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INFORMATION AND COMMUNICATION TECHNOLOGIES, MARKETS AND ECONOMIC DEVELOPMENT[*]

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There is great optimism over the potential for information and communication technologies (ICT's) to promote economic development and alleviate poverty. Currently, however, there is neither a solid theoretical basis nor convincing empirical evidence to support such optimism. This chapter identifies the economic underpinnings of the argument for a significant role for ICT's in the development process. The basic premise is that information and communication are valuable commodities that can enhance the functioning of markets that are critical for the well-being of the poor. Recent advances in ICT's can bring these benefits to even the poorest of the poor in the developing world.

This chapter is organized as follows. We begin with a theoretical discussion of markets and economic efficiency, highlighting the desirable outcomes that result from well-functioning markets. Next, we discuss the critical role of information in generating efficient market outcomes. We then examine the extent of information flow, or lack thereof, in developing countries, and the consequences for market functioning. In doing so, we pay particular attention to the benefits well-functioning markets bring to even the poorest persons in the poorest nations. Finally, we evaluate the limited evidence to date on how bringing ICT's to information-isolated communities can promote welfare, and provide new evidence based on analysis of household data from China.

I. MARKETS AND ECONOMIC EFFICIENCY

What markets are and what they do. In the broadest sense, an economy is a group of individuals, or consumers, who need or want various things, such as different kinds of foods, clothing, shelter or entertainment. The most important task, and the biggest challenge, for an economy is to take its limited resources – land, labor, capital, natural resources – and convert them into the things people want. This problem, fundamentally to allocate resources to match production with consumption desires, is the core of economics. Markets are the key instrument to meet this challenge.

Markets are a set of transactions by agents over a range of goods and services. Such transactions allow for mutually beneficial exchange. Taken at this fundamental level, markets perform the important task of freeing individuals from self-reliance. In a modern economy, all economic activities, from the production and sales decisions of the smallest farmer to those of the largest corporation, rely on markets.

When markets perform well, consumption desires guide the production of all participants. Under these conditions, the economy is said to be performing efficiently, meaning that there is no opportunity to make someone better off without making someone worse off. This implies, for example, that there is no scope for re-adjusting production to produce more X and less Y, assuming consumers would value the gained X more than the lost Y. In other words, efficiency assures that resources are deployed to their highest value purposes.

The role of information in market coordination and efficiency. The coordination problem involved in allocating resources to their best uses is enormous. How can millions of independent, dispersed consumers communicate to millions of independent, dispersed producers exactly how much of each of the enormous variety of goods and services they want? Similarly, how do producers know how they can make the most money, usually without ever meeting more than a fraction of the people who buy their products? How do they know to supply the exact combination of goods that consumers want to buy, so that collectively there is not too much bread and too little clothing, or too much rice and too few onions? Prices, and market signals more generally, are the key instruments that facilitate this coordination.

In a market-based economy, prices transmit all of the information that participants in the economy require to make effective decisions. Producers need to know the prices of inputs they must buy and the prices of the outputs they wish to sell in order to decide what and how to produce. Consumers need to know the prices of the goods and services they might buy, and the going rate for their labor skills and other services they wish to sell, so they can make appropriate decisions about household consumption and labor force participation. On both the production and consumption sides, market prices act as coordinating signals.

In the classic, textbook version of a market-based economy, a good's price will rise when many people value it more than the current price. As consumers compete to buy the good, they will bid the price higher. Producers respond to the higher price by supplying more of the good. Thus, in a well-functioning economy, when there aren't enough eggs to meet demand (in a given region), the price of eggs increases, and farmers, seeing profitable opportunities, breed more hens to produce more eggs. People want more eggs, and like magic, more eggs appear. Consumers and producers react to the evolution of prices through multiple iterations of this sequence.[1] When quantity demanded at a given price just balances the quantity that producers want to supply at that price, the market reaches equilibrium. Whether Wall Street or West Africa, information makes markets work.

[1] Meyer, Van Huyck, Battalio, and Saving (1992) study the role of historical prices in coordinating decentralized allocation decisions.

When markets do work, consumers benefit alongside producers. Only a consumer whose value for the good exceeds, or at least equals, the going market price will end up buying it. Therefore, in market-based economies, those who want a good the most ultimately get it. This allocation process might seem to disadvantage the poor, but that is not the case. Even the poor get staples, such as food, because staples are cheap to provide, and the rich only want limited amounts of such goods. The market allocates scarce resources in a way that fosters the welfare of both rich and poor.

