Draft

Information and Communications Technologies and IFPRI's Mandate: A Conceptual Framework

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Table of Contents

Executive Summary

ICTs, the Standards, and the Case for Concerted Public Action to Alleviate Digital Poverty

A cluster of information and communications technologies (ICTs) has caught the world mostly by surprise during the twilight quinquennium of the 20th century. It has not only pervasively penetrated the world of communications and entertainment, but also affected the way we earn and spend, heal and learn, save and search, and share information, both important and banal. Finally—in some countries—it has brought changes to the universe of policymaking and governance. These technologies process various kinds of information (voice, video, audio, text, data) and also facilitate various forms of communication among human agents, between human agents and information systems, and among information systems. By pronouncing the death of distance, these technologies have fundamentally changed the techno-economic paradigm of production and distribution, especially of services. Amid a seamless convergence of computing and communications technologies, the Internet has become the undisputed center of the world's increasingly networked economy. Where bandwidth allows, as in the West, the economics of the Web, compared with rival modes of transactions, is tops in unit dollar costs, with convenience being an add-on. The demand for skills in any of these ICTs has dramatically increased. Competence in them, which often though not always requires extensive formal education, has paid well for those who possess the requisite skills.

Some skeptics, however, still do not see any role for ICTs in efforts to alleviate poverty and bring food security to rural and urban areas of developing countries. The poor can't eat high-speed Internet access, of course. The problem of poverty alleviation is much more complex. It requires, among other things, efficient production systems and physical infrastructure, for instance. And human resources in many poor countries simply do not have what it takes to ensure development. ICTs do not have any more to do with poverty and food security in the developing countries than rain dances have to do with rain, they say.

But realists respond that in the increasingly global village that the world is fast becoming, ICTs are rapidly changing the *standards for the economic person*. And ICTs have the potential to help the poor to acquire literacy or marketable skills, for instance, and thus to count for something in the markets. This is true for the millions of young people who are poor and who are in the prime of their learning abilities. Employment and growth are at stake in another way, too: a modern, high-speed information infrastructure is critical in determining where large international companies will locate. The Okinawa Charter issued by the Heads of the Governments in July 2000 recognized alleviation of the digital divide as a legitimate subject for concerted public action. ICTs have the potential to improve the access of the poor to information anytime, anywhere, and thus to increase their productivity. If providing this access requires some serious rethinking about policymaking and governance, then that should be par for the course.

The Information and Communications Technologies: Prevailing and Pipeline

What follows is a serialization of the ICTs, starting with prevailing ones (with technologies being highlighted).

- At the head of these technologies is the **World Wide Web.** It is the world's largest library and laboratory and an increasingly large marketplace. It is growing at an astonishing 12 percent *per month* at last count.
- **Distributed computing,** which among other things puts a premium on migration of small-ticket service jobs to low-wage parts of the world that have the right infrastructure and human resources, and a capacity for growth.
- **Web-enabled call center**s, which are being used to handle voice-based customer interactions in the United States, for instance, by young, female workers in information technology (IT)-enabled environments in developing countries on the other side of the world.
- Digital communications technologies (**mobile telephones, satellites, wireless local loops** (WLLs), Web-enabled **digital radio**, and so forth) have enabled a prized capacity to avoid the awkward embrace of terrestrial networks. Sometimes, as in the case of GrameenPhones in Bangladesh, they have demonstrated positive results on rural poverty. Coupled with the technological convergence of computing and communications, they have formed the basis of a globally distributed but narrowly task-oriented, user-customized, computing and communications environment. In particular, in this environment, the price-performance metrics of very small aperture satellite (VSAT) technologies have improved to the point where they are being adopted for electronic commerce in some developing countries.
- With the arrival of **speech-recognition technologies,** documents based on spoken words can be processed.

Among technologies in the pipeline, the following three rate a mention:

- **Next-generation computers** will be operated by voice. Indeed, within the foreseeable future, high-performance systems will let an individual access, query, or print any book, magazine, newspaper, video, data item, or reference document in any language by simply clicking a mouse, touching a computer screen, talking to a computer, or blinking an eye.
- **Precision agriculture** is coming of age in the developed countries. This mode of agriculture uses technologies and techniques such as geographic information systems (GIS), grid soil sampling, spatially matched variable-rate fertilizer use, and yield maps controlled by global positioning systems (GPS) to adjust inputs to specific conditions within each area of a field.
- **Satellite imaging**, having scaled the heights of *regional focus*, is moving toward *site-specific focus*. However, remote sensing is out of its depth when it comes to weed management, which needs resolution on the order of centimeters. This is where digital multispectral videography (DMSV) is increasingly challenging satellite imaging.

ICTs, Food Security, Poverty, and Nutrition Outcomes of the Poor

Against a background of rapid changes in markets and in the pipeline of technologies, the demand for real-time information and up-to-date knowledge to help make effective policy has become greater. Agricultural growth of a kind that assuredly lowers secular poverty has three essential ingredients: diffusion of modern farm technology; integration of markets, which enables cost gains to be shared throughout the market chain; and a diversified productive capacity in rural areas. The flow of information and knowledge is an integral part in all three. Also, the increasingly ascendant imperatives of natural resource management at watershed, landscape, and community levels point up the need for a sharp *spatial* focus in both research and policy. Dealing with malnutrition at policy and institutional levels also requires a keen locational or *geographical differentiation*. This again points up the relevance of geographical information systems (GIS), global positioning systems (GPS), and other informational techniques.

ICTs are relevant to each of the following imperatives: (1) give policymakers access to real-time information and best-practice knowledge distilled from the Web (by "servlets" and "Enterprise Javabeans" that combine to respond to "hot-button indents" from policymakers); (2) reduce private and public search and transactions costs; (3) respond to environmental modifiers at watershed, landscape and community levels; (4) foster diversification of the rural economy; (5) implement spatially sensitive informational strategies, which render food security and nutritional programs more effective and less costly; (6) harness the capability to mount early-warning information systems, with peoples' participation. ICTs would likely pay off by increasing the effectiveness of the tried-and-tested recipes, but they also add some bite of their own.

1. Introduction

It is difficult to speak of technological developments, especially relating to information processing and communications, during the final years of the 20th century without evoking the superlative.[1] Never before did technological developments capture the imagination of not only the professionals but also the common man so strongly over a five-year period as during 1995–99. These years witnessed perhaps the most prolific cluster of innovations ever in the universe of information, transactions processing, and human communications. Two essential characteristics of this cluster are that (1) ICTs, by decoupling information from a physical repository over increasingly large geographical areas, with rapidly declining unit costs, have pronounced the death of distance (Bedi 1999; Mulgan 1999; Cairncross 1999); (2) thereby they seem to have ushered in a period of significant change in the "techno-economic" paradigm of production and distribution, especially of services.[2] Software of various kinds provides much of the intelligence behind the automation that sweeps financial and manufacturing systems of the developed world. As an example of the changed techno-economic paradigm, satellite technologies have enabled a globally distributed but narrowly task-focused, user-customized computing environment (where computing and communications technologies have been coupled [Greenstein and Spiller 1996]). In this environment, offshore and onshore facilities and human resources, located in divergent time zones and of considerably varying unit costs, are harnessed as though to create the commercial equivalent of a relay race (Chowdhury 1999a). There has been an explosion of globally distributed design, publishing, legal, and software contracting (Bhattacharjee 1998). It has been argued that this property of being able to separate information over a vast area is one of the truly revolutionary aspects of ICTs (Evans and Wurster 1997). Fundamentally, this has been driven by rapidly changing economics: the cost of sending one megabyte of digital data per second over a given distance has fallen by a factor of 100 over the last 20 years, with much of the *commercial impact* of that secular decline concentrated in the last five years as a result of the explosive interest in the Internet (World Bank 1999). Countries (such as India, Ireland, the Philippines) that are well-placed to cash in have done so. According to Bhattacharjee (1998), India's software industry has been knocking at the door of the Superbowl of IT services and IT revenues—the global market—for years. But up until the end of 1996 these efforts had captured only a meager 0.05 percent market share in worldwide technology services and sale. In less than two years India has gleaned over 1 percent of global software services. As we shall see, private industry and, in its wake,

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[1] A good working definition is from Hamelink (1997). ICTs comprehend technologies that can process different kinds of information (voice, video, audio, text, data) and facilitate different forms of communications among human agents, among humans and information systems, and among information systems. These technologies can be further subdivided into capturing, storing, processing, sharing, display, protecting, and managing technologies. This footnote draws upon and extends Hamelink's treatment.

[2] Information separation allows access to ideas that are nonproprietary and have potentially large content-related externalities. Also, an increase in network size generates *network externalities*. To give an example when a network of farmers is joined by a number of qualified farm extension workers, it generates an external value quite apart from the decline in the unit fixed cost of operating the network. In simple terms, network effect means that as a network expands, it becomes exponentially more valuable to each and every user.

governments in developing countries in South Asia, for instance, are bracing for rapid changes.

What are these ICTs, and what are the relevant changes in them? The most outstanding ones are: microprocessor capacities that have increased at an *increasing* rate;[3] smart storage devices and networks, with intelligent routers sending exploding volumes of data to their destinations quickly and reliably; the World Wide Web (WWW) and the browser; significant advances in object-oriented programming languages, like Java, with powerful support for platform independence in hosting applications; the availability of a whole raft of "freebie" software resources on the Web, including the increasingly scaleable, enterprise-grade operating system, Linux; breakthroughs involving wireless technologies, including wireless local loops, which permit users to leapfrog over the handicaps imposed by costly wired telecommunication solutions; improvements in satellite technologies, including the VSATs and GPS, which greatly augment the capacity for spatial focus in information systems, for instance in a prioritization that precedes evaluation of results.

