agents, here too we begin to see that self-help and cooperative action outside the proprietary system offer an opportunity for those who wish to pursue it. In this case, it is an opportunity to achieve a more just distribution of the world's resources and a set of meaningful improvements in human development. Some of these solutions are "commons-based," in the sense that they rely on free access to existing information that is in the commons, and they facilitate further use and development of that information and those information-embedded goods and tools by releasing their information outputs openly, and managing them as a commons, rather than as property. Some of the solutions are specifically peer-production solutions. We see this most clearly in software, and to some extent in the more radical proposals for scientific publication. I will also explore here the viability of peer-production efforts in agricultural and biomedical innovation, although in those fields, commons-based approaches grafted onto traditional public-sector and nonprofit organizations at present hold the more clearly articulated alternatives.

Software

The software industry offers a baseline case because of the proven large scope for peer production in free software. As in other information-intensive industries, government funding and research have played an enormously important role, and university research provides much of the basic science. However, the relative role of individuals, nonprofits, and nonproprietary market producers is larger in software than in the other sectors. First, two-thirds of revenues derived from software in the United States are from services and do not depend on proprietary exclusion. Like IBM's "Linux-related services" category, for which the company claimed more than two billion dollars of revenue for 2003, these services do not depend on exclusion from the software, but on charging for service relationships.[7] Second, some of the most basic elements of the software environment—like standards and protocols—are developed in nonprofit associations, like the Internet Engineering Taskforce or the World Wide Web Consortium. Third, the role of individuals engaged in peer production—the free and open-source software development communities—is very large. Together, these make for an organizational ecology highly conducive to nonproprietary production, whose outputs can be freely usable around the globe. The other sectors have some degree of similar components, and commons-based strategies for development can focus on filling in the missing components and on leveraging nonproprietary components already in place.

In the context of development, free software has the potential to play two distinct and significant roles. The first is offering low-cost access to high-performing software for developing nations. The second is creating the potential for participation in software markets based on human ability, even without access to a stock of exclusive rights in existing software. At present, there is a movement in both developing and the most advanced economies to increase reliance on free software. In the United States, the Presidential Technology Advisory Commission advised the president in 2000 to increase use of free software in mission-critical applications, arguing the high quality and dependability of such systems. To the extent that quality, reliability, and ease of self-customization are consistently better with certain free software products, they are attractive to developing-country governments for the same reasons that they are to the governments of developed countries. In the context of developing nations, the primary additional arguments that have been made include cost, transparency, freedom from reliance on a single foreign source (read, Microsoft), and the potential of local software programmers to learn the program, acquire skills, and therefore easily enter the global market with services and applications for free software.[8] The question of cost, despite the confusion that often arises from the word "free," is not obvious. It depends to some extent on the last hope—that local software developers will become skilled in the free software platforms. The cost of software to any enterprise includes the extent, cost, and efficacy with which the software can be maintained, upgraded, and fixed when errors occur. Free software may or may not involve an up-front charge. Even if it does not, that does not make it cost-free. However, free software enables an open market in free software servicing, which in turn improves and lowers the cost of servicing the software over time. More important, because the software is open for all to see and because developer communities are often multinational, local developers can come, learn the software, and become relatively low-cost software service providers for their own government. This, in turn, helps realize the low-cost promise over and above the licensing fees avoided. Other arguments in favor of government procurement of free software focus on the value of transparency of software used for public purposes. The basic thrust of these arguments is that free software makes it possible for constituents to monitor the behavior of machines used in governments, to make sure that they are designed to do what they are publicly reported to do. The most significant manifestation of this sentiment in the United States is the hitherto-unsuccessful, but fairly persistent effort to require states to utilize voting machines that use free software, or at a minimum, to use software whose source code is open for public inspection. This is a consideration that, if valid, is equally suitable for developing nations. The concern with independence from a single foreign provider, in the case of operating systems, is again not purely a developing-nation concern. Just as the United States required American Marconi to transfer its assets to an American company, RCA, so that it would not be dependent for a critical infrastructure on a foreign provider, other countries may have similar concerns about Microsoft. Again, to the extent that this is a valid concern, it is so for rich nations as much as it is for poor, with the exceptions of the European Union and Japan, which likely do have bargaining power with Microsoft to a degree that smaller markets do not.

The last and quite distinct potential gain is the possibility of creating a context and an anchor for a free software development sector based on service. This was cited as the primary reason behind Brazil's significant push to use free software in government departments and in telecenters that the federal government is setting up to provide Internet service access to some of its poorer and more remote areas. Software services represent a very large industry. In the United States, software services are an industry roughly twice the size of the movie and video industry. Software developers from low- and middle-income countries can participate in the growing free software segment of this market by using their skills alone. Unlike with service for the proprietary domain, they need not buy licenses to learn and practice the services. Moreover, if Brazil, China, India, Indonesia, and other major developing countries were to rely heavily on free software, then the "internal market," within the developing world, for free software–related services would become very substantial. Building public-sector demand for these services would be one place to start. Moreover, because free software development is a global phenomenon, free software developers who learn their skills within the developing world would be able to export those skills elsewhere. Just as India's call centers leverage the country's colonial past with its resulting broad availability of English speakers, so too countries like Brazil can leverage their active free software development community to provide software services for free software platforms anywhere in the developed and developing worlds. With free software, the developing-world providers can compete as equals. They do not need access to permissions to operate. Their relationships need not replicate the "outsourcing" model so common in proprietary industries, where permission to work on a project is the point of control over the ability to do so. There will still be branding issues that undoubtedly will affect access to developed markets. However, there will be no baseline constraints of minimal capital necessary to enter the market and try to develop a reputation for reliability. As a development strategy, then, utilization of free software achieves transfer of information-embedded goods for free or at low cost. It also transfers information about the nature of the product and its operation—the source code. Finally, it enables transfer, at least potentially, of opportunities for learning by doing and of opportunities for participating in the global market. These would depend on knowledge of a free software platform that anyone is free to learn, rather than on access to financial capital or intellectual property inventories as preconditions to effective participation.

Scientific Publication

Scientific publication is a second sector where a nonproprietary strategy can be implemented readily and is already developing to supplant the proprietary model. Here, the existing market structure is quite odd in a way that likely makes it unstable. Authoring and peer review, the two core value-creating activities, are done by scientists who perform neither task in expectation of royalties or payment. The model of most publications, however, is highly proprietary. A small number of business organizations, like Elsevier Science, control most of the publications. Alongside them, professional associations of scientists also publish their major journals using a proprietary model.

Universities, whose scientists need access to the papers, incur substantial cost burdens to pay for the publications as a basic input into their own new work. While the effects of this odd system are heavily felt in universities in rich countries, the burden of subscription rates that go into the thousands of dollars per title make access to up-to-date scientific research prohibitive for universities and scientists working in poorer economies. Nonproprietary solutions are already beginning to emerge in this space. They fall into two large clusters.

The first cluster is closer to the traditional peer-review publication model. It uses Internet communications to streamline the editorial and peer-review system, but still depends on a small, salaried editorial staff. Instead of relying on subscription payments, it relies on other forms of payments that do not require charging a price for the outputs. In the case of the purely nonprofit Public Library of Science (PLoS), the sources of revenue combine author's payments for publication, philanthropic support, and university memberships. In the case of the for-profit BioMed Central, based in the United Kingdom, it is a combination of author payments, university memberships, and a variety of customized derivative products like subscription-based literature reviews and customized electronic update services. Author payments—fees authors must pay to have their work published—are built into the cost of scientific research and included in grant applications. In other words, they are intended to be publicly funded. Indeed, in 2005, the National Institutes of Health (NIH), the major funding agency for biomedical science in the United States, announced a requirement that all NIH-funded research be made freely available on the Web within twelve months of publication. Both PLoS and BioMed Central have waiver processes for scientists who cannot pay the publication fees. The articles on both systems are available immediately for free on the Internet. The model exists. It works internally and is sustainable as such. What is left in determining the overall weight that these open-access journals will have in the landscape of scientific publication is the relatively conservative nature of universities themselves. The established journals, like *Science* or *Nature*, still carry substantially more prestige than the new journals. As long as this is the case, and as long as hiring and promotion decisions continue to be based on the prestige of the journal in which a scientist's work is published, the ability of the new journals to replace the traditional ones will be curtailed. Some of the established journals, however, are operated by professional associations of scientists. There is an internal tension between the interests of the associations in securing their revenue and the growing interest of scientists in open-access publication. Combined with the apparent economic sustainability of the open-access journals, it seems that some of these established journals will likely shift over to the open-access model. At a minimum, policy interventions like those proposed by the NIH will force traditional publications to adapt their business model by making access free after a few months. The point here, however, is not to predict the overall likely success of open-access journals. It is to combine them with what we have seen happening in software as another example of a reorganization of the components of the industrial structure of an information production system. Individual scientists, government funding agencies, nonprofits and foundations, and nonproprietary commercial business models can create the same good—scientific publication—but without the cost barrier that the old model imposed on access to its fruits. Such a reorientation would significantly improve the access of universities and physicians in developing nations to the most advanced scientific publication.

The second approach to scientific publication parallels more closely free software development and peer production. This is typified by ArXiv and the emerging practices of self-archiving or self-publishing. ArXiv.org is an online repository of working papers in physics, mathematics, and computer science. It started out focusing on physics, and that is where it has become the sine qua non of publication in some subdisciplines. The archive does not perform review except for technical format compliance. Quality control is maintained by postpublication review and commentary, as well as by hosting updated versions of the papers with explanations (provided by authors) of the changes. It is likely that the reason ArXiv.org has become so successful in physics is the very small and highly specialized nature of the discipline. The universe of potential readers is small, and their capacity to distinguish good arguments from bad is high. Reputation effects of poor publications are likely immediate.