How challenging is the task of providing the information that enables markets to work? Little information would be required if prices stayed relatively constant from year to year. Farmers would know what to plant, laborers would know where to work, consumers would know what to pay for goods and farmers for inputs, just by relying on prices from the previous period. However, even in relatively underdeveloped economies, prices move considerably in response to such forces as weather, changes in taste and technology, and variation in supply and demand from outside the region.

Might there be alternatives to market signals for coordinating production and consumption? The multi-decade experience of centrally-planned economies, for example the pre-1990 nations of Eastern Europe and the former Soviet Union, the most ambitious experiment to supersede the traditional role of prices, indicates not. Severe coordination failures proved to be unavoidable when prices were not used to coordinate economic activities. Rather than letting producers and consumers communicate through prices, the governments in these economies set prices administratively, and directly allocated inputs and output quotas to manage the economy. The amount of information needed to ensure that the production of every good and service even roughly matched the desires of consumers could not be achieved. Often production was grossly inconsistent with demand at the prices set. The result was that many goods that consumers wanted could not be found or there were long queues for these goods, whereas many other goods were badly over-supplied, sitting unwanted on shelves. Further, because prices and production activities were set by planners, the opportunity for corruption or private financial and political gains to guide decision-making, rather than efficiency, was great. Experience with socialism underscores the great advantage of markets as coordinators of producers and consumers.

Information and markets in developed and developing nations. In the developed world, markets perform well because the prices of goods are known or can be found with minimal effort. However, in developing nations, especially in rural areas, such signals flow sluggishly, if at all. As a result, farmers often produce the wrong mixture of crops, often using inefficient technologies, and consumers do not receive goods even though they would willing to pay the market price. The result is inefficiency.

Efficiency failures reveal themselves as deviations from the “Law of One Price.” The Law is an important economic principle that holds that prices for homogeneous goods sold at different locations

should be equal, net of transportation costs. "Price dispersion is a manifestation - and, indeed, it is the measure - of ignorance in the market" (Stigler 1961: 214).[2] As markets become better integrated, the Law of One Price tends to hold for more and more goods and services, so that consumers and producers in different locations are tied together in an information network summarized by one critical piece of information, the prevailing market price.

In poor countries, the coordination of economic activity rarely works well. In isolated rural villages in most developing countries, there are virtually no sources of information regarding market prices and other production-related information. For them, "information is poor, scarce, maldistributed, inefficiently communicated, and intensely valued" (Geertz 1978: 29). The main reason is that many people lack access to even very basic communications infrastructure. As shown in Table 1, in low-income countries as a whole, there are only 18 telephone mainlines for every 1000 people, and the average waiting time for a telephone is almost 6 years. Access to more advanced forms of ICT's is generally even more limited. Barely 6 percent of the world's people have ever logged onto the Internet (ILO 2001). A household survey in Peru shows that 77.2% of households lacked telephones, including 99.8% of poor rural households (Torero, 2000, p.11).[3] With no way to communicate across distances, many rural poor are removed from the flow of information required to make markets work. In particular, price signals are faint or absent.

A vivid symptom of poor information flow is that prices vary widely within a geographic area, even for goods that are readily transported. A few empirical studies document the spatial dispersion of prices and how effectively or ineffectively price information is transmitted across markets. For example, studying monthly 1980-1993 maize prices in Ghana, Badiane and Shively (1998) find that "the estimated time to fully transmit a price shock [from the central market to each of two outlying markets] is about four months" (p.426).[4] Price adjustments may also be asymmetric; in Ghana, wholesale maize prices for

[2] Isard (1977) asserts that "in reality the Law of One Price is flagrantly and systematically violated by empirical data". Of course, there are other frictions that lead to divergence from the Law of One Price, including the cost of buyers' search; the fact that knowledge quickly becomes obsolete as supply and demand are constantly in flux; the entrance of new, inexperienced buyers and sellers into the market; the costs to dealers of ascertaining rivals' asking prices; and various indivisibilities (Stigler 1961). Engel and Rogers (1996) study deviations from the Law of One Price for U.S. and Canadian cities. They find that "the distance between cities explains a significant amount of the variation in the prices of similar good in different cities," and note "the failure of prices of similar goods to equalize between sites is a sign that the markets are not completely integrated" (ibid: 1113).