This cluster of innovations has enjoyed a stellar diffusion, especially in the developed countries, with the larger among the developing countries now playing catch up. The Internet took four years to reach the coveted penetration milestone of 50 million households. The corresponding period for radio and TV—the two previous communications icons of the last century—were 25 and 13 years, respectively (Mann, Eckert, and Knight 2000). The Internet has become the largest library of the world, with the number of Web pages doubling every 100 days and with the number of Web-hosting computers doubling every 7 months. With the growing availability of secure payments systems and with governments signing on e-signature enactments, the Internet has become a vast marketplace for various kinds of electronic commerce (Corrigan 1999, Cargill 2000). Such pervasive changes are altering the way people in developed countries buy and bank, create and manage wealth, learn and heal, entertain and interact, plan contingencies and deal with natural hazards. *Indeed, the Internet has changed the rules on how people in the West shall participate in the markets and the global economy.*

Is there, the skeptic inside each of us asks, any dampener at all? The Internet of course is often used as a code for the Information Revolution: "The Internet represents a technology that encapsulates much of the promise of this Information Revolution" (Charles and Hawkins 1998, 1). In reality, isn't the problem of development and poverty alleviation much more complex than a "simple" formula of providing high-speed and high-bandwidth connectivity? If groundwater utilization for cultivation is only on the order of 3%, (while the agroclimatic potential for this is more like 30%) , and if much of the countryside has severe water stress, restricting land productivity, what additional

[3] Moore's Law, formulated in the early 1970s, which posited that microprocessor capacity doubles every 18 months, has recently been second-guessed, as microprocessor capacity continues to double faster. Two reasons for this are, first, that competition has intensified within and between major countries, and second, that product and upgrade cycles have shortened. To quote the President's Information Advisory Committee, "The US information technology industry has created an awesome and continuous growth of capabilities based on the most intensely competitive marketplace the world has ever seen. Nearly every available person and dollar in this industry is focused on bringing the next version or the next product to market. Delivery product cycles are as short as every three or six months. The company that fails here misses the next short-term cycle and will not be successful" (PITAC 1999, 8). Another [factor…is the] intense global competition, which puts great pressure on prices, profits, and expenses" (PITAC 1999, 9).

good would GIS or GPS do for the millions of children who routinely starve in such a setting? What, after all, is the factor intensity *bias* of this cluster of technologies? How high are the access barriers to having to interact with the market niches that are prone to absorb these technologies? Let no one forget that, at times, in Africa, Western power generation companies have played strongly on myths of modernization that villages are getting *electricity* and *TV* , while such "positive changes" had in truth been achieved at the expense of the coverage of *health-care programs* and *regular water supplies* (Everard 1996, footnote 13). Clearly, development and poverty alleviation are about many other preconditions, too, like efficient production and processing technologies, enabling physical infrastructure, a well-trained and motivated workforce, an open and liberalized policy framework that creates a level playing field, foresighted incentives and compensation policies, and so forth. In this sense, is it possible that there is much hype, however well-meaning, about Internet access and ICTs in the literature?

It is idle to pretend that there has not been some considerable hubris around the role of the ICTs. Take, for instance, the forecast from the highly regarded IDC—a U.S. trade consultancy—which said in 1999 that business-to-business electronic commerce would balloon to $767 billion by 2003 (IDC 1999). In 1999, according to another consultancy (Veronis Suhler 2000), business-to-business e-commerce has amounted to only $23 billion, up only 8 percent from a year ago!

The truth about the potential of the ICT and the Internet-based commerce is probably somewhere between the hubris and the cold shoulder. Many people without their own axes to grind find the case compelling that the pervasive cluster of innovations of recent times heralds a period of significant opportunities for developing countries. If the major shifts forward executed by a number of governments in South Asia, for instance, are any guide, the changed techno-economic paradigm has seized the initiative in setting the policy agenda, and not the other way around (Appendix 1).

According to a 1997 witticism: "Information is not the same as knowledge, not to speak of wisdom" (Ventura 1997). Information morphs into knowledge, and the latter into wisdom, through a process of "successive approximation." Libraries and laboratories have a natural aptitude for speeding up this process. As well as being the world's largest library, the Internet is also quickly becoming a huge lab. Granted, there are important socioeconomic barriers to Internet access. The good news is that these barriers are mostly amenable to some policy or the other.

Undeniably, information and communications are each *valuable* elements in our lives, and technology has created even more value in this sphere in many ways. Geo-spatial information systems are changing farming in developed countries---the case of "precision farming". Data warehousing is slowly changing the conduct of environmental performance evaluations (EPEs) which have become or are becoming legally required in some developed countries (Ford 2000). And not only in the developed countries: geospatial technologies are being used in the long-term monitoring of the environmental effects of China's Three Gorges Dam project (www.geoplace.com/asiapac/2000/0700/0700dam.asp). Some semi-industrialized countries, such as Israel, are fortunate to have nationwide digital maps. They harness the latter to trace Hepatitis A to water pollution, to control the disposal of residential effluents, and wherever possible, to site new homes and businesses near sources of safe drinking water (Lan 1998).[4] Where there is political will or private or community entrepreneurship, even the poor are leveraging off access to cellular phone technologies and cashing in (Bayes, von Braun, and Akhter 1999). In some admittedly better-off developing countries, junior high schoolers from poor aboriginal families are being exposed to computers made available through public-goods investment. They cut their teeth by building Web pages—a robust currency of the "new economy" (Wong 2000).

The questions of central importance are these: Do ICTs help accelerate economic growth in these countries? Do ICTs help alleviate poverty and increase food security in these countries? Do they help make natural resource management more effective and less costly in these countries?

It is necessary to deal, first of all, with the ICT and economic growth nexus. There is evidence that both growth rates and productivity in the United States in the period after 1995 have accelerated: this virtuous cycle is due to the rapid rate of ICT diffusion (Jorgenson and Stiroh 1999; 2000).[5] It has been shown that in the United States, the industry group with the highest growth in total factor productivity (TFP) has been electrical equipment, which includes three of the icons of the "information age," namely, computers, semiconductors, and telecommunications equipment (Jorgenson and Stiroh 2000). In the developed countries, studies show productivity and wage rates at the level of individual firms are clearly *increasing* with the adoption of ICTs (Bedi 1999).

For developing countries, detailed quantitative studies proving this *a priori* nexus have still not materialized. Companies with large buyers overseas, in the garment export industry, for example, followed suit when the latter went online (Witcher 1999). This course often proved healthy for profits. For large companies in poor countries, convergence of communications and computing technologies enabled satellite-based virtual private data networks (VPN). They were thus able to circumvent the costly, unreliable state-run wire- line telecom network.[6] This is yet another example of a changing techno-economic paradigm.

Much casual empiricism supports the conclusion that a rapid country embrace of ICTs provides a strong positive for attracting *foreign direct investment* and, amid rapidly changing technology markets, for creating a sustainable transfer of these technologies through intra-industry conduits. As major Western companies globalize operations by harnessing the distance-defying Internet, the most important criteria for locating a business in a country is the openness, size, depth, modernity, and rapid scalability of the national information infrastructure, as well as the independence of the telecom authority of the country (Beardsley and Patsalox-Fox 1995).[7] It is not that old

[4] The following link explains what is being done in Israel: (www.geoplace.com/gia/1998/0998/998env.asp).
[5] Among the G-7 group of countries, the economies of Canada and the United States have registered the highest rates of growth in aggregate output after 1995, and it is in these two economies that ICTs have also registered the most pronounced penetration.
[6] In India, for instance, the number of VSAT sites has grown by more than 40 percent a year during the last four years. Globally, the number of VSAT sites, which stood at 386,000, is expected to double by 2003 (www.hns.com/news/channels/sedition/article1.htm).

[7] For a typical developing country, the *timely* creation of such an infrastructure itself implies a significantly high technical *knowledge barrier* as far as policymaking is concerned. Getting the right kind of strategic partnership based on insightful research would likely be key to pulling this one off.

issues such as protection of intellectual property rights, political correctness, cultural assimilation, and so forth have become unimportant. However, the pervasiveness of changes in ICTs is relentlessly tipping the scales in their favor as critical to competitiveness, as private industry, even developing-country governments, are coming round to the position that "information and communications technologies are the only competitive differentiation we have".[8]

What connection exists between ICTs and poverty in general and rural poverty in particular? The question has still not been answered. Even if ICTs, by increasing productivity, spur growth and exports, the benefits of such growth may not filter down to the rural poor. On a very limited scale, the study by Bayes, von Braun, and Akhter (1999) finds that introduction of start-up businesses selling cellular phone access in villages in Bangladesh has improved returns to the time of poor women. But more systematic research will be needed before we can answer this question definitively.

The causation between ICTs and rural poverty in the short run can go either way. If ICTs selectively *intensify the use* of skilled (or formally educated) workers in the economy, this may well squeeze out the unskilled workers and thus aggravate pressures on livelihoods and wages. If, however, ICTs are diffused in a given economy with relatively large pools of well-trained and motivated workers, amid a policy setting that dismantles all kinds of state monopolies and facilitates transparent rule of the contractual law and reasonably protects intellectual property rights of innovators, then the odds will be sufficiently high that, over time, total output in the economy will grow strongly enough to more than make amends for the short-run job and wage pain. Changes in total income and total productivity are more potent long-run determinants of average wages than distribution of output, in the short-run, between capital and labor. The important research question is about the impact ICTs are likely to have on total productivity and output growth rate in developing countries.