While ArXiv offers a single repository, a much broader approach has been the developing practice of self-archiving. Academics post their completed work on their own Web sites and make it available freely. The primary limitation of this mechanism is the absence of an easy, single location where one can search for papers on a topic of concern. And yet we are already seeing the emergence of tagging standards and protocols that allow anyone to search the universe of self-archived materials. Once completed, such a development process would in principle render archiving by single points of reference unnecessary. The University of Michigan Digital Library Production Service, for example, has developed a protocol called OAIster (pronounced like oyster, with the tagline "find the pearls"), which combines the acronym of Open Archives Initiative with the "ster" ending made popular in reference to peer-to-peer distribution technologies since Napster (AIMster, Grokster, Friendster, and the like). The basic impulse of the Open Archives Initiative is to develop a sufficiently refined set of meta-data tags that would allow anyone who archives their materials with OAI-compliant tagging to be searched easily, quickly, and accurately on the Web. In that case, a general Web search becomes a targeted academic search in a "database" of scientific publications. However, the database is actually a network of self-created, small personal databases that comply with a common tagging and search standard. Again, my point here is not to explore the details of one or another of these approaches. If scientists and other academics adopt this approach of self-archiving coupled with standardized interfaces for global, well-delimited searches, the problem of lack of access to academic publication because of their high-cost publication will be eliminated.

Other types of documents, for example, primary- and secondary-education textbooks, are in a much more rudimentary stage of the development of peer-production models. First, it should be recognized that responses to illiteracy and low educational completion in the poorer areas of the world are largely a result of lack of schoolteachers, physical infrastructure for classrooms, demand for children's schooling among parents who are themselves illiterate, and lack of effectively enforced compulsory education policy. The cost of textbooks contributes only a portion of the problem of cost. The opportunity cost of children's labor is probably the largest factor. Nonetheless, outdated materials and poor quality of teaching materials are often cited as one limit on the educational achievement of those who do attend school. The costs of books, school fees, uniforms, and stationery can amount to 20–30 percent of a family's income.[9] The component of the problem contributed by the teaching materials may be alleviated by innovative approaches to textbook and education materials authoring. Chapter 4 already discussed some textbook initiatives. The most successful commons-based textbook authoring project, which is also the most relevant from the perspective of development, is the South African project, Free High School Science Texts (FHSST). The FHSST initiative is more narrowly focused than the broader efforts of Wikibooks or the California initiative, more managed, and more successful. Nonetheless, in three years of substantial effort by a group of dedicated volunteers who administer the project, its product is one physics high school text, and advanced drafts of two other science texts. The main constraint on the efficacy of collaborative textbook authoring is that compliance requirements imposed by education ministries tend to require a great degree of coherence, which constrains the degree of modularity that these text-authoring projects adopt. The relatively large-grained contributions required limit the number of contributors, slowing the process. The future of these efforts is therefore likely to be determined by the extent to which their designers are able to find ways to make finer-grained modules without losing the coherence required for primary- and secondary-education texts. Texts at the post-secondary level likely present less of a problem, because of the greater freedom instructors have to select texts. This allows an initiative like MIT's Open Courseware Initiative to succeed. That initiative provides syllabi, lecture notes, problem sets, etc. from over 1,100 courses. The basic creators of the materials are paid academics who produce these materials for one of their core professional roles: teaching college- and graduate-level courses. The content is, by and large, a "side-effect" of teaching. What is left to be done is to integrate, create easy interfaces and search capabilities, and so forth. The university funds these functions through its own resources and dedicated grant funding. In the context of MIT, then, these functions are performed on a traditional model—a large, well-funded nonprofit provides an important public good through the application of full-time staff aimed at non-wealth-maximizing goals. The critical point here was the radical departure of MIT from the emerging culture of the 1980s and 1990s in American academia. When other universities were thinking of "distance education" in terms of selling access to taped lectures and materials so as to raise new revenue, MIT thought of what its basic mandate to advance knowledge and educate students in a networked environment entailed. The answer was to give anyone, anywhere, access to the teaching materials of some of the best minds in the world. As an intervention in the ecology of free knowledge and information and an act of leadership among universities, the MIT initiative was therefore a major event. As a model for organizational innovation in the domain of information production generally and the creation of educational resources in particular, it was less significant.

Software and academic publication, then, offer the two most advanced examples of commons-based strategies employed in a sector whose outputs are important to development, in ways that improve access to basic information, knowledge, and information-embedded tools. Building on these basic cases, we can begin to see how similar strategies can be employed to create a substantial set of commons-based solutions that could improve the distribution of information germane to human development.

COMMONS-BASED RESEARCH FOR FOOD AND MEDICINES

While computation and access to existing scientific research are important in the development of any nation, they still operate at a remove from the most basic needs of the world poor. On its face, it is far from obvious how the emergence of the networked information economy can grow rice to feed millions of malnourished children or deliver drugs to millions of HIV/AIDS patients. On closer observation, however, a tremendous proportion of the way modern societies grow food and develop medicines is based on scientific research and technical innovation. We have seen how the functions of mass media can be fulfilled by nonproprietary models of news and commentary. We have seen the potential of free and open source software and open-access publications to replace and redress some of the failures of proprietary software and scientific publication, respectively. These cases suggest that the basic choice between a system that depends on exclusive rights and business models that use exclusion to appropriate research outputs and a system that weaves together various actors—public and private, organized and individual—in a nonproprietary social network of innovation, has important implications for the direction of innovation and for access to its products. Public attention has focused mostly on the HIV/AIDS crisis in Africa and the lack of access to existing drugs because of their high costs. However, that crisis is merely the tip of the iceberg. It is the most visible to many because of the presence of the disease in rich countries and its cultural and political salience in the United States and Europe. The exclusive rights system is a poor institutional mechanism for serving the needs of those who are worst off around the globe. Its weaknesses pervade the problems of food security and agricultural research aimed at increasing the supply of nourishing food throughout the developing world, and of access to medicines in general, and to medicines for developing-world diseases in particular. Each of these areas has seen a similar shift in national and international policy toward greater reliance on exclusive rights, most important of which are patents. Each area has also begun to see the emergence of commons-based models to alleviate the problems of patents. However, they differ from each other still. Agriculture offers more immediate opportunities for improvement because of the relatively larger role of public research—national, international, and academic—and of the long practices of farmer innovation in seed associations and local and regional frameworks. I explore it first in some detail, as it offers a template for what could be a path for development in medical research as well.

Food Security: Commons-Based Agricultural Innovation

Agricultural innovation over the past century has led to a vast increase in crop yields. Since the 1960s, innovation aimed at increasing yields and improving quality has been the centerpiece of efforts to secure the supply of food to the world's poor, to avoid famine and eliminate chronic malnutrition. These efforts have produced substantial increases in the production of food and decreases in its cost, but their benefits have varied widely in different regions of the world. Now, increases in productivity are not alone a sufficient condition to prevent famine. Sen's observations that democracies have no famines—that is, that good government and accountability will force public efforts to prevent famine—are widely accepted today. The contributions of the networked information economy to democratic participation and transparency are discussed in chapters 6–8, and to the extent that those chapters correctly characterize the changes in political discourse, should help alleviate human poverty through their effects on democracy. However, the cost and quality of food available to accountable governments of poor countries, or to international aid organizations or nongovernment organizations (NGOs) that step in to try to alleviate the misery caused by ineffective or malicious governments, affect how much can be done to avoid not only catastrophic famine, but also chronic malnutrition. Improvements in agriculture make it possible for anyone addressing food security to perform better than they could have if food production had lower yields, of less nutritious food, at higher prices. Despite its potential benefits, however, agricultural innovation has been subject to an unusual degree of sustained skepticism aimed at the very project of organized scientific and scientifically based innovation. Criticism combines biological-ecological concerns with social and economic concerns. Nowhere is this criticism more strident, or more successful at moving policy, than in current European resistance to genetically modified (GM) foods. The emergence of commons-based production strategies can go some way toward allaying the biological-ecological fears by locating much of the innovation at the local level. Its primary benefit, however, is likely to be in offering a path for agricultural and biological innovation that is sustainable and low cost, and that need not result in appropriation of the food production chain by a small number of multinational businesses, as many critics fear.

Scientific plant improvement in the United States dates back to the establishment of the U.S. Department of Agriculture, the land-grant universities, and later the state agricultural experiment stations during the Civil War and in the decades that followed. Public-sector investment dominated agricultural research at the time, and with the rediscovery of Mendel's work in 1900, took a turn toward systematic selective breeding. Through crop improvement associations, seed certification programs, and open-release policies allowing anyone to breed and sell the certified new seeds, farmers were provided access to the fruits of public research in a reasonably efficient and open market. The development of hybrid corn through this system was the first major modern success that vastly increased agricultural yields. It reshaped our understanding not only of agriculture, but also more generally of the value of innovation, by comparison to efficiency, to growth. Yields in the United States doubled between the mid-1930s and the mid-1950s, and by the mid-1980s, cornfields had a yield six times greater than they had fifty years before. Beginning in the early 1960s, with funding from the Rockefeller and Ford foundations, and continuing over the following forty years, agricultural research designed to increase the supply of agricultural production and lower its cost became a central component of international and national policies aimed at securing the supply of food to the world's poor populations, avoiding famines and, ultimately, eliminating chronic malnutrition. The International Rice Research Institute (IRRI) in the Philippines was the first such institute, founded in the 1960s, followed by the International Center for Wheat and Maize Improvement (CIM-MYT) in Mexico (1966), and the two institutes for tropical agriculture in Colombia and Nigeria (1967). Together, these became the foundation for the Consultative Group for International Agricultural Research (CGIAR), which now includes sixteen centers. Over the same period, National Agricultural Research Systems (NARS) also were created around the world, focusing on research specific to local agroecological conditions. Research in these centers preceded the biotechnology revolution, and used various experimental breeding techniques to obtain high-yielding plants: for example, plants with shorter growing seasons, or more adapted to intensive fertilizer use. These efforts later introduced varieties that were resistant to local pests, diseases, and to various harsh environmental conditions.