[3] Many Peruvian households do have access to public telephones, however, so reported rates based on residential phones no doubt understate access to telephone services (Torero 2000: 15).

[4] One outlying market, closer in proximity to the central market and characterized by "high intensity of trading activity", seems to be well integrated with the central market in the sense that central market price history was more important than local price history in explaining price changes. In the second, geographically further outlying market, "local market history was the predominant determinant of prices" (Badiane and Shively 1998: 429).

producers in local markets respond more swiftly to increases than decreases in central market prices (Abdulai 2000).[5]

Table 1. Access to Telecommunications in 2000, by World Region

REGION	Mobile Phones (per 1,000 people)	Radios (per 1,000 people)	Telephone Mainlines (per 1,000 people)	Waiting Time for Telephones (years)	Television Sets (per 1,000 people)
Low-Income	6.0	157.3	17.6	5.9	85.5
Middle-Income	90.0	359.4	153.2	1.1	279.2
High Income	615.3	1288.5	557.2	0.0	692.8
East Asia / Pacific	179.5	302.3	200.6	1.2	252.5
South Asia	7.5	112.7	27.8	1.6	71.0
Sub-Saharan Africa	27.7	201.5	24.4	6.0	43.2
Europe/Central Asia	329.5	446.0	323.5	2.0	369.6
Latin America/Carib	88.7	418.6	241.9	0.5	271.8
World	156.7	420.1	202.5	1.4	268.3

The data on mobile phones and telephone mainlines are for 2000, based on authors' calculations from International Telecommunications Union (October 2001 update) using regional fixed factors from Easterly and Sewadeh (2001). The data for radios, waiting times for telephone mainlines, and television sets are for 1999 as reported in the World Bank World Development Indicator Database (available at www.worldbank.org).

Not surprisingly, therefore, many studies have shown that market integration fails for important products in a variety of countries. Examples include rice in Bangladesh (Ravallion 1986), rice sorghum and oil in India (Palaskas, Hariss-White and Crowe 1997), grains in Nigeria (Heytens 1986, Delgado 1986), livestock in Niger (Fafchamps and Gavian 1997), and rice in China (Zhou, Wan and Chen 2000).

We can examine these issues further using the interesting case of rural China. Despite decades of urban growth, China remains largely a rural country; over two-thirds of the population resides in rural areas, and nearly three-quarters of employed men and women are engaged in the agricultural sector. To explore the nature of market efficiency and price dispersion, as well as to later show the potential role of ICT's for promoting income growth among the poor, we make use of household- and village-level data from the China Health and Nutrition Survey (CHNS).[6] The CHNS is a stratified random sample of 3,800

[5] The price transmission mechanism also affects the variability of prices across regions. This may occur because high prices entice inventory holders to sell, leaving less of the good available to cushion later changes in demand. Lower inventories then produce higher future price variance. In contrast, lower prices lead to higher inventories and lower future price variance. Badiane and Shively (1998) identify such an effect in Ghana: "a 1 cedi decline in the [central market] maize price led to a 0.5 cedi reduction in price variance in the relatively well-integrated [outlying] market, but only a 0.1 cedi reduction in price variance in the relatively isolated [other outlying] market" (p.430).

[6] This survey was a panel study conducted in 8 provinces in China between 1989 and 1997 by the Carolina Population Center at the University of North Carolina at Chapel Hill, the Institute of Nutrition and Food Hygiene

households across 200 villages in China. In addition to information on employment, income and expenditures, the survey gathered information on the market prices at which various goods can be purchased, for each village in which the survey was conducted. Table 2 provides data on the distribution of prices across areas in 1991 for several of the most commonly consumed foods. Columns 1 through 4 respectively show the means, standard deviations, and highest and lowest prices recorded (in RMB yuan) across the villages sampled in the survey.

Table 2. Prices (per kg) of Various Commodities in Chinese Villages, 1991

Commodity	Mean	Standard Deviation	Highest	Lowest
Fish	6.5	2.0	14.1	5.2
Pork	5.9	1.4	8.0	3.8
Eggs	4.6	1.5	7.0	1.9
Vegetables	.64	.61	4.5	.35

The table reveals that that the Law of One Price is strongly violated. For most of the commodities, the standard deviations are quite large relative to the means, indicating a great deal of price dispersion. In every case illustrated, the highest price is at least two times greater than the lowest price. Such gaps in price greatly exceed possible transport costs for the commodities (for which some data in the CHNS are available). These results roughly indicate how far these markets are from being integrated, which implies severe underlying inefficiencies.