The severity of the socioeconomic barrier to participation by the poor in the diffusion of ICTs in developing countries raises an important question. What are the educational and training preconditions necessary for the poor to avail themselves of the opportunities presented by the ICTs?. The admittedly scant evidence available is not altogether supportive of *labor-market pessimism* (see Rajan 2000 for data on Indian teletrade workers). Also relevant here is a report by some of the United States' greatest IT experts, which says that several quantitatively important fields of information technology jobs do not require *any undergraduate degree* (PITAC 1999, 20, emphasis added). India has had an explosion of private, informal for-profit training facilities to speedily produce IT skills. If, therefore, certain significant IT skills are relatively quick to learn and if the supply of requisite management/entrepreneurship is reasonably elastic at prices that are open to policy intervention, ICTs may well generate livelihood opportunities for the poor. However, such a favorable turn of events depends on liberalized telecom price policies, rapid rollout of appropriate information infrastructure, and independent regulation—three issues that call to the fore *large knowledge gaps* and *quality political leadership*. This would clearly be a knowledge issue of some importance, to which we shall return later in the paper.

[8] This quotation is from the Chief Executive of Computer Associates Inc., the world's third largest software company, after Microsoft and Oracle. The quote itself is from *InformationWeek* of June, 1999.

2. The ICT Shelf

The ICT shelf is composed of (1) prevailing technologies and (2) pipeline technologies.

Prevailing Technologies

World Wide Web

The World Wide Web, or what has become popularly known as the Internet, must be at the top of the chart here. The World Wide Web is the largest network of computers; currently it has about 300 million users. The number of computers that are connected is growing at 30–35 percent in the world as a whole. Virtually, all countries of the world have at least one host that is connected to the Internet. Based on open standards such as Transport Control Protocol/Internet Protocol (TCP/IP), Hypertext Transfer Protocol (HTTP), and Hypertext Markup Language (HTML), the Internet has become the communications medium with the most rapid penetration ever in the United States (Mann, Eckert, and Knight 2000).

All transmission media (terrestrial networks, wireless networks, cable TV, satellites) are now Web-enabled. This makes for an exceedingly large user base, driven by convergence among technologies publicly mandated by the U.S. Federal Communications Commission. The Internet, with its improving search engines (of which there are now more than a hundred) and a large collection of context-sensitive "hyperlinks," has become a gigantic library and laboratory open at all hours round the year to anyone with a suitable connection.[9] The Internet is fast becoming a global marketplace, with secure and private connections to billing and payments systems, with business-to-business and business-to-customer transactions, where price discovery and transactions take place virtually round the clock. An emigrant in North America can easily send gifts of flowers and candy to mother on her birthday, whether she lives in South Africa or India. And now even governance and citizen's services are also being brought on-line (*The Economist*, June 24, 2000).

Distributed Computing

Distributed computing takes place among computers that are internetworked, using what has come to be called "fat-servers-thin-clients" architecture. The future of computing looks decidedly distributed, networked, and "object-oriented."[10] This computing regimen

[9] Just consider this. The computer operating system, Linux, in its original version, was given away to humanity on the Web by a Finnish computer science student, Linus Thorvalds. Over the past four years, it was continuously tweaked, *gratis*, by other programmers on the Web. The system has thus far been so improved through these community efforts that Linux has become a *de facto* standard—so much so that all major hardware vendors now offer enterprise-grade Linux-based servers and desktops. Indeed, when Intel, the titan that contributed the second half of the hybrid juggernaut, WINTEL, showcased its fastest and newest server computer on August 23 in Silicon Valley, its top hardware guru demonstrated features on a Linux-based system. Linux is a precocious gift cradled, in part, on the Web. The Web has a remarkable capacity for bonding communities. In Africa, surveys show that 65 percent of the e-mails are communications that would not have been made in the absence of an e-mail system (Jensen 2000). When a U.S. federal agency posted on its web site a proposed rule book and invited user comments, it got *five* times the amounts of comments it was expecting on past experience (Leo 1999).

[10] Bill Joy, co-founder of Sun Microsystems and one of the most visionary computer scientists of our times, credits Jacques Attali of France, as the father of an idea called "nomadic computing" in a book Attali wrote in French in 1988. Joy says his reading of Attali's book first set him to thinking of network computing

is analogous to a multisite organization, that is, any large enterprise with corporate, manufacturing, parts, and sales offices spatially scattered. Distributed computing has been motivated to achieve optimality in the geographical allocation of tasks, indeed sometimes across national borders, taking advantage of aspects such as time zones, site specialization, and wage differentials. Distributed computing and standard-based Internet have teamed up to spur globalization in this information age. In distributed computing, "objects" can be anything: a database connection, a file, an image, a recorded tutorial, or whatever. Objects that are part of an object-oriented application may lie anywhere on a network, but they are able to operate as a unified whole. No matter where in the world each object lives outside an application, when time comes for them to fuse, they appear as though they were local to an application. This is the powerful logic of the strength of such standards-based, object-oriented programming languages, Java for instance.

Web-enabled Call Centers.

Technologists have harnessed the Web and thereby galvanized what had become a moribund technology, namely, the call center. This has been done using interactive voice response in the framework of computer-telephony integration (CTI). Human agents manning the traditional call centers can readily update customer records and can trigger a chain of remedial services that may be rendered immediately, either locally (in the same premises as the call center itself) or remotely (anywhere in the world provided it is part of the network). If the customer call is about a faulty component, an entry will also be made in the "part ID" column of the "customer" table in the database. These details provide the substance for decision support systems (DSS), which has ramifications for all aspects of customer satisfaction. Call centers mine the global reach of the Web; they are always open. Because call centers respond to the deeply ingrained customer preference for human interaction, their combination of technology and sensibility is a winner.

Satellite Technologies

The prospects of satellite technologies have dramatically turned around in the past few years, for several reasons. One major factor has been improvements in the price-performance ratios of satellite technologies. The other has been about VSAT access technology becoming amenable to Internet Protocol (IP). VSATs talk digitally to remote terminals that connect to a central hub via satellites using small diameter antenna dishes (0.6 to 3.8 meters). Typically, a VSAT system would comprise a satellite communications network, two or more hub stations, and hundreds of sites. The hub would comprise land-based switching equipment, mediating traffic from VSAT network into or out of public switched telephone network (PSTN) systems. However, a VSAT site can directly talk to another site on the same network without any land-based switching involving PSTN, thus totally avoiding the often state-owned, slow, terrestrial networks. VSATs can also interface seamlessly to computers ranging from the

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which ultimately led to the creation of Java. And now Java has spawned its "nomadic" offshoot, the Gini, which will provide the "intelligence" to all conceivable kinds of gadgets and handhelds with a microprocessor inside. Microsoft is about to bring to market its Windows Next Generation Services (WNGS)---a Gini rival.

mainframe to desktop. Telecommunications companies in developing countries provide satellite communications services to clients—in manufacturing, retail, petroleum, and financial services segments, for instance—who require wide area network (WAN) connectivity. Such a WAN will support not only applications such as IP multicast, point-of-sale (POS) credit authorization, inventory control, bank branch automation, and online stock trading, but also Enterprise Resource Planning (ERP) packages. Compared to rivals, VSAT delivers flexible bandwidth (larger downlink bandwidth than uplink), optimized TCP/IP application support and greater user-friendliness of maintenance and hub management.

It is a major stamp of approval for VSAT that, in 1997, it was estimated that as much as 70 percent of worldwide capacity (a little over 200,000 sites) was in the United States, as part of business clients' virtual private network (Cosper 1997). Major U.S. and European banks and multinational corporations have converted to satellite-based VSAT links to connect their remote branches. Europe's largest VSAT network is an AT&T–Peugeot–Citroen installation, with as many as 3,500 sites. By way of an example, another major customer of VSAT is the British pharmaceutical company, SmithKline Beecham. Using a VSAT network, the company links its two large groups—consumer health care and pharmaceutical units—their branch offices, plants, depots, and agents, spread across 55 locations. It connects all locations to two central IBM mainframes (AS400s) in New Delhi and Bangalore. An international lease line from a hub station in Bangalore connects VSATs to a British host, allowing all VSATs access to the central computer network as well as domestic systems (Aspinall 1999). This is a good example of distributed computing using satellite-VSAT connections. It is not dependent on the Internet, although it can still connect to it.

In 1999, the world had 386,000 VSATs installed, and this number represents an annual growth rate of about 45 percent. In India, VSAT capacity installed (close to 9,000 VSATs) is growing at close to 50 percent a year. The largest VSAT network planned anywhere is going to be in India, where Hughes Communications Solutions has been hired to create a network of 50,000 sites spread among 1,000 towns and cities in India, at a cost of US$90 million. That works out to $1,800 per site. In 1997, the cost of a typical "star-configuration" VSAT site was about $3,000–$3,500 (Cosper 1997). The price-performance ratio is thus enabling.

Wireline and Wireless Technologies

Teledensity—the number of wireline (telephone and fax) connections per hundred people—has remained low in developing countries, leading to much unmet demand. While teledensity in the OECD countries averaged 75 percent in 1997, the corresponding number for all developing countries is 13 percent. For the largest developing countries, where most of the world's poor people live, the index is less than 0.5 to 2.0 percent. There has been a tendency for the market in these large but poor countries to leverage off scarce capacity by creating mom-and-pop telephone access stores, selling access usually for a tidy profit. In India, there are as many as 0.6 million of these phone-and-fax centers. In Bangladesh, China, Indonesia, and Pakistan, thousands of these stores have opened up, providing the unwired with the benefits of access for a price. For the poor and unwired, this has been the market's way to foster connectivity.