The "Green Revolution," as the introduction of these new, scientific-research-based varieties has been called, indeed resulted in substantial increases in yields, initially in rice and wheat, in Asia and Latin America. The term "Green Revolution" is often limited to describing these changes in those regions in the 1960s and 1970s. A recent study shows, however, that the growth in yields has continued throughout the last forty years, and has, with varying degrees, occurred around the world.[10] More than eight thousand modern varieties of rice, wheat, maize, other major cereals, and root and protein crops have been released over the course of this period by more than four hundred public breeding programs. One of the most interesting finds of this study was that fewer than 1 percent of these modern varieties had any crosses with public or private breeding programs in the developed world, and that private-sector contributions in general were limited to hybrid maize, sorghum, and millet. The effort, in other words, was almost entirely public sector, and almost entirely based in the developing world, with complementary efforts of the international and national programs. Yields in Asia increased sevenfold from 1961 to 2000, and fivefold in Latin America, the Middle East/North Africa, and Sub-Saharan Africa. More than 60 percent of the growth in Asia and Latin America occurred in the 1960s–1980s, while the primary growth in Sub-Saharan Africa began in the 1980s. In Latin America, most of the early-stage increases in yields came from increasing cultivated areas (~40 percent), and from other changes in cultivation—increased use of fertilizer, mechanization, and irrigation. About 15 percent of the growth in the early period was attributable to the use of modern varieties. In the latter twenty years, however, more than 40 percent of the total increase in yields was attributable to the use of new varieties. In Asia in the early period, about 19 percent of the increase came from modern varieties, but almost the entire rest of the increase came from increased use of fertilizer, mechanization, and irrigation, not from increased cultivated areas. It is trivial to see why changes of this sort would elicit both environmental and a social-economic critique of the industrialization of farm work. Again, though, in the latter twenty years, 46 percent of the increase in yields is attributable to the use of modern varieties. Modern varieties played a significantly less prominent role in the Green Revolution of the Middle East and Africa, contributing 5–6 percent of the growth in yields. In Sub-Saharan Africa, for example, early efforts to introduce varieties from Asia and Latin America failed, and local developments only began to be adopted in the 1980s. In the latter twenty-year period, however, the Middle East and North Africa did see a substantial role for modern varieties—accounting for close to 40 percent of a more than doubling of yields. In Sub-Saharan Africa, the overwhelming majority of the tripling of yields came from increasing area of cultivation, and about 16 percent came from modern varieties. Over the past forty years, then, research-based improvements in plants have come to play a larger role in increasing agricultural yields in the developing world. Their success was, however, more limited in the complex and very difficult environments of Sub-Saharan Africa. Much of the benefit has to do with local independence, as opposed to heavier dependence on food imports. Evenson and Gollin, for example, conservatively estimate that higher prices and a greater reliance on imports in the developing world in the absence of the Green Revolution would have resulted in 13–14 percent lower caloric intake in the developing world, and in a 6–8 percent higher proportion of malnourished children. While these numbers may not seem eye-popping, for populations already living on marginal nutrition, they represent significant differences in quality of life and in physical and mental development for millions of children and adults.

The agricultural research that went into much of the Green Revolution did not involve biotechnology—that is, manipulation of plant varieties at the genetic level through recombinant DNA techniques. Rather, it occurred at the level of experimental breeding. In the developed world, however, much of the research over the past twenty-five years has been focused on the use of biotechnology to achieve more targeted results than breeding can, has been more heavily based on private-sector investment, and has resulted in more private-sector ownership over the innovations. The promise of biotechnology, and particularly of genetically engineered or modified foods, has been that they could provide significant improvements in yields as well as in health effects, quality of the foods grown, and environmental effects. Plants engineered to be pest resistant could decrease the need to use pesticides, resulting in environmental benefits and health benefits to farmers. Plants engineered for ever-higher yields without increasing tilled acreage could limit the pressure for deforestation. Plants could be engineered to carry specific nutritional supplements, like golden rice with beta-carotene, so as to introduce necessarily nutritional requirements into subsistence diets. Beyond the hypothetically optimistic possibilities, there is little question that genetic engineering has already produced crops that lower the cost of production for farmers by increasing herbicide and pest tolerance. As of 2002, more than 50 percent of the world's soybean acreage was covered with genetically modified (GM) soybeans, and 20 percent with cotton. Twenty-seven percent of acreage covered with GM crops is in the developing world. This number will grow significantly now that Brazil has decided to permit the introduction of GM crops, given its growing agricultural role, and now that India, as the world's largest cotton producer, has approved the use of Bt cotton—a GM form of cotton that improves its resistance to a common pest. There are, then, substantial advantages to farmers, at least, and widespread adoption of GM crops both in the developed world outside of Europe and in the developing world.

This largely benign story of increasing yields, resistance, and quality has not been without critics, to put it mildly. The criticism predates biotechnology and the development of transgenic varieties. Its roots are in criticism of experimental breeding programs of the American agricultural sectors and the Green Revolution. However, the greatest public visibility and political success of these criticisms has been in the context of GM foods. The critique brings together odd intellectual and political bedfellows, because it includes five distinct components: social and economic critique of the industrialization of agriculture, environmental and health effects, consumer preference for "natural" or artisan production of foodstuffs, and, perhaps to a more limited extent, protectionism of domestic farm sectors.

Perhaps the oldest component of the critique is the social-economic critique. One arm of the critique focuses on how mechanization, increased use of chemicals, and ultimately the use of nonreproducing proprietary seed led to incorporation of the agricultural sector into the capitalist form of production. In the United States, even with its large "family farm" sector, purchased inputs now greatly exceed nonpurchased inputs, production is highly capital intensive, and large-scale production accounts for the majority of land tilled and the majority of revenue captured from farming.[11] In 2003, 56 percent of farms had sales of less than $10,000 a year. Roughly 85 percent of farms had less than $100,000 in sales.[12] These farms account for only 42 percent of the farmland. By comparison, 3.4 percent of farms have sales of more than $500,000 a year, and account for more than 21 percent of land. In the aggregate, the 7.5 percent of farms with sales over $250,000 account for 37 percent of land cultivated. Of all principal owners of farms in the United States in 2002, 42.5 percent reported something other than farming as their principal occupation, and many reported spending two hundred or more days off-farm, or even no work days at all on the farm. The growth of large-scale "agribusiness," that is, mechanized, rationalized industrial-scale production of agricultural products, and more important, of agricultural inputs, is seen as replacing the family farm and the small-scale, self-sufficient farm, and bringing farm labor into the capitalist mode of production. As scientific development of seeds and chemical applications increases, the seed as input becomes separated from the grain as output, making farmers dependent on the purchase of industrially produced seed. This further removes farmwork from traditional modes of self-sufficiency and craftlike production to an industrial mode. This basic dynamic is repeated in the critique of the Green Revolution, with the added overlay that the industrial producers of seed are seen to be multinational corporations, and the industrialization of agriculture is seen as creating dependencies in the periphery on the industrial-scientific core of the global economy.

The social-economic critique has been enmeshed, as a political matter, with environmental, health, and consumer-oriented critiques as well. The environmental critiques focus on describing the products of science as monocultures, which, lacking the genetic diversity of locally used varieties, are more susceptible to catastrophic failure. Critics also fear contamination of existing varieties, unpredictable interactions with pests, and negative effects on indigenous species. The health effects concern focused initially on how breeding for yield may have decreased nutritional content, and in the more recent GM food debates, the concern that genetically altered foods will have some unanticipated negative health reactions that would only become apparent many years from now. The consumer concerns have to do with quality and an aesthetic attraction to artisan-mode agricultural products and aversion to eating industrial outputs. These social-economic and environmental-health-consumer concerns tend also to be aligned with protectionist lobbies, not only for economic purposes, but also reflecting a strong cultural attachment to the farming landscape and human ecology, particularly in Europe.

This combination of social-economic and postcolonial critique, environmentalism, public-health concerns, consumer advocacy, and farm-sector protectionism against the relatively industrialized American agricultural sector reached a height of success in the 1999 five-year ban imposed by the European Union on all GM food sales. A recent study of a governmental Science Review Board in the United Kingdom, however, found that there was no evidence for any of the environmental or health critiques of GM foods.[13] Indeed, as Peter Pringle masterfully chronicled in *Food, Inc.*, both sides of the political debate could be described as having buffed their cases significantly. The successes and potential benefits have undoubtedly been overstated by enamored scientists and avaricious vendors. There is little doubt, too, that the near-hysterical pitch at which the failures and risks of GM foods have been trumpeted has little science to back it, and the debate has degenerated to a state that makes reasoned, evidence-based consideration difficult. In Europe in general, however, there is wide acceptance of what is called a "precautionary principle." One way of putting it is that absence of evidence of harm is not evidence of absence of harm, and caution counsels against adoption of the new and at least theoretically dangerous. It was this precautionary principle rather than evidence of harm that was at the base of the European ban. This ban has recently been lifted, in the wake of a WTO trade dispute with the United States and other major producers who challenged the ban as a trade barrier. However, the European Union retained strict labeling requirements. This battle among wealthy countries, between the conservative "Fortress Europe" mentality and the growing reliance of American agriculture on biotechnological innovation, would have little moral valence if it did not affect funding for, and availability of, biotechnological research for the populations of the developing world. Partly as a consequence of the strong European resistance to GM foods, the international agricultural research centers that led the way in the development of the Green Revolution varieties, and that released their developments freely for anyone to sell and use without proprietary constraint, were slow to develop capacity in genetic engineering and biotechnological research more generally. Rather than the public national and international efforts leading the way, a study of GM use in developing nations concluded that practically all GM acreage is sown with seed obtained in the finished form from a developed-world supplier, for a price premium or technology licensing fee.[14] The seed, and its improvements, is proprietary to the vendor in this model. It is not supplied in a form or with the rights to further improve locally and independently. Because of the critique of innovation in agriculture as part of the process of globalization and industrialization, of environmental degradation, and of consumer exploitation, the political forces that would have been most likely to support public-sector investment in agricultural innovation are in opposition to such investments. The result has not been retardation of biotechnological innovation in agriculture, but its increasing privatization: primarily in the United States and now increasingly in Latin America, whose role in global agricultural production is growing.