Of course, there may be other factors that could explain why a given village would have a high price for commodity A or a low one for commodity B. For example, if the village imported A and exported B, and middlemen were exploiting its residents, price dispersion would also arise. Therefore, to test for integration, we must look further. With integration, even if there is exploitation or transport costs are steep, prices for these commodities in the village would tend to move in concert with urban prices. Thus, finding that prices move in different directions across different areas, i.e., the price for a given good is rising in one area while falling in another, would indicate poor integration. Figure 1 graphs the prices of pork, vegetables, eggs and fish in 1989 and 1993. The horizontal axis represents the price in 1989 and the vertical axis the price in 1993. The 45-degree line represents the set of points where (deflated) prices are equal in both years. Prices move substantially over this time for all of these commodities. Tracing up from any given price in 1989, there are cases where the price goes up in many villages and down in many others. Thus, prices are not moving in tandem in across areas.

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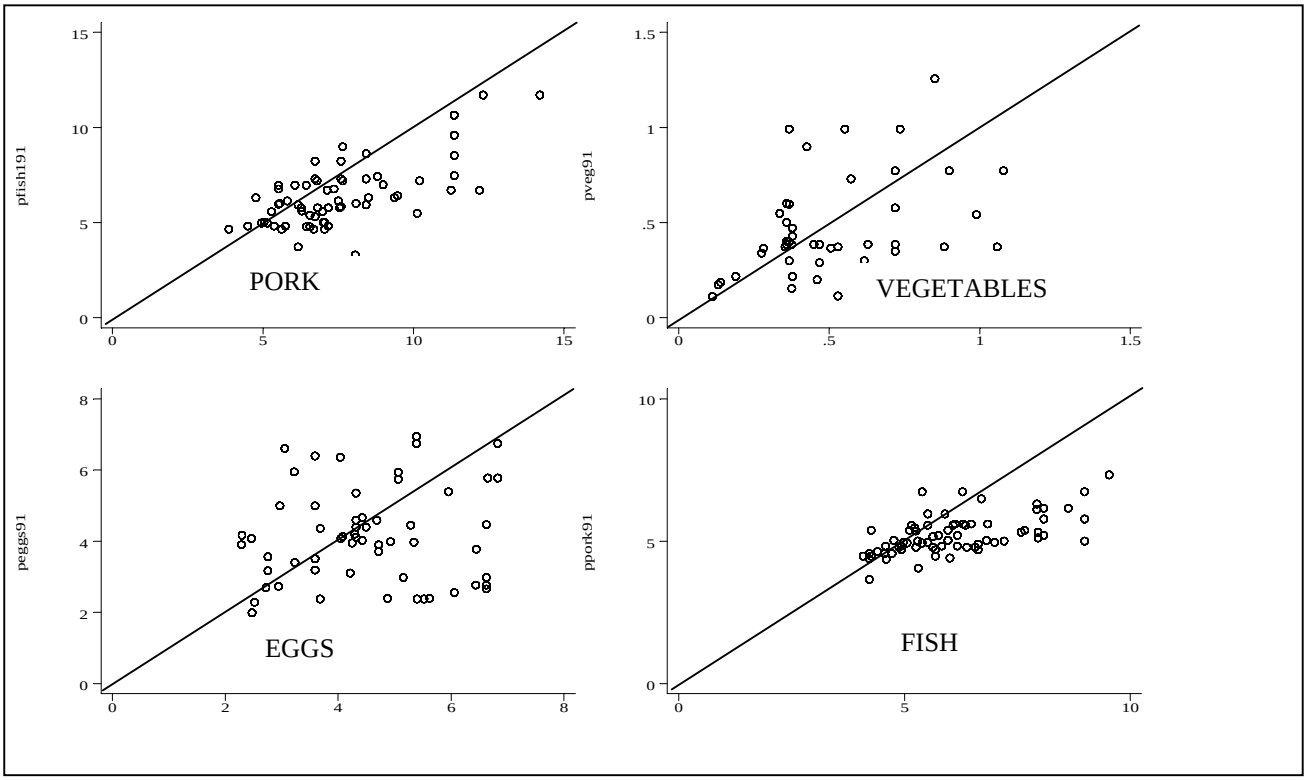
and the Chinese Academy of Preventative Medicine. The data and additional information can be found at http://www.cpc.unc.edu/projects/china/home.html.