Use of wireless technologies has grown faster than wireline connections, especially in Europe and in China and the Philippines. The situation in other developing countries also suggests fairly strong growth trends. From a small base, the number of mobile phone users has grown 35–40 percent annually in developing countries as a whole. Chief attractions of the wireless telecommunications for developing country planners is the leapfrogging it makes possible: there is no need for capital-intensive capacity build-out, at least not to the same degree as for wireline capacity. In China, for example, mobile phone use has grown more than three times faster than wireline phone use. In Bangladesh, mom-and-pop stores have become visible in periurban and rural areas that don't have any wireline connections. They sell access using mobile phones on the Global Systems Mobile (GSM) standard. The original insight that led to this market metamorphosis was from Muhammad Yunus, the founder of the Grameen Bank, which was the first private vendor in the country to commercialize mobile-phone access in villages, using poor women as entrepreneurs. This suggests that it is possible to harness technology to alleviate poverty by letting the poor participate in the market for services. The success of Yunus' idea has been recognized by leaders in the West. In a meeting in the White House on April 5, 2000, President Clinton used the Grameen as an example of how to harness technology to alleviate the digital divide.

Wireless penetration is expected to grow rapidly (even if we take these "forecasts" with a grain of salt). International Data Corporation (IDC) research predicts that by 2002, there will be more than 55 million handheld and notebook-style information appliance devices. By 2005, shipments of these appliances will exceed shipments of PCs.

Web-enabled Digital Radio

Central to the Web-enabled digital radio is broadcast technology that converts AM and FM bands to digital, while keeping tabs on sound fidelity, improved reception, and new data services. Use will be made of the existing AM and FM bands (In-Band) by adding digital carriers to a radio station's analog signal, allowing broadcasters to transmit digitally on their existing channel assignments (On-Channel). Right now, the digital radio industry is pitching a "dual" technology, in the name of backward compatibility. Some vendors have marketed an option wherein a station converts digital radio to a system that transmits a simultaneous analog and digital signal, known as the "Hybrid Mode." These radios will be backward and forward compatible, allowing them to receive traditional analog broadcasts from stations that have yet to convert and digital broadcasts from stations that have converted. Current analog radios will continue to receive the analog portion of the broadcast, allowing for a smooth transition to a digital world over many years.

Speech-Recognition Applications

Software, marketed by a number of vendors including IBM, can word-process documents from "his master's voice." These software products are gradually becoming more error free. Users simply talk in a natural manner and pace. The spoken words immediately appear on the screen with words spelled correctly for the most part. Text editing and formatting capabilities allow users to change the font or to designate bold or italics, for instance, using voice commands. The probability of repetitive strain injuries from keyboard use is minimized. Doctors, lawyers, and executives avoid the cost and time of using transcription services. And anyone who types less than 120 words per minute will increase their productivity. Dictating an e-mail becomes almost as quick as leaving a voice message!

Pipeline Technologies

Pipeline technologies are assumed to include those that are likely to have a noticeable commercial impact within the next 5 to7 years.

Voice-Activated Computer Operating Systems

Key pipeline projects in the speech-recognition area include voice-activated handheld/mobile devices, smart phones, on-board computers, voice-to-voice translation technologies, to name just a few. On the horizon are prototype handheld devices utilizing a large vocabulary, a continuous speech dictation engine, and text-to-speech (TTS) to easily send and receive e-mail, surf the Web, and conduct e-commerce transactions. Many languages are supported in the continuous speech dictation engines that are in the pipelines of major vendors in this field.

Rapid commercialization of speech-recognition software in the telephony, medical, legal, and healthcare industries will compete with globalization of relatively low-end services to the possible *disadvantage* of developing countries. This issue needs more research.

The next milestone, according to PITAC, is to create high-performance systems that let “an individual […] access, query, or print any book, magazine, newspaper, video, data item, or reference document in any language by simply clicking a mouse, touching a computer screen, talking to a computer, or blinking an eye” (PITAC 1999, 13). One major attraction of such technologies will be their often hands-free operation. The image that springs to mind is of millions of people who have never even learned to touch-type or to negotiate any kind of keyboard turning into avid “computer-literate” users. Such operating systems are still several years out but are relentlessly drawing near.

Precision farming

In parts of developed countries, agriculture is becoming a high-tech “industry”: precision agriculture is coming of age. This mode of agriculture uses information- and technology-based management systems to increase production efficiency by adjusting farmer inputs to specific conditions within each area of a field. This consists of grid-soil sampling and spatially matching variable-rate fertilizer, herbicide, and seed applications in an effort to maximize efficiency and protect the environment. Technology is the backbone and service is all-important in this type of agriculture. Precision farming actively uses a combination of satellite data including GIS, GPS-based raw yield maps or some enhancements thereof, and computer-aided variable inputs. If the current trend toward more environmental regulation continues, farmers may soon be required to have nutrient management plans. Leading farm supply companies in the United States are already getting ready with precision farming equipment.

Satellite Imaging
Despite significant advances, satellite imaging still has a long way to go before it becomes a really dependable toolkit for precision farming. Image-based remote sensing for soil and crop management has to meet three major kinds of requirement of resolution: spatial, spectral, and timely. The spatial resolution of satellite imagery has increased enough to allow a graduation from *a regional* to a *site-specific focus.* Weed management, however, requires resolutions in the order of centimeters. Satellite imagery has not honed its spatial-resolution that high as yet. This is where *satellite imaging* is being increasingly challenged by *airborne videography,* where software can dramatically increase the resolution at low unit costs. For instance, digital multispectral video (DMSV) can capture high-resolution images of the same site simultaneously through four narrow spectral channels located in the visible and near infrared region of the spectrum. A single four-band image file, which can be processed by any of the object-oriented programming languages and zapped through the Internet into any Internet host in the world, will contain the digitally registered data. Current costs of fully processed data with two-meter spatial and high multispectral resolution have been estimated in Australian conditions at A$100 per square kilometer (about US$65). This compares with a cost of US$10,000 for a typical U.S. farm in the Corn Belt, for the standard fare of precision-farming gear (*The Economist*, June 24, 2000).

Even so, several advances in the use of satellite imaging of interest to developing countries rate a mention. Computer algorithms that improve the mining of satellite imaging data in the interest of monitoring the basic health of coral reefs are on the near-term horizon (Calamai 2000). Remote-imaging applications with power to predict impact points of landslides (Krishna 2000), crop yield stress (Metternicht 2000), and the degree of fish habitat mining are being tested. High-resolution pollution maps (measuring toxicity, for instance) of surface water, overlain on geo-referenced maps of chemical effluents, is not only a desirable idea but an idea whose time has come. Indeed, the possibilities in applying remote imaging to the problems of sustainable development, if still costly, are only limited by our imagination. Once again, the good news is that costs are coming down: they would come down even faster if competition were allowed full throttle.

3. ICTs and Food Security, Poverty, and Nutrition Outcomes of the Poor

Food security is "access by all people at all times to enough food for an active and healthy life" (World Bank 1986, 6). Hunger is largely rooted in poverty, although external shocks that suddenly accentuate its impact causing famine and even death are occasionally to blame, too. Poverty and hunger work hand in hand against the children of the developing world (Pinstrup-Andersen, Pelletier, and Alderman 1995). A major currency in the fight against poverty and food insecurity, necessarily a long-run effort, is agricultural development fueled by growing productivity and supplemented by a regime of productive rural economic diversification. A major element in the fight against child malnutrition is the information available to the household, especially the mother (Behrman 1995). Information and communications technologies (ICTs), which essentially are about increasing productivity and information access anytime, anywhere, thus appear to have an important role in this fight.

Poverty means inadequate ownership or gainful control over assets, whether tangible or intangible. This means that the poor have inadequate capacity to buy what it takes to be active and healthy. Where agro-climatic endowments have been relatively favorable, as in the Asian Rice Belt, gains in agricultural growth rates based on modern technologies have been rather broadly diffused across regions and farm sizes. Agricultural growth, facilitated by the emergence of labor-intensive market chains to increase integration, has been a time-tested recipe for poverty alleviation. The role of information flows, infrastructure, and farm institutions (tasked with determining transactions costs) in bringing about spillover effects further down the supply chain is important in sustaining technological progress. In Sub-Saharan Africa, where physical endowments are poorer, markets are shallower, and marketing margins are higher (Ahmed and Rustagi 1993), agriculture is extensive and nonspecialist. The lack of informational access and services creates a barrier of high transaction costs to market participation by the poor and women producers, especially in Africa (Delgado 1997, 167). Also, environmental modifiers (that cue the imperative of sustainability) are now increasingly stressed: we must "pay more attention in agricultural research to sustainability features of recommended technologies, to broader aspects of natural resource management at *watershed and landscape levels, and to the problems of resource-poor areas*" (Hazell 1999, 3, emphasis added). Factors and relationships specific to certain locations and geographical features have also loomed importantly in mounting effective nutritional interventions (Pinstrup-Andersen, Pelletier, and Alderman 1995). Poverty alleviation is also seen as being about paying "attention to the *whole* of the rural economy—food, livestock, exports, and rural small scale enterprises" (Bryant 1988, 11, italics in the original): the accent on rural enterprises is about *diversification*.