Private-sector investment, in turn, operates within a system of patents and other breeders' exclusive rights, whose general theoretical limitations are discussed in chapter 2. In agriculture, this has two distinct but mutually reinforcing implications. The first is that, while private-sector innovation has indeed accounted for most genetically engineered crops in the developing world, research aimed at improving agricultural production in the neediest places has not been significantly pursued by the major private-sector firms. A sector based on expectation of sales of products embedding its patents will not focus its research where human welfare will be most enhanced. It will focus where human welfare can best be expressed in monetary terms. The poor are systematically underserved by such a system. It is intended to elicit investments in research in directions that investors believe will result in outputs that serve the needs of those with the highest willingness and ability to pay for their outputs. The second is that even where the products of innovation can, as a matter of biological characteristics, be taken as inputs into local research and development—by farmers or by national agricultural research systems—the international system of patents and plant breeders' rights enforcement makes it illegal to do so without a license. This again retards the ability of poor countries and their farmers and research institutes to conduct research into local adaptations of improved crops.

The central question raised by the increasing privatization of agricultural biotechnology over the past twenty years is: What can be done to employ commons-based strategies to provide a foundation for research that will be focused on the food security of developing world populations? Is there a way of managing innovation in this sector so that it will not be heavily weighted in favor of populations with a higher ability to pay, and so that its outputs allow farmers and national research efforts to improve and adapt to highly variable local agroecological environments? The continued presence of the public-sector research infrastructure—including the international and national research centers, universities, and NGOs dedicated to the problem of food security—and the potential of harnessing individual farmers and scientists to cooperative development of open biological innovation for agriculture suggest that commons-based paths for development in the area of food security and agricultural innovation are indeed feasible.

First, some of the largest and most rapidly developing nations that still have large poor populations—most prominently, China, India, and Brazil—can achieve significant advances through their own national agricultural research systems. Their research can, in turn, provide a platform for further innovation and adaptation by projects in poorer national systems, as well as in nongovernmental public and peer-production efforts. In this regard, China seems to be leading the way. The first rice genome to be sequenced was japonica, apparently sequenced in 2000 by scientists at Monsanto, but not published. The second, an independent and published sequence of japonica, was sequenced by scientists at Syngenta, and published as the first published rice genome sequence in *Science* in April 2002. To protect its proprietary interests, Syngenta entered a special agreement with *Science*, which permitted the authors not to deposit the genomic information into the public Genbank maintained by the National Institutes of Health in the United States.[15] Depositing the information in GenBank makes it immediately available for other scientists to work with freely. All the major scientific publications require that such information be deposited and made publicly available as a standard condition of publication, but *Science* waved this requirement for the Syngenta japonica sequence. The same issue of *Science*, however, carried a similar publication, the sequence of Oryza sativa L.ssp. indica, the most widely cultivated subspecies in China. This was sequenced by a public Chinese effort, and its outputs were immediately deposited in GenBank. The simultaneous publication of the rice genome by a major private firm and a Chinese public effort was the first public exposure to the enormous advances that China's public sector has made in agricultural biotechnology, and its focus first and foremost on improving Chinese agriculture. While its investments are still an order of magnitude smaller than those of public and private sectors in the developed countries, China has been reported as the source of more than half of all expenditures in the developing world.[16] China's longest experience with GM agriculture is with Bt cotton, which was introduced in 1997. By 2000, 20 percent of China's cotton acreage was sown to Bt cotton. One study showed that the average acreage of a farm was less than 0.5 hectare of cotton, and the trait that was most valuable to them was Bt cotton's reduced pesticide needs. Those who adopted Bt cotton used less pesticide, reducing labor for pest control and the pesticide cost per kilogram of cotton produced. This allowed an average cost savings of 28 percent. Another effect suggested by survey data—which, if confirmed over time, would be very important as a matter of public health, but also to the political economy of the agricultural biotechnology debate—is that farmers who do not use Bt cotton are four times as likely to report symptoms of a degree of toxic exposure following application of pesticides than farmers who did adopt Bt cotton.[17] The point is not, of course, to sing the praises of GM cotton or the Chinese research system. China's efforts offer an example of how the larger national research systems can provide an anchor for agricultural research, providing solutions both for their own populations, and, by making the products of their research publicly and freely available, offer a foundation for the work of others.

Alongside the national efforts in developing nations, there are two major paths for commons-based research and development in agriculture that could serve the developing world more generally. The first is based on existing research institutes and programs cooperating to build a commons-based system, cleared of the barriers of patents and breeders' rights, outside and alongside the proprietary system. The second is based on the kind of loose affiliation of university scientists, nongovernmental organizations, and individuals that we saw play such a significant role in the development of free and open-source software. The most promising current efforts in the former vein are the PIPRA (Public Intellectual Property for Agriculture) coalition of public-sector universities in the United States, and, if it delivers on its theoretical promises, the Generation Challenge Program led by CGIAR (the Consultative Group on International Agricultural Research). The most promising model of the latter, and probably the most ambitious commons-based project for biological innovation currently contemplated, is BIOS (Biological Innovation for an Open Society).

PIPRA is a collaboration effort among public-sector universities and agricultural research institutes in the United States, aimed at managing their rights portfolio in a way that will give their own and other researchers freedom to operate in an institutional ecology increasingly populated by patents and other rights that make work difficult. The basic thesis and underlying problem that led to PIPRA's founding were expressed in an article in *Science* coauthored by fourteen university presidents.[18] They underscored the centrality of public-sector, land-grant university-based research to American agriculture, and the shift over the last twenty-five years toward increased use of intellectual property rules to cover basic discoveries and tools necessary for agricultural innovation. These strategies have been adopted by both commercial firms and, increasingly, by public-sector universities as the primary mechanism for technology transfer from the scientific institute to the commercializing firms. The problem they saw was that in agricultural research, innovation was incremental. It relies on access to existing germplasm and crop varieties that, with each generation of innovation, brought with them an ever-increasing set of intellectual property claims that had to be licensed in order to obtain permission to innovate further. The universities decided to use the power that ownership over roughly 24 percent of the patents in agricultural biotechnology innovations provides them as a lever with which to unravel the patent thickets and to reduce the barriers to research that they increasingly found themselves dealing with. The main story, one might say the "founding myth" of PIPRA, was the story of golden rice. Golden rice is a variety of rice that was engineered to provide dietary vitamin A. It was developed with the hope that it could introduce vitamin A supplement to populations in which vitamin A deficiency causes roughly 500,000 cases of blindness a year and contributes to more than 2 million deaths a year. However, when it came to translating the research into deliverable plants, the developers encountered more than seventy patents in a number of countries and six materials transfer agreements that restricted the work and delayed it substantially. PIPRA was launched as an effort of public-sector universities to cooperate in achieving two core goals that would respond to this type of barrier—preserving the right to pursue applications to subsistence crops and other developing-world-related crops, and preserving their own freedom to operate vis-à-vis each other's patent portfolios.

The basic insight of PIPRA, which can serve as a model for university alliances in the context of the development of medicines as well as agriculture, is that universities are not profit-seeking enterprises, and university scientists are not primarily driven by a profit motive. In a system that offers opportunities for academic and business tracks for people with similar basic skills, academia tends to attract those who are more driven by nonmonetary motivations. While universities have invested a good deal of time and money since the Bayh-Dole Act of 1980 permitted and indeed encouraged them to patent innovations developed with public funding, patent and other exclusive-rights-based revenues have not generally emerged as an important part of the revenue scheme of universities. As table 9.2 shows, except for one or two outliers, patent revenues have been all but negligible in university budgets.[19] This fact makes it fiscally feasible for universities to use their patent portfolios to maximize the global social benefit of their research, rather than trying to maximize patent revenue. In particular, universities can aim to include provisions in their technology licensing agreements that are aimed at the dual goals of (a) delivering products embedding their innova-

Table 9.2: Selected University Gross Revenues and Patent Licensing Revenues

	Total Revenues	Licensing and Royalties		Government Grants & Contracts	
	(millions $)	(millions $)	% of total	(millions $)	% of total
All universities	$227,000	$ 1270	0.56%	$31,430	13.85%
Columbia University	$ 2,074	$178.4	8.6%	$532	25.65%
		$100–120[a]	4.9–5.9%		
University of California	$ 14,166	$ 81.3	0.57%	$2372	16.74%
		$ 55 (net)[b]	0.39%		
Stanford University	$ 3,475	$ 43.3	1.25%	$860	24.75%
		$ 36.8[c]	1.06%		
Florida State	$ 2,646	$ 35.6	1.35%	$238	8.99%
University of Wisconsin-Madison	$ 1,696	$ 32	1.89%	$417.4	24.61%
University of Minnesota	$ 1,237	$ 38.7	3.12%	$323.5	26.15%
Harvard	$ 2,473	$ 47.9	1.94%	$416	16.82%
				$548.7[d]	22.19%
Cal Tech	$ 531	$ 26.7[e]	5.02%	$268	50.47%
		$ 15.7[f]	2.95%		

Sources: Aggregate revenues: U.S. Dept. of Education, National Center for Education Statistics, *Enrollment in Postsecondary Institutions, Fall 2001, and Financial Statistics, Fiscal Year 2001* (2003), Table F; Association of University Technology Management, *Annual Survey Summary FY 2002* (AUTM 2003), Table S-12. Individual institutions: publicly available annual reports of each university and/or its technology transfer office for FY 2003.