Figure 1. Price Changes Across Chinese Villages, 1989-1993



Our guiding premise suggests that price dispersion will be diminished by the presence of communications infrastructure. Greater information flows should reduce the variation in prices; as markets become more integrated, trade should push toward price equalization. Telephones offer a very basic means to communicate prices. Table 3 provides the same information as Table 2, but disaggregated by whether the village has a phone.

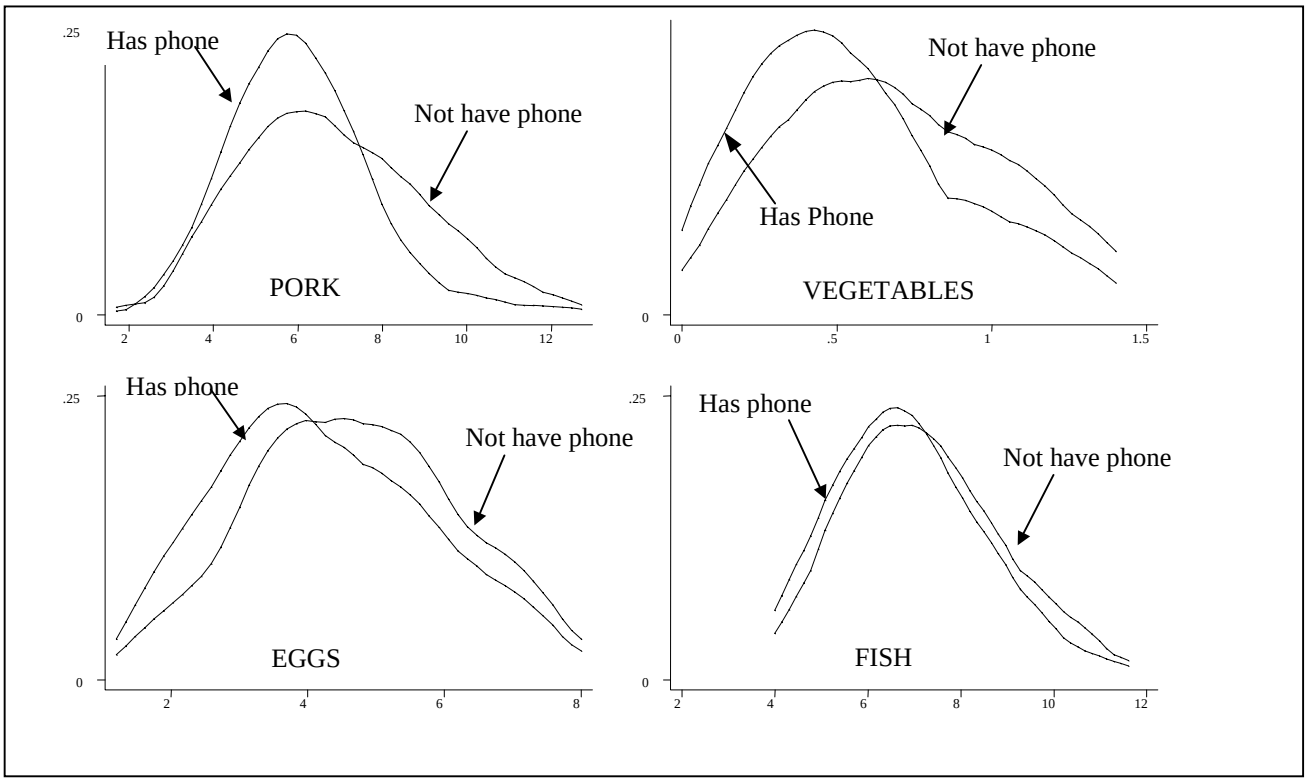
Table 3. Prices (per kilo) of Various Commodities, Telephone vs. No Telephone