This paper will seek to show that ICTs are relevant to each of the following imperatives: (1) giving policymakers access to real-time information and best-practice knowledge distilled from the Web (by "servlets" and " Enterprise Javabeans" that combine to respond to "hot button indents" from policymakers); (2) reducing private and public search and transactions costs; (3) responding to environmental modifiers at watershed, landscape, and community levels; (4) fostering diversification of the rural economy; (5) using spatially-sensitive informational strategies to render food security and nutritional programs more effective and less costly; and (6) harnessing the capability to mount early-warning information systems, with peoples' participation. ICTs would likely pay off by increasing the effectiveness of the tried-and-tested recipes, and then by adding some bite of their own.

(1) Knowledge-networking ICTs that stay abreast of real-time information can help make policymaking itself more effective in securing food security and poverty alleviation. Some examples may help drive home the point:

- The Food Minister in a developing country may want to have updates on closing public grain inventories for the previous day, both system-wide and by individual storage depots. The current system, heavily paper-based, is slow, error-prone, and open to disruption by human or natural causes. In a well-designed information system where the storage depots are all networked (a VSAT satellite-hub combination with terminals interfacing to workstation computers, for example), it is possible to use a central database server in the Minister's office to retrieve the closing stocks from all the workstations in the system during an offpeak hour, say, during the night. The Minister, at his office the following morning, will click on a desktop icon that displays closing inventories by depot, with a country total. If the Minister desires, an intranet, also comprising the relevant computers in the donor community, could share the same data for purposes of monitoring the quantity and performance of food aid.

- Similar networked management information could also improve governance by enabling some version of "just-in-time" inventory policies, which track inventories inside the system spatially and temporally. Because public stocks often crowd out trade stocks in dual-mode public-private food systems such as those in South Asia (Chowdhury 1994), widespread availability of real-time public stocks information, on the Web for instance, would appear to be an important element of food security policy in the information age. Moreover, such management information systems would promote transparency and sharing, improve investors' ratings, and help foster the right kind of skills among the government's own staff, to name just three attendant benefits.

Knowledge networking and e-governance:

- Top policymakers often crave "best-practice" cues on the fly. A Secretary of Agriculture, eager to emphasize to sustainability, might have a query about what is done in another developing country about environmental management at the watershed level. An icon on, say, IFPRI's web welcome page, if clicked by the Secretary, would trigger an application. After verifying user id and password, the application would launch an intelligent agent to invoke a search engine, and return the desired information or links. From that point on, the Secretary is being "served" by the application, until the session ends. Several developing countries now have the skills to turn this kind of application-writing job around. A lot of the times, the Secretary would be sending the indent when IFPRI's network is off-peak. The quality of policies in developing countries can be enhanced by enabling policymakers with the tools appropriate for the global information society that harnesses the Web to its own ends. Best-practice-on-demand, "e-information agents" that serve up fresh updates from the Web in response to top policymakers' acknowledged "policy hot buttons," and electronic registration/renewal/commerce for food dealers affiliated with the public food distribution system (which could eventually become a "smart" information system that monitors the inventory levels within private marketing systems) are just three examples.

Governments' need for strategic ICT advice:

- Because the pace of ICT change is so rapid, governments are, even in the narrow fields of poverty and nutrition, likely to need expert ICT advice to sort "the fad from the cool," as they start to harness the Web.[11] The model of electronic governance is being increasingly embraced, with the pace being set by the G-7 countries. Developing countries that are favorably endowed with

[11] Needless to say, taking advantage of the ICTs would require continuous developments in the fields of applications, content, and connectivity and human resource management capacity in governments.

ICT capabilities are also playing catch-up. Ministries of Information Technology (MITs) are being created afresh, and ambitious milestones are being adopted by various developing-country governments (Appendix 1).

(2) Private search, transaction, and marketing costs:

- Intelligent use of ICTs would likely lower search and marketing costs for farmers and small traders. It would also lower the costs of accessing information about work opportunities and new technologies; lower the cost of farm extension and procuring other needed farm services; improve returns from in-kind investments such as grain stocks by increasing farmers' informational efficiency; and help lower the private cost of imports (and not just of food items). Pan-alliance electronic commerce could increase rural artisans' export earnings, too (PEOPlink 1998).

Continuing on with the demand for information by the poor:

- In poverty alleviation, ICTs would likely affect the quantity, quality, and timeliness of valuable information that matters to the poor. This could be related, without being limited, to marketing. Initially, this could be mainly related to market intelligence. With experience, it could even embrace electronic commerce, cutting out the middleman altogether. Modest beginnings have already been made in this field (PEOPlink 1998).
- There is a gender dimension, too (Telecommons Development Group 1999). In many developing countries, women producers and traders have become numerically more visible, as the result of Grameen-style microcredit social engineering, the gender-centricity of chit funds, or communities of small savers, as in China (Wong 2000). Women's dual role (in direct production and in caring for the family) typically implies reduced physical business mobility. For these working women, network connectivity (at a reasonable price) can often make a difference in their competitiveness, informational access, and empowerment.

Public-information productivity tools for the poor:

- Passenger information (such as train schedules) on public transport networks, available on the Web or digital radio sets, can save traders' time. This is by way of an example of public-information productivity tools. Computerization of land records (Scott 2000), digitization of cadastral survey data, local-call billing on telephony for internet access, are the three other examples that come to mind.

(3) Responding to environmental modifiers:

- The recognition of environmental "modifiers" and emphasis on sustainability in selecting winners in discussions on agricultural growth strategies have now put the focus on backward regions within developing countries, although the agriculturally better endowed regions are not accorded any the less importance. A sharp focus on backward regions requires that a prominent role be given to the use of geospatial information technology, in which GIS and GPS systems are integrated. Satellite data could thus form the bedrock of improved management information in many fields, such as overexploitation of common properties like coral reefs and inland fishing shoals, and the creation of National Spatial Data Infrastructure.

(4) Promoting food security through rural diversification:

- In the increasingly global marketplace for informational services, low-end data-processing jobs will have to migrate to low-wage countries. Based on current estimates, the offshore outsourcing market will balloon to about $35 billion by 2008. Business as usual scenarios suggest that developing countries would source this added activity from facilities in their cities, many of which are dangerously overcrowded and polluted (World Bank 2000). VSAT or Wireless Local Loop (WLL) technologies can provide a much cleaner solution by nudging the location of this added business to the rural areas, where young women could be mobilized for these livelihood opportunities. Let no one laugh at this. When in the late 1970s, a retired top civil servant of Bangladesh modeled the first garments-exporting unit in that country on South Korean best-practice, in which young, single, females would work for hours as seamstresses in factories, critics thought he was crazy. In less than a third of a generation, Bangladesh's garments industry had become the source of choice for cheap but efficient workers for many multinational producers (Witcher 1999).

- Diversification of the sources of growth in rural areas of developing countries is good for food security on the demand side, and this puts a premium on using production credit and gender-differentiated training to launch skills that would be useful for remote-processing livelihood opportunities. These jobs are clean, require training that frequently does not exceed a couple of months, can be footloose, and dovetail with the desire of young, rural women to earn a living without leaving their communities. This of course demands the right kind of information infrastructure, and community-level connectivity. Most of the remote-processing jobs are likely to be of the low-skill variety.

(5) Geo-Referenced Spatially Sensitive Nutritional and Food Security Programs:

- In developed countries, health GIS, dating from 1854, is a standard fare. However, developing countries are a far cry in this context. If a suitable national spatial data infrastructure exists in a developing country—a big if—it would be possible to overlay, say, a pollution or water-toxicity digital map over another map of liver diseases among preschool children---with a telling effect among policymakers. Even if a pair of such maps by themselves might not establish either the fact or the direction of causality, the mosaic would pinpoint, with graphic detail, the geographic coordinates of the most at-risk children. This would create demand for other data, perhaps a map of tanneries with putrid effluents. Forging spatially sensitive nutritional programs could benefit from data collected using an *interface* to *geo-referenced information systems*, in other words GIS integrated with GPS. (This concept needs an elaborate explanation, which is omitted here for space reasons.)

(6) Mounting Early-Warning Systems, with Peoples' Participation:

- During natural calamities, public-safety information systems are severely tested in developing countries, and, more often than not, found to be woefully deficient. If watersheds or landscapes form part of the "public information backbone" (connected wirelessly, for example), then members at upper reaches of a riparian entity could easily alert those further downstream of rising flood water levels or landslides in real time, which might help contain collateral damage and even save lives.

A Hypothetical Standoff

The following presents a hypothetical facing off between an ICT skeptic and an ICT realist. Their arguments provide yet another example of the positions that traverse the gamut in this particular debate, arraying "for" and "against." I hope this "role playing" is beneficial without being overdramatic.

Skeptic: What the poor need today is access to food, clothing, shelter, and health care. The role of the goods and services through which ICTs could affect the welfare of the poor, either as producers or consumers, is too small to constitute a viable strategy of poverty alleviation. I see little point in disturbing the structure of public investment. I see a lot of point in increasing investment in physical infrastructure, farm research and extension, education, and training in the development budget.