Notes:

a. Large ambiguity results because technology transfer office reports increased revenues for year-end 2003 as $178M without reporting expenses; University Annual Report reports licensing revenue with all "revenue from other educational and research activities," and reports a 10 percent decline in this category, "reflecting an anticipated decline in royalty and license income" from the $133M for the previous year-end, 2002. The table reflects an assumed net contribution to university revenues between $100-120M (the entire decline in the category due to royalty/royalties decreased proportionately with the category).

b. University of California Annual Report of the Office of Technology Transfer is more transparent than most in providing expenses—both net legal expenses and tech transfer direct operating expenses, which allows a clear separation of net revenues from technology transfer activities.

c. Minus direct expenses, not including expenses for unlicensed inventions.

d. Federal- and nonfederal-sponsored research.

e. Almost half of this amount is in income from a single Initial Public Offering, and therefore does not represent a recurring source of licensing revenue.

f. Technology transfer gross revenue minus the one-time event of an initial public offering of LiquidMetal Technologies.

tions to developing nations at reasonable prices and (b) providing researchers and plant breeders the freedom to operate that would allow them to research, develop, and ultimately produce crops that would improve food security in the developing world.

While PIPRA shows an avenue for collaboration among universities in the public interest, it is an avenue that does not specifically rely on, or benefit in great measure from, the information networks or the networked information economy. It continues to rely on the traditional model of publicly funded research. More explicit in its effort to leverage the cost savings made possible by networked information systems is the Generation Challenge Program (GCP). The GCP is an effort to bring the CGIAR into the biotechnology sphere, carefully, given the political resistance to genetically modified foods, and quickly, given the already relatively late start that the international research centers have had in this area. Its stated emphasis is on building an architecture of innovation, or network of research relationships, that will provide low-cost techniques for the basic contemporary technologies of agricultural research. The program has five primary foci, but the basic thrust is to generate improvements both in basic genomics science and in breeding and farmer education, in both cases for developing world agriculture. One early focus would be on building a communications system that allows participating institutions and scientists to move information efficiently and utilize computational resources to pursue research. There are hundreds of thousands of samples of germplasm, from "landrace" (that is, locally agriculturally developed) and wild varieties to modern varieties, located in databases around the world in international, national, and academic institutions. There are tremendous high-capacity computation resources in some of the most advanced research institutes, but not in many of the national and international programs. One of the major goals articulated for the GCP is to develop Web-based interfaces to share these data and computational resources. Another is to provide a platform for sharing new questions and directions of research among participants. The work in this network will, in turn, rely on materials that have proprietary interests attached to them, and will produce outputs that could have proprietary interests attached to them as well. Just like the universities, the GCP institutes (national, international, and nonprofit) are looking for an approach aimed to secure open access to research materials and tools and to provide humanitarian access to its products, particularly for subsistence crop development and use. As of this writing, however, the GCP is still in a formative stage, more an aspiration than a working model. Whether it will succeed in overcoming the political constraints placed on the CGIAR as well as the relative latecomer status of the international public efforts to this area of work remains to be seen. But the elements of the GCP certainly exhibit an understanding of the possibilities presented by commons-based networked collaboration, and an ambition to both build upon them and contribute to their development.

The most ambitious effort to create a commons-based framework for biological innovation in this field is BIOS. BIOS is an initiative of CAMBIA (Center for the Application of Molecular Biology to International Agriculture), a nonprofit agricultural research institute based in Australia, which was founded and is directed by Richard Jefferson, a pioneer in plant biotechnology. BIOS is based on the observation that much of contemporary agricultural research depends on access to tools and enabling technologies—such as mechanisms to identify genes or for transferring them into target plants. When these tools are appropriated by a small number of firms and available only as part of capital-intensive production techniques, they cannot serve as the basis for innovation at the local level or for research organized on nonproprietary models. One of the core insights driving the BIOS initiative is the recognition that when a subset of necessary tools is available in the public domain, but other critical tools are not, the owners of those tools appropriate the full benefits of public domain innovation without at the same time changing the basic structural barriers to use of the proprietary technology. To overcome these problems, the BIOS initiative includes both a strong informatics component and a fairly ambitious "copyleft"-like model (similar to the GPL described in chapter 3) of licensing CAMBIA's basic tools and those of other members of the BIOS initiative. The informatics component builds on a patent database that has been developed by CAMBIA for a number of years, and whose ambition is to provide as complete as possible a dataset of who owns what tools, what the contours of ownership are, and by implication, who needs to be negotiated with and where research paths might emerge that are not yet appropriated and therefore may be open to unrestricted innovation.

The licensing or pooling component is more proactive, and is likely the most significant of the project. BIOS is setting up a licensing and pooling arrangement, "primed" by CAMBIA's own significant innovations in tools, which are licensed to all of the initiative's participants on a free model, with grant-back provisions that perform an openness-binding function similar to copyleft.[20] In coarse terms, this means that anyone who builds upon the contributions of others must contribute improvements back to the other participants. One aspect of this model is that it does not assume that all research comes from academic institutions or from traditional government-funded, nongovernmental, or intergovernmental research institutes. It tries to create a framework that, like the open-source development community, engages commercial and noncommercial, public and private, organized and individual participants into a cooperative research network. The platform for this collaboration is "BioForge," styled after Sourceforge, one of the major free and open-source software development platforms. The commitment to engage many different innovators is most clearly seen in the efforts of BIOS to include major international commercial providers and local potential commercial breeders alongside the more likely targets of a commons-based initiative. Central to this move is the belief that in agricultural science, the basic tools can, although this may be hard, be separated from specific applications or products. All actors, including the commercial ones, therefore have an interest in the open and efficient development of tools, leaving competition and profit making for the market in applications. At the other end of the spectrum, BIOS's focus on making tools freely available is built on the proposition that innovation for food security involves more than biotechnology alone. It involves environmental management, locale-specific adaptations, and social and economic adoption in forms that are locally and internally sustainable, as opposed to dependent on a constant inflow of commoditized seed and other inputs. The range of participants is, then, much wider than envisioned by PIPRA or the GCP. It ranges from multinational corporations through academic scientists, to farmers and local associations, pooling their efforts in a communications platform and institutional model that is very similar to the way in which the GNU/Linux operating system has been developed. As of this writing, the BIOS project is still in its early infancy, and cannot be evaluated by its outputs. However, its structure offers the crispest example of the extent to which the peer-production model in particular, and commons-based production more generally, can be transposed into other areas of innovation at the very heart of what makes for human development—the ability to feed oneself adequately.

PIPRA and the BIOS initiative are the most salient examples of, and the most significant first steps in the development of commons-based strategies to achieve food security. Their vitality and necessity challenge the conventional wisdom that ever-increasing intellectual property rights are necessary to secure greater investment in research, or that the adoption of proprietary rights is benign. Increasing appropriation of basic tools and enabling technologies creates barriers to entry for innovators—public-sector, nonprofit organizations, and the local farmers themselves—concerned with feeding those who cannot signal with their dollars that they are in need. The emergence of commons-based techniques—particularly, of an open innovation platform that can incorporate farmers and local agronomists from around the world into the development and feedback process through networked collaboration platforms—promises the most likely avenue to achieve research oriented toward increased food security in the developing world. It promises a mechanism of development that will not increase the relative weight and control of a small number of commercial firms that specialize in agricultural production. It will instead release the products of innovation into a self-binding commons—one that is institutionally designed to defend itself against appropriation. It promises an iterative collaboration platform that would be able to collect environmental and local feedback in the way that a free software development project collects bug reports—through a continuous process of networked conversation among the user-innovators themselves. In combination with public investments from national governments in the developing world, from the developed world, and from more traditional international research centers, agricultural research for food security may be on a path of development toward constructing a sustainable commons-based innovation ecology alongside the proprietary system. Whether it follows this path will be partly a function of the engagement of the actors themselves, but partly a function of the extent to which the international intellectual property/trade system will refrain from raising obstacles to the emergence of these commons-based efforts.

Access to Medicines: Commons-Based Strategies for Biomedical Research

Nothing has played a more important role in exposing the systematic problems that the international trade and patent system presents for human development than access to medicines for HIV/AIDS. This is so for a number of reasons. First, HIV/AIDS has reached pandemic proportions. One quarter of all deaths from infectious and parasitic diseases in 2002 were caused by AIDS, accounting for almost 5 percent of all deaths in the world that year.[21] Second, it is a new condition, unknown to medicine a mere twenty-five years ago, is communicable, and in principle is of a type—infectious diseases—that we have come to see modern medicine as capable of solving.