	HAS PHONE				*NO PHONE*			
Commodity	**Mean**	**Standard Deviation**	**Highest**	**Lowest**	**Mean**	**Standard Deviation**	**Highest**	**Lowest**
Fish	6.2	1.8	9.0	6.2	6.8	2.0	14.1	5.2
Pork	5.8	.71	7.0	4.6	6.0	2.1	8.0	3.8
Eggs	4.3	1.2	7.0	1.9	4.8	1.6	7.0	1.9
Vegetables	.64	.50	4.5	.39	.64	.67	4.0	.35

Several striking features are apparent in this table. For three of the commodities, the mean price is lower in villages with telephones. And for all the goods, in villages lacking phones, as the information-promotes-market-integration theory would predict, the standard deviation is much higher. So too is the

spread between the highest and lowest prices. The greater price dispersion can be seen more clearly in Figure 2, which shows estimates of the densities of the prices of pork, vegetables, eggs and fish.

Figure 2. Densities of prices



Of course, there may be other differences between villages with and without phones that may also influence prices and market performance. For example, villages with phones may be nearer to cities, have better access to roads or lower transportation costs. The CHNS data provide information on such factors, which do in fact differ slightly across villages. However, even after statistically controlling for these various differences, we still conclude that the means and standard deviations are lower in the villages with phones. Further, since the CHNS visited the same villages in several rounds over the course of 8 years, we can examine the *change* in prices, and change in price variance, for villages that add phones during the course of the survey. This will allow us to control for any fixed differences across villages, as well as changes in other factors that may affect prices. Making use of this strategy, the results yield similar conclusions; villages that add even the most basic communications technology, the telephone, experience declines in the purchase price of various commodities and lower future price variability.

II. THE IMPORTANCE TO THE POOR OF INFORMATION AND MARKETS

We have detailed the benefits of market coordination, the role of information in enabling market coordination, and the widespread lack of such coordination in developing countries. We have also hinted at, and will provide evidence in the next section, on the ways ICT's can foster market integration. We now describe how such information and integration can help the poor by promoting poverty alleviation and fostering economic growth. The vast majority of the poor in rural areas of low-income countries are either farmers or surplus laborers. Each group depends heavily on markets, and thus can be assisted through better functioning markets, as outlined below.

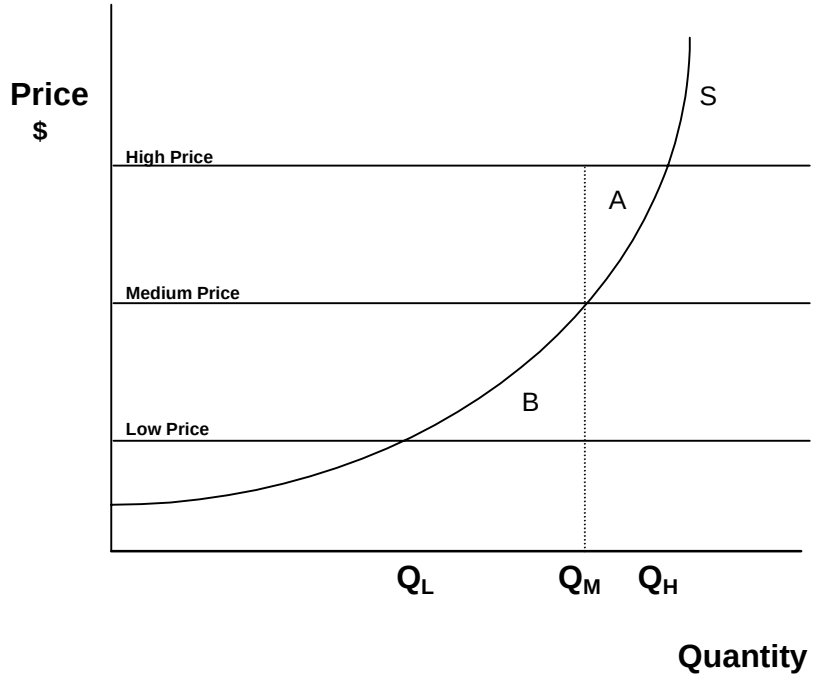
Productive efficiency. The farmers' primary interest is to maximize the profits they earn from their farms. To achieve this goal, farmers need price information for four important purposes: First, relative prices allow the farmer to make decisions on the mixture of crops to produce. Even if conditions restrict him to one crop, its price tells him how much to produce. Second, prices enable him to produce in a more efficient manner. He is able to purchase inputs – e.g., fertilizer, irrigation equipment -- when and where they are cheapest. Prices may also alert him to the existence of inputs that would profitably boost his production. Third, price information allows him to know where to sell his output, and the appropriate price to accept. For example, while prices often differ across villages, the farmer typically knows only the local price. So even if, say, the urban price is higher, he doesn't know to send his output to the city. Nor does he realize that it is profitable to produce more of that output (and perhaps less of another). He misses opportunities to earn more income, and urban consumers face excess prices. By not being able to pursue the highest price, farmers are not sending their output to where they are valued most, and lowering the price there for consumers. The same principle applies if there are multiple cities, and the farmer does not know which one will offer the highest price. He could search for the best prices for his crop or for his inputs, but each price-seeking foray could take considerable time. In response to high search costs, farmers may just choose the same market year after year, which would imply that prices across markets could be highly variable, as we have seen they are.