Realist: Research in Bangladesh, evaluating the Grameen cell-phone program, shows that access to real-time price quotes (via mobile phones) made a significantly higher increase in the producer surplus for poorer egg vendors (Bayes, von Braun, and Akhter 1999). In addition to letting poor sellers of cell-phone access increase their take-home incomes, this ICT program has spillover effects. Craftsmen in Bangladesh, Botswana, India, Senegal, Uganda, and several countries in Latin America are marketing their products worldwide using electronic commerce (Charles and Hawkins 1998; PEOPlink 1998). This has added global reach to their marketing, improved labor returns, provided quick customer feedback about color, texture, and fabric. Under traditional marketing, such valuable feedback would have gone firsthand to the middlemen. Besides, the economics of the Internet for communications and conducting business remotely is so terrific that private business and industry in all countries will simply have to embrace it with open arms. Clearly, the Internet is going to change all standards of global sharing and trading. When standards, such as the metric system, change, it is in the interest of everyone, including the poor, to adapt.

Skeptic: ICTs do not have any clear link to the generation of high-yielding cultivars, or hybrid crops, or genetically-modified crops, all of which are major requirements of sustained agricultural growth.
Realist: The most promising trend is gene sequencing. Take the recent advances on vitamin-A-fortified rice varieties. Genomic sequencing for rice has given rise to immense data sets, with millions of rows of data. Going any further in this field is impossible without knowing how to use powerful servers arrayed in harness. This also requires either object-relational or object-oriented database tools. Note that Monsanto recently said it would release gratis its rice genomic sequence database on a new Web site (www.rice-research.org), and will provide royalty-free licenses for all its technology leading to further development of "golden rice." Only institutions that have mature expertise in keeping on top of information technology demands for the task would seriously consider going down that road.
Skeptic: It's not clear how ICTs could improve the effectiveness of farm extension in developing countries.
Realist: The Web can be a scaleable medium for farm extension content. Take for instance a news item published in the *New York Times* on August 22, 2000. It said that over a two-year period Chinese farmers, in perhaps the largest farm-technology experiment ever held in China, doubled rice yields by virtually eliminating what is called rice blast, a deadly disease for rice plants. All they did was to move from monoculture to biodiversity. In the process, they have been able to abandon the use of chemical fungicides. This news item was available on the *New York Times* website at midnight on the22nd. Within minutes of its posting, it could have been read by an intelligent "agent" launched into the cyberspace by a browser on a PC anywhere in rice-growing Asia. Within weeks, if not days, this information had the potential of changing the actual planting decisions of rice villagers in any number of countries. Not all villages need be physically wired: there are many other options available, such as a hub-and-spoke model of connectivity, or digital radio, or wireless WAN. (I am not saying that farmers elsewhere should plunge headlong into adoption of an experimental result without doing some experimentation of their own or asking their own farm extension workers. However, the point here is that the global "real-time information bank" makes the Web a destination of choice even for farm extension).
Skeptic: ICTs do not have anything to offer by way of the benefits of physical infrastructure such as roads and the like, which are major requirements for growth.
Realist: In the form of satellite technologies, wireless local loops, or digital Web-enabled radio, ICTs offer a viable alternative for at least one type of physical infrastructure, namely, terrestrial phone networks. Moreover, ICTs can make the utilization of physical infrastructure more purposeful, by making possible just-in-time inventory control. Mobile units, combining bar-code readers and GPS-controlled wireless LAN transceivers will enable tracking of inventory movement, in the name of cost control. Such outcome would also be more "green." More and more, countries and companies are factoring "green" considerations in their policy choices. It is clearly less costly and less energy-intensive to send video-conferencing images than to send people.

Skeptic: The poor in the developing countries are too often illiterate, and I don't see how ICTs can help with this problem.
Realist: What the poor need most of all is an opportunity. Give them that and they will surprise you by how eager they are to learn and how quickly some of them in fact learn. (A famous South Asian, whose name literally meant "The sea of knowledge," did his classwork under the streetlights in his early life and went on to become a role model for the undivided Bengal.) The Web makes it possible to mount literacy "boot camps" after hours much more cheaply than would be possible using brick-and-mortar facilities. And that is just one example.
***Skeptic*:** Remote processing is unlikely to fly in many developing countries because few poor people, even in the cities, have any comprehension of English, a vital ingredient.
Realist: Much remote processing of information consists of repetitive tasks and needs nimble fingers, keen eyesight, good health, and mental retention. It takes no more than eight odd weeks for young people to get up to speed, as far as competence in operating systems and applications is concerned. The English that workers need to understand is highly specific to the tasks at hand: because they are highly motivated they learn what they need to know quickly. A clear vision of the benefits of these livelihood opportunities makes these people earnest learners and adaptable.

The Linkages Between ICTs and IFPRI's Mandate: A Taxonomy

Tables 1 and 2 are about the linkages between IFPRI's mandates and ICTs. The average poor household in developing countries is recognized in two concurrent roles: "producer" and "consumer". Two classes of production activities are recognized: (1) goods and services for current consumption, and (2) own-account human capital formation. Competitive production activities, as always, involve the use of farm extension and market intelligence, but are also assumed here to demand productive electronic infrastructure for marketing that cuts out the middlemen.

Human capital formation implies own-account attainment of basic computer literacy and IT skills. Virtually all of these will be informal, "after-hours" kind of tasks. The Web is a big help on this count. Instructional materials related to many basic IT skills are regularly available on the Web (for example, one can learn about HTML, Web publishing, and computer-aided design). Though much of this content is in English, this is not set in stone. Government policies, it can be argued, should be about creating vernacular Web content in a number of fields of interest and letting people retrain as they see fit. This own-account production of IT skills is like investing in intangible assets, which are so important in today's knowledge economy.

As a "consumer", the household is interested in public or government services. ICTs have sizable interconnections with a long list of these services.[12] Some examples of these services include (1) agricultural research using gene sequencing at crop organism levels using relatively high-end computing; (2) Web-enabled farm and microcredit extension content and outreach;[13] (3) agricultural and food policies seeking to be more

[12] One informed recent document in the field of electronic governance can be found in an article titled "A Survey of Electronic Governance" in *The Economist* , June 24, 2000.
[13] I use nonfarm and microcredit income-generation activities as equivalents for the purpose of this paper. The use of microcredit is in a generic sense, to highlight the proactive isolation of poor women as change

knowledge-based by using the powers of the Web and Web-enabled applications; (4) the use of geo-spatial information systems (digital maps) in maintaining data on land ownership, residence, disease incidence, and water pollution, for instance; (5) the use of remote sensing and GPS in mounting various kinds of early-warning systems (wave actions, landslides, flood, bush fires, crop epidemics), whose updates are on the Web; (6) the provision of Internet connectivity for a significant majority of the rural population; (7) distance literacy and "continuous education programs" on the Web; (8) government portals that offer "public-information" kinds of productivity tools customized for rural people (various public-transport schedules; commodity freight moving into major terminal markets; real-time staples prices in major markets; large international auctions of fertilizer, live cattle, and so forth).[14]

The household is also interested in the services it receives from private and nongovernmental organization (NGO) sources, which may well impact favorably on its productivity. These sources can be located on the Web.

Finally, consider the law of the "network effects" in the diffusion of ICT, which is essentially about scale economies: the larger the network user-base, the cheaper it is to set up and service it. While it is good economics for institutions to start from their core competencies in figuring if and how much to embrace ICT, spending all one's time thinking "inside one's own box" could mean missing the forest for the trees. The significance of this "network effect" will vary from country to country. This is itself an important dimension of policy discussion, as a changeover to ICTs begins in earnest.

Table 1 looks at the various interconnections between ICTs and the welfare of poor producers, and Table 2 looks at the same for poor consumers. The entries in each cell of the two tables are outcomes that mediate between ICTs and IFPRI mandates. Those outcomes that appear to me to be directly relevant to IFPRI's mandate are highlighted: these are "go-go" outcomes that IFPRI should facilitate. The others are not highlighted. Where the average household is, potentially, both a "producer" and "consumer", the same entry is highlighted in both tables, as, for example, in the case of online farm extension.

As can be seen, more than 70 percent of the outcomes are highlighted in both tables.

Table 1: **Linkages between ICTs and welfare of the poor who are producers**

Categories of IFPRI's Mandate	Poor as producers of goods and services	
	Producer	"Own-account investor in IT skills"

agents based on a lifeline of small amounts of seed capital. Though microcredit units are traditionally composed of female producers, this may not always be so.

[14] For many developing countries, this brave new world may appear to be an insanely remote possibility. But not all elements are equally far-fetched. Important issues of resource prioritization, choice of technology, capacity building, international cooperation, and stakeholder networking would present themselves to developing-country policymakers, and that is precisely the point. Developing countries would need advice from intellectual partners at this juncture. In light of IFPRI's mandate, this task will be an important one. No one seems better suited to this task than IFPRI. Does a possible demand for ICT policy support call for IFPRI to change too, especially in terms of the desired skills? I don't know the answer to this question for sure, but I guess it probably does.