This makes it different from much bigger killers—like the many cancers and forms of heart disease—which account for about nine times as many deaths globally. Third, it has a significant presence in the advanced economies. Because it was perceived there as a disease primarily affecting the gay community, it had a strong and well-defined political lobby and high cultural salience. Fourth, and finally, there have indeed been enormous advances in the development of medicines for HIV/AIDS. Mortality for patients who are treated is therefore much lower than for those who are not. These treatments are new, under patent, and enormously expensive. As a result, death—as opposed to chronic illness—has become overwhelmingly a consequence of poverty. More than 75 percent of deaths caused by AIDS in 2002 were in Africa. HIV/AIDS drugs offer a vivid example of an instance where drugs exist for a disease but cannot be afforded in the poorest countries. They represent, however, only a part, and perhaps the smaller part, of the limitations that a patent-based drug development system presents for providing medicines to the poor. No less important is the absence of a market pull for drugs aimed at diseases that are solely or primarily developing-world diseases—like drugs for tropical diseases, or the still-elusive malaria vaccine.

To the extent that the United States and Europe are creating a global innovation system that relies on patents and market incentives as its primary driver of research and innovation, these wealthy democracies are, of necessity, choosing to neglect diseases that disproportionately affect the poor. There is nothing evil about a pharmaceutical company that is responsible to its shareholders deciding to invest where it expects to reap profit. It is not immoral for a firm to invest its research funds in finding a drug to treat acne, which might affect 20 million teenagers in the United States, rather than a drug that will cure African sleeping sickness, which affects 66 million Africans and kills about fifty thousand every year. If there is immorality to be found, it is in the legal and policy system that relies heavily on the patent system to induce drug discovery and development, and does not adequately fund and organize biomedical research to solve the problems that cannot be solved by relying solely on market pull. However, the politics of public response to patents for drugs are similar in structure to those that have to do with agricultural biotechnology exclusive rights. There is a very strong patent-based industry—much stronger than in any other patent-sensitive area. The rents from strong patents are enormous, and a rational monopolist will pay up to the value of its rents to maintain and improve its monopoly. The primary potential political push-back in the pharmaceutical area, which does not exist in the agricultural innovation area, is that the exorbitant costs of drugs developed under this system is hurting even the well-endowed purses of developed-world populations. The policy battles in the United States and throughout the developed world around drug cost containment may yet result in a sufficient loosening of the patent constraints to deliver positive side effects for the developing world. However, they may also work in the opposite direction. The unwillingness of the wealthy populations in the developed world to pay high rents for drugs retards the most immediate path to lower-cost drugs in the developing world—simple subsidy of below-cost sales in poor countries cross-subsidized by above-cost rents in wealthy countries.

The industrial structure of biomedical research and pharmaceutical development is different from that of agricultural science in ways that still leave a substantial potential role for commons-based strategies. However, these would be differently organized and aligned than in agriculture. First, while governments play an enormous role in funding basic biomedical science, there are no real equivalents of the national and international agricultural research institutes. In other words, there are few public-sector laboratories that actually produce finished drugs for delivery in the developing world, on the model of the International Rice Research Institute or one of the national agricultural research systems. On the other hand, there is a thriving generics industry, based in both advanced and developing economies, that stands ready to produce drugs once these are researched. The primary constraint on harnessing its capacity for low-cost drug production and delivery for poorer nations is the international intellectual property system. The other major difference is that, unlike with software, scientific publication, or farmers in agriculture, there is no existing framework for individuals to participate in research and development on drugs and treatments. The primary potential source of nongovernmental investment of effort and thought into biomedical research and development are universities as institutions and scientists, if they choose to organize themselves into effective peer-production communities.

Universities and scientists have two complementary paths open to them to pursue commons-based strategies to provide improved research on the relatively neglected diseases of the poor and improved access to existing drugs that are available in the developed world but unaffordable in the developing. The first involves leveraging existing university patent portfolios—much as the universities allied in PIPRA are exploring and as CAMBIA is doing more aggressively. The second involves work in an entirely new model—constructing collaboration platforms to allow scientists to engage in peer production, cross-cutting the traditional grant-funded lab, and aiming toward research into diseases that do not exercise a market pull on the biomedical research system in the advanced economies.

Leveraging University Patents. In February 2001, the humanitarian organization Doctors Without Borders (also known as Médecins Sans Frontières, or MSF) asked Yale University, which held the key South African patent on stavudine—one of the drugs then most commonly used in combination therapies—for permission to use generic versions in a pilot AIDS treatment program. At the time, the licensed version of the drug, sold by Bristol-Myers-Squibb (BMS), cost $1,600 per patient per year. A generic version, manufactured in India, was available for $47 per patient per year. At that point in history, thirty-nine drug manufacturers were suing the South African government to strike down a law permitting importation of generics in a health crisis, and no drug company had yet made concessions on pricing in developing nations. Within weeks of receiving MSF's request, Yale negotiated with BMS to secure the sale of stavudine for fifty-five dollars a year in South Africa. Yale, the University of California at Berkeley, and other universities have, in the years since, entered into similar ad hoc agreements with regard to developing-world applications or distribution of drugs that depend on their patented technologies. These successes provide a template for a much broader realignment of how universities use their patent portfolios to alleviate the problems of access to medicines in developing nations.

We have already seen in table 9.2 that while universities own a substantial and increasing number of patents, they do not fiscally depend in any significant way on patent revenue. These play a very small part in the overall scheme of revenues. This makes it practical for universities to reconsider how they use their patents and to reorient toward using them to maximize their beneficial effects on equitable access to pharmaceuticals developed in the advanced economies. Two distinct moves are necessary to harness publicly funded university research toward building an information commons that is easily accessible for global redistribution. The first is internal to the university process itself. The second has to do with the interface between the university and patent-dependent and similar exclusive-rights-dependent market actors.

Universities are internally conflicted about their public and market goals.

Dating back to the passage of the Bayh-Dole Act, universities have increased their patenting practices for the products of publicly funded research. Technology transfer offices that have been set up to facilitate this practice are, in many cases, measured by the number of patent applications, grants, and dollars they bring in to the university. These metrics for measuring the success of these offices tend to make them function, and understand their role, in a way that is parallel to exclusive-rights-dependent market actors, instead of as public-sector, publicly funded, and publicly minded institutions. A technology transfer officer who has successfully provided a royalty-free license to a nonprofit concerned with developing nations has no obvious metric in which to record and report the magnitude of her success (saving X millions of lives or displacing Y misery), unlike her colleague who can readily report X millions of dollars from a market-oriented license, or even merely Y dozens of patents filed. Universities must consider more explicitly their special role in the global information and knowledge production system. If they recommit to a role focused on serving the improvement of the lot of humanity, rather than maximization of their revenue stream, they should adapt their patenting and licensing practices appropriately. In particular, it will be important following such a rededication to redefine the role of technology transfer offices in terms of lives saved, quality-of-life measures improved, or similar substantive measures that reflect the mission of university research, rather than the present metrics borrowed from the very different world of patent-dependent market production. While the internal process is culturally and politically difficult, it is not, in fact, analytically or technically complex. Universities have, for a very long time, seen themselves primarily as dedicated to the advancement of knowledge and human welfare through basic research, reasoned inquiry, and education. The long-standing social traditions of science have always stood apart from market incentives and orientations. The problem is therefore one of reawakening slightly dormant cultural norms and understandings, rather than creating new ones in the teeth of long-standing contrary traditions. The problem should be substantially simpler than, say, persuading companies that traditionally thought of their innovation in terms of patents granted or royalties claimed, as some technology industry participants have, to adopt free software strategies.

If universities do make the change, then the more complex problem will remain: designing an institutional interface between universities and the pharmaceutical industry that will provide sustainable significant benefits for developing-world distribution of drugs and for research opportunities into developing-world diseases. As we already saw in the context of agriculture, patents create two discrete kinds of barriers: The first is on distribution, because of the monopoly pricing power they purposefully confer on their owners. The second is on research that requires access to tools, enabling technologies, data, and materials generated by the developed-world research process, and that could be useful to research on developing-world diseases. Universities working alone will not provide access to drugs. While universities perform more than half of the basic scientific research in the United States, this effort means that more than 93 percent of university research expenditures go to basic and applied science, leaving less than 7 percent for development—the final research necessary to convert a scientific project into a usable product.[22] Universities therefore cannot simply release their own patents and expect treatments based on their technologies to become accessible. Instead, a change is necessary in licensing practices that takes an approach similar to a synthesis of the general public license (GPL), of BIOS's licensing approach, and PIPRA.

Universities working together can cooperate to include in their licenses provisions that would secure freedom to operate for anyone conducting research into developing-world diseases or production for distribution in poorer nations. The institutional details of such a licensing regime are relatively complex and arcane, but efforts are, in fact, under way to develop such licenses and to have them adopted by universities.[23] What is important here, for understanding the potential, is the basic idea and framework. In exchange for access to the university's patents, the pharmaceutical licensees will agree not to assert any of their own rights in drugs that require a university license against generics manufacturers who make generic versions of those drugs purely for distribution in low- and middle-income countries. An Indian or American generics manufacturer could produce patented drugs that relied on university patents and were licensed under this kind of an equitable-access license, as long as it distributed its products solely in poor countries. A government or nonprofit research institute operating in South Africa could work with patented research tools without concern that doing so would violate the patents. However, neither could then import the products of their production or research into the developed world without violating the patents of both the university and the drug company. The licenses would create a mechanism for redistribution of drug products and research tools from the developed economies to the developing. It would do so without requiring the kind of regulatory changes advocated by others, such as

Jean Lanjouw, who have advocated policy changes aimed similarly to achieve differential pricing in the developing and developed worlds.[24] Because this redistribution could be achieved by universities acting through licensing, instead of through changes in law, it offers a more feasible political path for achieving the desired result. Such action by universities would, of course, not solve all the problems of access to medicines. First, not all health-related products are based on university research. Second, patents do not account for all, or perhaps even most, of the reason that patients in poor nations are not treated. A lack of delivery infrastructure, public-health monitoring and care, and stable conditions to implement disease-control policy likely weigh more heavily. Nonetheless, there are successful and stable government and nonprofit programs that could treat hundreds of thousands or millions of patients more than they do now, if the cost of drugs were lower. Achieving improved access for those patients seems a goal worthy of pursuit, even if it is no magic bullet to solve all the illnesses of poverty.