Another possibility is that middlemen or dealers will enter the picture. As Geertz (1978: 30) pointed out, one of the most common responses to high search costs due to poor information is "clientelization," establishing long-term trading relationships. Although trust may develop over multiple transactions, the paucity of information continues to handicap the farmer, since he cannot independently assess the integrity of the dealer, or the reasonableness of the prices he offers, by comparing purchase prices across many markets and many dealers. The fourth purpose of price information for farmers is to prevent their exploitation by middlemen, a matter we take up below.

Production given price uncertainty. We are not suggesting that price information never arrives at the isolated village, just that it arrives too late, when it may no longer be accurate or relevant. Consider a farmer in an uncertain world; he knows prices on average, but not the actual price at the time he must make production decisions. Even if he produces only a single crop, and ultimately gets the market price, he will produce the wrong amount. The curve labeled S is a supply curve, telling how much the farmer can produce at any price. The curve slopes upward, because beyond some minimum each extra unit of output costs more in terms of hired labor, fertilizer, better seeds, etc. The farmer knows that the price is 50% likely to be high and 50% likely to be low. If he does not know the price, the best he can do is to assume the average (medium) price. He will produce amount Q_M. (The subscripts H, M and L refer to high, medium and low.) If he knew the prices, he would produce Q_H if high and Q_L if low. As opposed to producing Q_M, he would earn area A more if the price was high, and would avoid losing area B if price were low (when he incurs production costs above the price). On average, the farmer would be (A+B)/2 ahead if he knew prices before making production decisions.[7] To be fair, even farmers in the information-suffused environments of developed nations do not know ultimate sale prices before they produce, but price projections and futures markets usually give them a reasonable idea. Further, the absence of the latter markets is in itself an indication of the weak flow of information in developing countries, and the potential benefit better information flows could bring.

[7] Areas A and B in Figure 1 illustrate the loss to a supplier when the alternative to ignorance is precise knowledge of the prices P_L and P_H , assuming the supplier is risk neutral. The loss in expected value of (A+B)/2 is itself an expectation for a supplier with only imperfect knowledge of future prices—as is usually the case even for well-functioning markets in developed economies.

Figure 3. A Farmer's Loss from Price Uncertainty



Laborers and markets. Landless laborers, who together with farmers comprise the overwhelming majority of the population of poor rural areas, are hurt in a somewhat different fashion when price information and effective markets are not available. Their productivity suffers, since they often stand around waiting for work. In rural villages, and in neighboring urban areas with informal sectors that draw workers from villages, most employers' labor needs vary greatly from day to day, often unpredictably. Hence, permanent employment relationships are rare. For example, Breman (1996) studies the informal economy in a region of India. He reports that about half of the workforce is employed under daily contracts, with little vertical mobility into semi-permanent and permanent jobs.

Given this reliance of landless laborers on day-to-day job opportunities, lack of information can severely constrain income opportunities. Often, hours are wasted searching for brief employment opportunities, or worse, workers in one village may stand idle while employers in nearby villages or slightly further removed urban areas can't find enough workers. Better coordination would mean that there would be many fewer idle workers and wasted opportunities.