Rural development/poverty alleviation	**Online farm extension; farm marketing without middlemen; Web as a "farmers' community or information exchange"; better deals from Web auctions; reduction of informational inefficiency; remote processing of data; other rural nonfarm ICT services output (telecom access, hardware repair and assembly**, etc.); empowerment of women and the young.	Paid computer literacy lessons in after-hours rural schools for farmers' children; "continued farmers computer education".
Food security	**Web-enabled early-warning applications; geospatial focus on impact points of disasters; knowledge-based more direct market participation by poor organizations; real-time coordination of food aid or private food imports; market integration using mobile telecoms.**	Production of computer and Internet skills
Natural resource management	**Web's impact on sustainability in resource use and getting the facts out anytime, anywhere.**	Production of computer and Internet skills
Nutritional status of preschool children and women	**Greater readiness and ability by the farmer to respond to nutritional education and information efforts.**	Production of computer and Internet skills

Table 2: **Linkages between ICTs and welfare of the poor as consumers**

Categories of IFPRI's Mandate	Poor as consumers of goods and services	
	Government or public services	Private/NGO/microcredit services

Rural development/poverty alleviation	**More knowledge-based policies in rural development and natural resource management; "public-information" productivity tools; digitization of geographical, asset-ownership and essential environmental data.**	Private/NGO led informal ICT training facilities.
Food security	**Web-enabled early-warning applications; geospatial focus on impact points of disasters; knowledge-based more direct market participation by poor organizations; real-time coordination of food aid or private food imports; market integration using mobile telecoms**.	Championing of community-level production of nutritional content for the Web.
Natural resource management	**Web's impact on sustainability in resource use and getting the facts out anytime, anywhere.**	Championing of community-level production of nutritional content for the Web.
Nutritional status of preschool children and women	**Nutritional education and information campaign on the Web; using digital radio enabled with the Web.**	Championing of community-level production of nutritional content for the Web.

Table 3 presents my own judgment by way of a ranking of various technologies at issue. The legends are self-evident. The motivation here is to initiate some intensive discussion among readers about such a ranking. Perhaps, one can have some voting on this exercise.

Table 3: **A suggested ranking among the ICTs for IFPRI mandate rubrics**

ICTs / Goals	Internet/ Distributed Computing	Call-Centers	Satellite Technology Information Infrastructure	Digital Radio Network	GIS/ GPS	Remote Sensing
Real-time info, knowledge networking, Interactive Web sites	***		***	**	**	
Search and transactions costs	***		***	**		
Environmental case for spatial focus	***		**	**	***	***
Rural economic diversification	***	***				
Nutritional programs with locational specificities	***			*	***	
Early-warnings systems with peoples' participation	**		**	**	**	***

Notes: *** = very important; ** = important; * = somewhat important

Knowledge Gaps for Further Analyses

- What precisely is the ICT-economic growth nexus, quantitatively, for a representative sample of developing countries?
- What are the relevant economic aspects of the process whereby a given rate of ICT diffusion propagates itself using income and employment multipliers into the mainsprings of urban and rural growth rates and total factor productivity of developing countries?
- What is the factor intensity bias, if any, of ICTs, and how high are the economic barriers against the poor being able to access them? A related question is whether the barriers against exposure of the poor to the initial ICT skills are so high that the poor can not compete in the skills market?
- Are ICT rural and urban employment and income multipliers themselves significantly different from each other, in quantitative terms?
- What kind of institutional delivery mechanisms are more appropriate in terms of maximizing the multipliers, especially the rural ones?
- Is there an intrinsic urban bias in the orientation of ICTs as they locate themselves in developing countries? If so, could this amount to a market failure?
- What are the returns to public investment in Internet connectivity by female and young entrepreneurs, farmers, and traders in a “representative” developing country in Sub-Saharan Africa and in a populous and poor Asian country? And what are the returns to investment on mounting literacy-cum-farm extension programs using the Internet ?
- What is needed to ensure that the imperatives of knowledge networking and access to real-time market information for developing-country policymakers are reliably met?
- Should widespread prevalence of a digital divide in the developing world be considered as a market failure, and if so, what change should this prompt in the conventional repertoire of prescriptions that policy economists or institutions press into service for developmental effectiveness?
- What are the requirements, by way of appropriate hardware, network, and software resources, of harnessing the Internet as a tool for furthering food security, rural diversification and natural resources management in Africa and Asia?

4. Summary and Conclusions

With lightning speed, a cluster of ICTs has pervasively penetrated the world not only of communications and entertainment, but also of earning and spending, healing and learning during the last five years. This cluster has changed the techno-economic paradigm of production and distribution, especially of services. As computing and communications technologies have seamlessly converged, the rapidly burgeoning public network of computers, the Internet—growing at 12 percent a month—has become the soul and center of the world's increasingly networked economy. Where bandwidth allows, as in the West, the economics of the Web is for most purposes markedly superior in unit dollar costs and convenience, compared with rival modes of transaction, whether paper or brick and mortar. Computerization and networking are rapidly driving changes in regulatory framework, technologies, incentives, and education and training policies, and not just in the developed countries.

ICTs have a number of transparent linkages with IFPRI's mandates, including poverty alleviation, food security, natural resource management, and nutritional status of women and children.

First, ICTs can play an important role in facilitating policymakers' knowledge networking, access to real-time information, and automatic updates related to international market developments that impact national food security and policy imperatives. By improving the scope, quality and currency of information available to private and public participants in food market operations in developing countries, ICTs would likely improve inventory control and neutrality of food market incentives, thus helping these countries achieve food security objectives. Allowing top policymakers the means to leverage the Web in a timely fashion could help lower costs, increase the transparency of governance, and improve investor confidence.

Second, because the pace of ICT changes is so rapid, governments are, even in the narrow fields of poverty and food security, likely to need expert ICT advice as they start to harness the Web to their own ends.

Third, lack of information and communications services creates high search and transactions costs that hinder the participation by the poor and women in markets, as in Africa. In Asia and Latin America, where farming is technologically more innovative and commercialized, access to ICTs could favorably impact returns to in-kind investment (such as farm stocks), choice of farm and nonfarm technologies, and informational efficiency in planting decisions, among others.

Fourth, to meet the imperative of environmental sustainability in agricultural research and to promote the use of watershed, landscape, and community criteria for spatial focus, the use of ICTs is a natural.

Fifth, to promote diversification of rural growth sources, microcredit programs could be combined with programs to provide access to digital communications technologies, computer skills, and skills in remote informational processing, thus empowering young, rural women and high school students in particular. To this end, there could profitably be a greater coupling between the food aid dollar and investment in rural information infrastructure and Internet connectivity.

Sixth, the poor can benefit from "public information" productivity tools. The production of these kinds of public goods would probably have large content and network externalities. Governments could usefully consider forging partnerships with NGOs or microcredit leaders, creating such tools in ways that distribute costs and risks.

Seventh, georeferenced nutritional or health or pollution GIS could contribute to the health and nutritional outcomes of the rural poor. Research data sets should be generated so that they offer a *georeferencing interface* (using GPS coordinates) to other geo-spatial data available.

Appendix 1
Policy Changes in South Asia, 1997–2000

The meteoric rise in the international visibility of India, riding on the crest of its software capability, itself a result of a vigorous policy reorientation since 1992, has made liberalization of the telecommunications economy *de riguer* among South Asian countries. This appendix presents several country-specific examples. Their highlight is that traditionally *dirigiste* policy postures of state-owned telecom organizations are collapsing in South Asia. (Full-throttle liberalization, including the creation of truly independent telecom regulators, however, has a way to go.)

India

Policy shifts in India have been the most sweeping (Mitra 2000). The Department of Telecom Services (DTS) will be turned into a public limited company effective October 1, 2000, thus essentially closing a parastatal. Automatic clearance of the following activities will be permitted:

- For units in the Special Economic Zones, up to 100 percent foreign equity in all industries except those that produce cigarettes, alcohol, narcotics, or atomic substances;
- Up to 100 percent foreign equity for Internet Service Providers (ISP) not having gateways, electronic mail, or voice mail;
- Investment by offshore venture capital companies in Indian firms;
- Royalty payments, on the order of 8 percent on export receipts and 5 percent on domestic sales by wholly owned subsidiaries to offshore parent companies; and
- Payment of 2 percent royalty on exports and 1 percent on domestic sales of goods with benchmarks and brand names of foreign collaborators, where no technology transfer is involved.

In addition, the monopoly of Videsh Sanchar Nizam Limited (VSNL) will be abolished from the Internet gateway for marketing bandwidth among private ISPs.

A Telecommunications Regulatory Authority of India (TRAI) was established in 1997, with a significant degree of independence. An influential Information Technology Committee was established in 1998 and a fully fledged Ministry of Information Technology (MIT) was established in the same year to implement the vision spawned by the first-named committee for India's IT industry. Finally, approval of Voice Over Internet Protocol (VOIP) is expected in the near future.

Pakistan

Changes in Pakistan have also been sweeping.

- The increase in the budget allocation for the Science and Technology Ministry has been staggering, on the order of 1200 percent in 2000—about 0.5 percent of the total budget of the country.

- The entire country will be treated as an Export Processing Zone (EPZ) by companies that export software services and/or products, with all attendant export incentives accorded to them.
- All telephony using “dial-up modems” into any ISP will be billed as a local call, regardless of the distances involved.
- Incentives announced for private colleges will offer informal IT training to students with other than computer science backgrounds, leading up to their certification along U.S. vendor-specific tracks.
- VOIP has been approved as a concept. The state-owned PCTL is waiting for proposals from Pakistan’s private industrialists about implementation of VOIP. This is a sea change in official attitude, compared with only a year ago, when VOIP was illegal, punishable by penalties severe enough to cause imminent bankruptcy.

Bangladesh

- Bangladesh has lowered tariffs on long-distance telephony and on the cost of leased lines (Chowdhury 1999b).
- The country has expressed a willingness to consider VOIP. It was illegal at the beginning of 2000. The state-owned BTTB is considering a proposal submitted by Singapore Telecom (SingTel) for regularizing VOIP as a way of giving the customer a break from high prices for long-distance telephony. SingTel has even offered to provide Bangladesh the infrastructure needed to transport voice traffic over the Internet at no cost. In return, SingTel has demanded a contract from BTTB to roll out the Internet backbone for Bangladesh. SingTel has proposed a graduated tariff structure related to VOIP telephony to be carried by its network, which shows tariffs falling fast between 2000 and 2002.