Nonprofit Research. Even a successful campaign to change the licensing practices of universities in order to achieve inexpensive access to the products of pharmaceutical research would leave the problem of research into diseases that affect primarily the poor. This is because, unless universities themselves undertake the development process, the patent-based pharmaceuticals have no reason to. The "simple" answer to this problem is more funding from the public sector or foundations for both basic research and development. This avenue has made some progress, and some foundations—particularly, in recent years, the Gates Foundation—have invested enormous amounts of money in searching for cures and improving basic public-health conditions of disease in Africa and elsewhere in the developing world. It has received a particularly interesting boost since 2000, with the founding of the Institute for One World Health, a nonprofit pharmaceutical dedicated to research and development specifically into developing-world diseases. The basic model of One World Health begins by taking contributions of drug leads that are deemed unprofitable by the pharmaceutical industry—from both universities and pharmaceutical companies. The firms have no reason not to contribute their patents on leads purely for purposes they do not intend to pursue. The group then relies on foundation and public-sector funding to perform synthesis, preclinical and clinical trials, in collaboration with research centers in the United States, India, Bangladesh, and Thailand, and when the time comes around for manufacturing, the institute collaborates with manufacturers in developing nations to produce low-cost instances of the drugs, and with government and NGO public-health providers to organize distribution. This model is new, and has not yet had enough time to mature and provide measurable success. However, it is promising.

Peer Production of Drug Research and Development. Scientists, scientists-in-training, and to some extent, nonscientists can complement university licensing practices and formally organized nonprofit efforts as a third component of the ecology of commons-based producers. The initial response to the notion that peer production can be used for drug development is that the process is too complex, expensive, and time consuming to succumb to commons-based strategies. This may, at the end of the day, prove true. However, this was also thought of complex software projects or of supercomputing, until free software and distributed computing projects like SETI@Home and Folding@Home came along and proved them wrong. The basic point is to see how distributed nonmarket efforts are organized, and to see how the scientific production process can be broken up to fit a peer-production model.

First, anything that can be done through computer modeling or data analysis can, in principle, be done on a peer-production basis. Increasing portions of biomedical research are done today through modeling, computer simulation, and data analysis of the large and growing databases, including a wide range of genetic, chemical, and biological information. As more of the process of drug discovery of potential leads can be done by modeling and computational analysis, more can be organized for peer production. The relevant model here is open bioinformatics. Bioinformatics generally is the practice of pursuing solutions to biological questions using mathematics and information technology. Open bioinformatics is a movement within bioinformatics aimed at developing the tools in an open-source model, and in providing access to the tools and the outputs on a free and open basis. Projects like these include the Ensmbl Genome Browser, operated by the European Bioinformatics Institute and the Sanger Centre, or the National Center for Biotechnology Information (NCBI), both of which use computer databases to provide access to data and to run various searches on combinations, patterns, and so forth, in the data. In both cases, access to the data and the value-adding functionalities are free. The software too is developed on a free software model. These, in turn, are complemented by database policies like those of the International HapMap Project, an effort to map common variations in the human genome, whose participants have committed to releasing all the data they collect freely into the public domain. The economics of this portion of research into drugs are very similar to the economics of software and computation. The models are just software. Some models will be able to run on the ever-more-powerful basic machines that the scientists themselves use. However, anything that requires serious computation could be modeled for distributed computing. This would allow projects to harness volunteer computation resources, like Folding@Home, Genome@Home, or FightAIDS@Home—sites that already harness the computing power of hundreds of thousands of users to attack biomedical science questions. This stage of the process is the one that most directly can be translated into a peer-production model, and, in fact, there have been proposals, such as the Tropical Disease Initiative proposed by Maurer, Sali, and Rai.[25]

Second, and more complex, is the problem of building wet-lab science on a peer-production basis. Some efforts would have to focus on the basic science. Some might be at the phase of optimization and chemical synthesis. Some, even more ambitiously, would be at the stage of preclinical animal trials and even clinical trials. The wet lab seems to present an insurmountable obstacle for a serious role for peer production in biomedical science. Nevertheless, it is not clear that it is actually any more so than it might have seemed for the development of an operating system, or a supercomputer, before these were achieved. Laboratories have two immensely valuable resources that may be capable of being harnessed to peer production. Most important by far are postdoctoral fellows. These are the same characters who populate so many free software projects, only geeks of a different feather. They are at a similar life stage. They have the same hectic, overworked lives, and yet the same capacity to work one more hour on something else, something interesting, exciting, or career enhancing, like a special grant announced by the government. The other resources that have overcapacity might be thought of as petri dishes, or if that sounds too quaint and old-fashioned, polymerase chain reaction (PCR) machines or electrophoresis equipment. The point is simple. Laboratory funding currently is silo-based. Each lab is usually funded to have all the equipment it needs for run-of-the-mill work, except for very large machines operated on time-share principles. Those machines that are redundantly provisioned in laboratories have downtime. That downtime coupled with a postdoctoral fellow in the lab is an experiment waiting to happen. If a group that is seeking to start a project defines discrete modules of a common experiment, and provides a communications platform to allow people to download project modules, perform them, and upload results, it would be possible to harness the overcapacity that exists in laboratories. In principle, although this is a harder empirical question, the same could be done for other widely available laboratory materials and even animals for preclinical trials on the model of, "brother, can you spare a mouse?" One fascinating proposal and early experiment at the University of Indiana-Purdue University Indianapolis was suggested by William Scott, a chemistry professor. Scott proposed developing simple, low-cost kits for training undergraduate students in chemical synthesis, but which would use targets and molecules identified by computational biology as potential treatments for developing-world diseases as their output. With enough redundancy across different classrooms and institutions around the world, the results could be verified while screening and synthesizing a significant number of potential drugs. The undergraduate educational experience could actually contribute to new experiments, as opposed simply to synthesizing outputs that are not really needed by anyone. Clinical trials provide yet another level of complexity, because the problem of delivering consistent drug formulations for testing to physicians and patients stretches the imagination. One option would be that research centers in countries affected by the diseases in question could pick up the work at this point, and create and conduct clinical trials. These too could be coordinated across regions and countries among the clinicians administering the tests, so that accruing patients and obtaining sufficient information could be achieved more rapidly and at lower cost. As in the case of One World Health, production and regulatory approval, from this stage on, could be taken up by the generics manufacturers. In order to prevent the outputs from being appropriated at this stage, every stage in the process would require a public-domain-binding license that would prevent a manufacturer from taking the outputs and, by making small changes, patenting the ultimate drug.

This proposal about medicine is, at this stage, the most imaginary among the commons-based strategies for development suggested here. However, it is analytically consistent with them, and, in principle, should be attainable. In combination with the more traditional commons-based approaches, university research, and the nonprofit world, peer production could contribute to an innovation ecology that could overcome the systematic inability of a purely patent-based system to register and respond to the health needs of the world's poor.

COMMONS-BASED STRATEGIES FOR DEVELOPMENT: CONCLUSION

Welfare, development, and growth outside of the core economies heavily depend on the transfer of information-embedded goods and tools, information, and knowledge from the technologically advanced economies to the developing and less-developed economies and societies around the globe. These are important partly as finished usable components of welfare. Perhaps more important, however, they are necessary as tools and platforms on which innovation, research, and development can be pursued by local actors in the developing world itself—from the free software developers of Brazil to the agricultural scientists and farmers of Southeast Asia. The primary obstacles to diffusion of these desiderata in the required direction are the institutional framework of intellectual property and trade and the political power of the patent-dependent business models in the information-exporting economies. This is not because the proprietors of information goods and tools are evil. It is because their fiduciary duty is to maximize shareholder value, and the less-developed and developing economies have little money. As rational maximizers with a legal monopoly, the patent holders restrict output and sell at higher rates. This is not a bug in the institutional system we call "intellectual property." It is a known feature that has known undesirable side effects of inefficiently restricting access to the products of innovation. In the context of vast disparities in wealth across the globe, however, this known feature does not merely lead to less than theoretically optimal use of the information. It leads to predictable increase of morbidity and mortality and to higher barriers to development.

The rise of the networked information economy provides a new framework for thinking about how to work around the barriers that the international intellectual property regime places on development. Public-sector and other nonprofit institutions that have traditionally played an important role in development can do so with a greater degree of efficacy. Moreover, the emergence of peer production provides a model for new solutions to some of the problems of access to information and knowledge. In software and communications, these are directly available. In scientific information and some educational materials, we are beginning to see adaptations of these models to support core elements of development and learning. In food security and health, the translation process may be more difficult. In agriculture, we are seeing more immediate progress in the development of a woven fabric of public-sector, academic, nonprofit, and individual innovation and learning to pursue biological innovation outside of the markets based on patents and breeders' rights. In medicine, we are still at a very early stage of organizational experiments and institutional proposals. The barriers to implementation are significant. However, there is growing awareness of the human cost of relying solely on the patent-based production system, and of the potential of commons-based strategies to alleviate these failures.

Ideally, perhaps, the most direct way to arrive at a better system for harnessing innovation to development would pass through a new international politics of development, which would result in a better-designed international system of trade and innovation policy. There is in fact a global movement of NGOs and developing nations pursuing this goal. It is possible, however, that the politics of international trade are sufficiently bent to the purposes of incumbent industrial information economy proprietors and the governments that support them as a matter of industrial policy that the political path of formal institutional reform will fail. Certainly, the history of the TRIPS agreement and, more recently, efforts to pass new expansive treaties through the WIPO suggest this. However, one of the lessons we learn as we look at the networked information economy is that the work of governments through international treaties is not the final word on innovation and its diffusion across boundaries of wealth. The emergence of social sharing as a substantial mode of production in the networked environment offers an alternative route for individuals and nonprofit entities to take a much more substantial role in delivering actual desired outcomes independent of the formal system. Commons-based and peer production efforts may not be a cure-all. However, as we have seen in the software world, these strategies can make a big contribution to quite fundamental aspects of human welfare and development. And this is where freedom and justice coincide.

The practical freedom of individuals to act and associate freely—free from the constraints of proprietary endowment, free from the constraints of formal relations of contract or stable organizations—allows individual action in ad hoc, informal association to emerge as a new global mover. It frees the ability of people to act in response to all their motivations. In doing so, it offers a new path, alongside those of the market and formal governmental investment in public welfare, for achieving definable and significant improvements in human development throughout the world.

33. Howard Rheingold, *Smart Mobs, The Next Social Revolution* (Cambridge, MA: Perseus Publishing, 2002).
34. Data taken from *CIA World Fact Book* (Washington, DC: Central Intelligence Agency, 2004).
35. Lawrence Solum and Minn Chung, "The Layers Principle: Internet Architecture and the Law" (working paper no. 55, University of San Diego School of Law, Public Law and Legal Theory, June 2003).
36. Amnesty International, People's Republic of China, State Control of the Internet in China (2002).
37. A synthesis of news-based accounts is Babak Rahimi, "Cyberdissent: The Internet in Revolutionary Iran," *Middle East Review of International Affairs* 7, no. 3 (2003).

CHAPTER 8. Cultural Freedom: A Culture Both Plastic and Critical

1. Karl Marx, "Introduction to a Contribution to the Critique of Hegel's Philosophy of Right," *Deutsch-Französicher Jahrbucher* (1844).
2. Bruce A. Ackerman, *Social Justice and the Liberal State* (New Haven, CT, and London: Yale University Press, 1980), 333–335, 141–146.
3. Michael Walzer, *Spheres of Justice: A Defense of Pluralism and Equality* (New York: Basic Books, 1983), 29.
4. Will Kymlicka, *Multicultural Citizenship: A Liberal Theory of Minority Rights* (Oxford: Clarendon Press, 1995), 76, 83.
5. Jurgen Habermas, *Between Facts and Norms, Contributions to a Discourse Theory of Law and Democracy* (Cambridge, MA: MIT Press, 1998), 22–23.
6. Encyclopedia.com is a part of Highbeam Research, Inc., which combines free and pay research services. Bartleby provides searching and access to many reference and high-culture works at no charge, combining it with advertising, a book store, and many links to Amazon.com or to the publishers for purchasing the printed versions of the materials.
7. Jack Balkin, "Digital Speech and Democratic Culture: A Theory of Freedom of Expression for the Information Society," *New York University Law Review* 79 (2004): 1.

CHAPTER 9. Justice and Development

1. Anne Alstott and Bruce Ackerman, *The Stakeholder Society* (New Haven, CT: Yale University Press, 1999).
2. Numbers are all taken from the *2004 Human Development Report* (New York: UN Development Programme, 2004).
3. Amartya Sen, *Development as Freedom* (New York: Knopf, 1999), 46–47.
4. Carol Tenopir and Donald W. King, *Towards Electronic Journals: Realities for Scientists, Librarians, and Publishers* (Washington, DC: Special Libraries Association, 2000), 273.

5. Harold Varmus, *E-Biomed: A Proposal for Electronic Publications in the Biomedical Sciences* (Bethesda, MD: National Institutes of Health, 1999).
6. C. K. Prahald, *The Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits* (Upper Saddle River, NJ: Wharton School of Publishing, 2005), 319–357, Section 4, "The ITC e-Choupal Story."
7. For the sources of numbers for the software industry, see chapter 2 in this volume. IBM numbers, in particular, are identified in figure 2.1.
8. These arguments were set out most clearly and early in a public exchange of letters between Representative Villanueva Nunez in Peru and Microsoft's representatives in that country. The exchange can be found on the Web site of the Open Source Initiative, http://www.opensource.org/docs/peru_and_ms.php.
9. A good regional study of the extent and details of educational deprivation is Mahbub ul Haq and Khadija ul Haq, *Human Development in South Asia 1998: The Education Challenge* (Islamabad, Pakistan: Human Development Center).
10. Robert Evenson and D. Gollin, eds., *Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research* (New York: CABI Pub., 2002); results summarized in Robert Evenson and D. Gollin, "Assessing the Impact of the Green Revolution, 1960–2000," *Science* 300 (May 2003): 758–762.
11. Jack R. Kloppenburg, Jr., *First the Seed: The Political Economy of Plant Biotechnology 1492–2000* (Cambridge and New York: Cambridge University Press, 1988), table 2.2.
12. USDA National Agriculture Statistics Survey (2004), http://www.usda.gov/nass/aggraphs/fncht3.htm.
13. First Report of the GM Science Review Panel, *An Open Review of the Science Relevant to GM Crops and Food Based on the Interests and Concerns of the Public*, United Kingdom, July 2003.
14. Robert E. Evenson, "GMOs: Prospects for Productivity Increases in Developing Countries," *Journal of Agricultural and Food Industrial Organization* 2 (2004): article 2.
15. Elliot Marshall, "A Deal for the Rice Genome," *Science* 296 (April 2002): 34.
16. Jikun Huang et al., "Plant Biotechnology in China," *Science* 295 (2002): 674.
17. Huang et al., "Plant Biotechnology."
18. Richard Atkinson et al., "Public Sector Collaboration for Agricultural IP Management," *Science* 301 (2003): 174.
19. This table is a slightly expanded version of one originally published in Yochai Benkler, "Commons Based Strategies and the Problems of Patents," *Science* 305 (2004): 1110.
20. Wim Broothaertz et al., "Gene Transfer to Plants by Diverse Species of Bacteria," *Nature* 433 (2005): 629.
21. These numbers and others in this paragraph are taken from the 2004 WHO *World Health Report*, Annex Table 2.
22. National Science Foundation, Division of Science Resource Statistics, *Special Report: National Patterns of Research and Development Resources: 2003 NSF 05–308* (Arlington, VA: NSF, 2005), table 1.
23. The detailed analysis can be found in Amy Kapzcynzki et al., "Addressing Global

Health Inequities: An Open Licensing Paradigm for Public Sector Inventions," *Berkeley Journal of Law and Technology* (Spring 2005).

24. See Jean Lanjouw, "A New Global Patent Regime for Diseases: U.S. and International Legal Issues," *Harvard Journal of Law & Technology* 16 (2002).
25. S. Maurer, A. Sali, and A. Rai, "Finding Cures for Tropical Disease: Is Open Source the Answer?" *Public Library of Science: Medicine* 1, no. 3 (December 2004): e56.

CHAPTER 10. Social Ties: Networking Together

1. Sherry Turkle, "Virtuality and Its Discontents, Searching for Community in Cyberspace," *The American Prospect* 7, no. 24 (1996); Sherry Turkle, *Life on the Screen: Identity in the Age of the Internet* (New York: Simon & Schuster, 1995).
2. Robert Kraut et al., "Internet Paradox, A Social Technology that Reduces Social Involvement and Psychological Well Being," *American Psychologist* 53 (1998): 1017–1031.
3. A fairly typical statement of this view, quoted in a study commissioned by the Kellogg Foundation, was: "TV or other media, such as computers, are no longer a kind of 'electronic hearth,' where a family will gather around and make decisions or have discussions. My position, based on our most recent studies, is that most media in the home are working against bringing families together." Christopher Lee et al., "Evaluating Information and Communications Technology: Perspective for a Balanced Approach," Report to the Kellogg Foundation (December 17, 2001), http://www.si.umich.edu/pne/kellogg/013.html.
4. Norman H. Nie and Lutz Ebring, "Internet and Society, A Preliminary Report," Stanford Institute for the Quantitative Study of Society, February 17, 2000, 15 (Press Release), http://www.pkp.ubc.ca/bctf/Stanford_Report.pdf.
5. Ibid., 42–43, tables CH-WFAM, CH-WFRN.
6. See John Markoff and A. Newer, "Lonelier Crowd Emerges in Internet Study," *New York Times*, February 16, 2000, section A, page 1, column 1.
7. Nie and Ebring, "Internet and Society," 19.
8. Amitai Etzioni, "Debating the Societal Effects of the Internet: Connecting with the World," *Public Perspective* 11 (May/June 2000): 42, also available at http://www.gwu.edu/~ccps/etzioni/A273.html.
9. Manuel Castells, *The Rise of Networked Society* 2d ed. (Malden, MA: Blackwell Publishers, Inc., 2000).
10. Barry Wellman et al., "The Social Affordances of the Internet for Networked Individualism," *Journal of Computer Mediated Communication* 8, no. 3 (April 2003).
11. Robert Kraut et al., "Internet Paradox Revisited," *Journal of Social Issues* 58, no. 1 (2002): 49.
12. Keith Hampton and Barry Wellman, "Neighboring in Netville: How the Internet Supports Community and Social Capital in a Wired Suburb," *City & Community* 2, no. 4 (December 2003): 277.
13. Gustavo S. Mesch and Yael Levanon, "Community Networking and Locally-Based