Bibliography

Ahmed, R., and N. Rustagi. 1993. Marketing margins and costs in marketing of agricultural products: Asian African comparisons. In *Agricultural markets and economic development*, ed. H. J. Mittendorf. Geneva: Swiss Development Corporation.

Aspinall, R. 1999. Putting VSAT networks to work. *International Telecommunications*, (May).

Bayes, A., J. von Braun, and R. Akhter. 1999. The impact of village pay phones in Bangladesh. ZED Discussion Papers on Development Policy, Bonn, June. Photocopy.

Beardsley, S., and M. Patsalox-Fox. 1995. Getting telecoms privatization right. McKinsey & Co.

Bedi, A. S. 1999. The role of information and communications technologies in economic development: A partial survey. ZED Discussion Papers on Development Policy, Bonn, May Photocopy.

Behrman, J. 1995. Household behavior, preschool child health and nutrition, and the role of information. In *Child growth and nutrition in developing countries: Priorities for action*, ed. P. Pinstrup-Andersen, D. Pelletier, and H. Alderman. Ithaca, N.Y.: Cornell University Press.

Bhattacharjee, A. 1998. The big glitch: India turns the bug into a cash cow, *The worldPaper Online*, (June).

Bond, J. 1997a. The drivers of information evolution: Cost, computing, and convergence. In *The information revolution and the future of telecommunications*, Washington D.C.: World Bank.

———. 1997b. How information infrastructure is changing the world. In *The information revolution and the future of telecommunications*, Washington D.C.: World Bank.

———. 1997c. Telecommunications is dead, long live networking—The effect of the information revolution on the telecom industry. In *The information revolution and the future of telecommunications.* Washington D.C.: World Bank.

Bryant, C. 1988. *Poverty, policy, and food security in Southern Africa.* Boulder, Colo., USA: Lynne Rienner Publishers.

Cairncross, F. 1999. *How the communications revolution will change our lives.* Cambridge, Mass.: Harvard University Press.

Calamai, P., 2000. Coral reef crisis seen in new light: Ontario scientist searches for answers in satellite images. *Toronto Star*, July 31 <www.thestar.com/thestar/back issues/ED200007.html>.

Cargill, Inc. 2000. IBP, Cargill, Smithfield, Tyson, Gold Kist, Farmland Plan e-commerce system for meat and poultry. <www.cargill.com/today/releases/00_4_11tyson.html>.

Charles, K., and R. Hawkins. 1998. Internet economic toolkit for African policy makers. World Bank . Photocopy.

Chowdhury, N. 1994. Commercialization of Bangladesh's rice economy: The discovery of private stocks. Bangladesh Food Policy Project. International Food Policy Research Institute, Washington, DC. Photocopy.

———. 1999a. Putting Bangladesh's poor women using electronic commerce on the World Wide Web: Towards a global economic village. Paper prepared for the International Development Research Center, Ottawa, Canada. Photocopy.

—— 1999b. Bangladesh's information and communications technology infrastructure: First thoughts on a roadmap. Paper presented to a session under the auspices of Expatriate Bangladeshis. Washington D.C., November. <www.eb2000.org>.

CNN. 2000. Monsanto to provide royalty-free licenses for "Golden Rice" development. <www.cnn.com/2000/FOOD/news/08/04/monsanto.rice.ap/index.html>.

Corrigan, F. 1999. Open trade: The key to future prosperity for US agrifood business. Keynote speech to the U.S. Agricultural Retailers Association 7th Annual Conference, December 2.

Cosper, A. C. 1997. VSATs find their voice. *Global Telephony (* September) <www.internettelephony.com/Global Telephony/archives/GT997/GT997feature3.htm>.

Delgado, C. L. 1997. The role of smallholder income generation from agriculture in Sub-Saharan Africa. In *Achieving food security in Southern Africa*, ed. L. Haddad. Washington, D.C.: International Food Policy Research Institute.

Dinerman, T. 1998. India: A normal spacefaring nation. *SpaceEquity.com*. <www.spaceequity.com/spotlightindia.html>.

The Economist. 2000. A survey of electronic governance. June 24.

Evans, P. B., and T. S. Wurster. 1997. Strategy and the new economics of information. In *Perspectives on strategy from the Boston Consulting Group*, ed. C. W. Stern and G. Stalk Jr. New York: John Wiley & Sons.

Ford, G. J. 2000. Using information technology to measure, monitor, and report on environmental performance. <www.greenware.ca/eps/EPS_paper.htm>.

Greenstein, S. M., and P. T. Spiller. 1996. Estimating the welfare effects of digital infrastructure. NBER Working Paper 5770.

Hamelink, C. J. 1997. New information and communication technologies: Social development and cultural change. Discussion Paper No. 86. New York, UNRISD.

Hannah, B. B. 2000. An island caught up in the Web. *Choices* (June).

Hazell, P. 1999. Agricultural growth, poverty alleviation, and environmental sustainability: Having it all. March <www.ifpri.cgiar.org/2020/briefs/number59.htm>.

IDC (International Development Cooperation). 1999. Internet commerce market model V5.0. New York, April. Photocopy.

Jensen, M. 2000. African internet status. < www.demiurge.wn.apc.org/africa/afstat.htm>, May.

Jorgenson, D., and K. J. Stiroh. 1999. Information technology and growth. *American Economic Review* 89 (May):

———. 2000. Productivity growth at industry-level, 1958-1995. *American Economic Review* 90 (no. 2, May): .

Krishna, A. P. 2000. Landslide management in the Himalayas. *GeoAsiaPacific* (June/July). < www.geoplace.com/asiapac/2000/0700/0700lnd.asp>.

Lan, N. 1998. Prosperity in the pipeline. *GeoPlace.com* <www.geoplace.com/gia/1998/0998/998env.asp>.

Leo, J. 1999. Statement of Joseph Leo, Chief Information Officer, USDA before the Subcommittee on Agriculture, Rural Development, Food and Drug Administration and Related Agencies. Washington D.C., House Committee on Appropriations.

Lustyan, D. B. 2000. Center for Sustainable Agriculture and Land Management. A proposal prepared by Ag Paradigm Consulting LLC, Clovis, Calif., USA.

Mann, K. L., S. E. Eckert, and S. C. Knight. 2000. *A policy primer: Global electronic commerce.* Washington, D.C.: Institute for International Economics.

Metternicht, G. 2000. Video-based precision farming. *GeoPlace.com* (June/July). <www.geoplace.com/asiapac/2000/0700/0700frm.asp>.

Mitra, R. 2000. Recent ICT developments in India: Industry trends, project proposals, institutional arrangements and contacts. A report prepared for the Global ICT Department of the World Bank (draft), June 7.

Mitter, S. 2000. Teleworking and teletrade in India. *Economic and Political Weekly*. June 24.

Mudur, G. 2000. Indian satellite will boost, medicine, education. *Space.com.* March 20. <www.space.com/missionlaunches/launches/arine_preview_000320.html>.

Mulgan, Geoff. 1999. *How to live in a connected world*, Cambs. Mass.: Harvard University Press.

D'Orville, H. 2000. Knowledge and information: New levers for development and prosperity. *Choices* (published by United Nations Development Programme), June.

PEOPlink. 1998. Linking poor producers to global markets: Feasibility study and toolkit. Paper prepared for InfoDev, World Bank . <www.peoplink.org/reports/infodev>.

Pinstrup-Andersen, P., D. Pelletier, and H. Alderman. 1995. *Child growth and nutrition in developing countries: Priorities for action.* Ithaca, N.Y.: Cornell University Press.

PITAC (President's Information Technology Advisory Committee). 1999. Investing in America's future. A report prepared for the Office of the U.S. President, February.

Rajan, P. 2000. Training and educational needs for teletrade. *Economic and Political Weekly*, June 24.

Scott, G. 2000. Peru's government goes high-tech. *Choices.* (June).

TeleCommons Development Group. 2000. Rural access to information and communications technologies: The challenge for Africa. Paper prepared for the African Connection Secretariat, World Bank.

Vaitsos, C. 1996. Policy agenda for the information revolution and exclusion phenomena in developing countries. Paper presented to the International Workshop on the Information Revolution and Economic and Social Exclusion in Developing Countries, October 1996. Maastricht, Netherlands. Photocopy.

Ventura, A. 1997. National information and communication technology strategies for development: A United Nations Commission on Science and Technology for Development perspective. UNCSTD, New York.

Veronis Suhler 2000. (www.veronissuhler.com) quoted in Sydney Morning Herald, Sept 2

Witcher, S. K. 1999. Family garment business in Hong Kong uses internet to gain access to global customer pool. *New York Times*, November 24.

Wong, S. L. 2000. Internet on wheels, *Choices* (June).

World Bank, 1986. *Poverty and hunger: Issues and options for food security in developing countries*. Washington, D.C.

———. 1999. *Knowledge for development: World development Indicators 1998/1999.* Washington D.C.: Oxford University Press for the World Bank.

———. 2000. *Entering the 21st century: World development indicators 1999/2000*, Washington D.C.: Oxford University Press for the World Bank.

World Bank (InfoDev). The networking revolution: Opportunities and challenges for developing countries. Global ICT Department. Washington, DC. Photocopy

Yoon, C. K. 2000. Simple method found to vastly increase crop yields. *New York Times*, August 22. <www.nytimes.com/library/national/science/082200sci-gm-rice.html>.