Middlemen: Too Many, or Too Few?. Middlemen often act as intermediaries between agents, say between farmers and consumers, or even between laborers and employers in a distant locale. Middlemen may travel from cities to villages to purchase crops and sell inputs, or they may just have an outpost in a

town market. Anecdote and speculation around the ways ICT's can help the poor has frequently involved discussions of the role of middlemen. The common perception is that middlemen gouge both buyers and sellers, and that ICT's can therefore help farmers, either by improving their bargaining position or by enabling direct sales, removing the middlemen.[8]

However, the presence of middlemen is not necessarily a symbol of an information-starved market. Even in advanced economies, middlemen, wholesalers and retailers, play a major role. They perform many valuable tasks of what is called intermediation, for example sorting for and attesting to quality, storing goods, transport, organizing sales, assuming or pooling risk, or supplying credit (Stigler 1961; Biglaiser 1993; Li 1998; Van Raalte and Webers 1998). It would be highly inefficient for rural farmers to assume all of these tasks; rather they should focus on what they do best, namely produce agricultural commodities. Theoretical work confirms that under most circumstances, the optimal amount of intermediation is positive (e.g., Biglaiser 1993). For example, in a model with endogenous middlemen (who invest in quality-verifying technology), even though the middlemen are not engaged directly in production, when "people do not execute trades because they cannot recognize the true quality to goods, expert middlemen can improve welfare" (Li 1998).

The big difference between middlemen for an isolated farmer in the developing world and, say, producers in Europe, is that the European middlemen face competition, which assures that they get an appropriate but not excess price for their services. In information-isolated settings, the problem with middlemen is often not that there are too many of them, but too few. Middlemen can only price-gouge if they have few or no competitors. If a farmer has many traders or middlemen available, no one can exploit him by paying inadequate prices for his crops or charging too much for farm inputs or consumption goods. If one middleman refuses to pay a reasonable price, a farmer can follow the strategy of the European producer and refuse to sell to him, instead marketing to another middleman who pays a better price. Similarly, if a middleman demands too much for inputs sold to farmers, another middleman can lure away his customers by offering more favorable prices. Competition among middlemen constrains their ability to exploit information asymmetry to reap excessive profits. Middlemen often have a monopoly because of well-developed relationships or high costs of search and information. If information were available through ICT's, however, even if it were merely the identity of farmers and middlemen, it would be easier for others to enter the market as traders or middlemen and thus increase competition.

[8] Kirkman and Sachs (2001) note how Mongolian goat herders benefit from Internet access to arrange cashmere business transactions, bypassing traditional Chinese middlemen. The extreme vision, recounted in occasional tales of Internet wizardry, are of developing country craftsmen selling their quality wares directly to developed country consumers. Such an approach, even if successful, probably would not account for more than a small share of total of production by the rural poor in developing countries.

Many studies find that competition among middlemen constrains the exploitation of customers. For example, Hayami, Kikuchi and Marciano (1999) report survey information indicating that rice marketing in the Philippines (at least in the area studied) is highly competitive, preventing middlemen from exploiting peasants and consumers through monopoly/monopsony pricing. The authors estimate that 50-70% of the consumer price goes to farmers, with the remaining 30-50% marketing margin split between collectors/middlemen (~5%), rice mills (~15%), and retailers (~10%). In other countries, such as the former Zaire, producers receive only 35 to 41 percent of the wholesale price of several main commodities, although transportation costs account for most of the balance of the price (Minten and Kyle 1999). Middlemen operating in areas of the Brazilian Amazon rainforest receive 40 to 50 percent of the final prices of fruit and vegetables (Roberts 1995). Some socialist countries such as Maoist China illustrate the impact of a monopoly middleman, the government. By imposing a "price scissors" on farmers—paying a lower-than-market price for agricultural output and charging a higher-than-market price for nonagricultural goods—the Chinese government raised implicit tax revenues. Imai (2000) estimates the real income loss for farmers to have been equivalent to a 16.7% labor income tax during the 1964 to 1978 period.[9]

Information and productivity. Making information available, including information other than price, can enhance production in isolated villages in other ways as well. At the most basic level, the ability to monitor weather expectations could enable farmers to plant and harvest at appropriate times. It may also allow important information flow in the opposite direction, as well. For example, a greater flow of information could allow farmers gain trust and build reputations, which could enhance the functioning of credit markets. Information flows and monitoring by creditors could help farmers receive access to loans and other financial resources, which in turn could enable them to implement new production technologies.

Over the long run, one of the significant gains from information may come through the transformation of production processes. New technologies diffuse slowly in developing nations, often passing from producer to producer by word of mouth. Effective markets change this pattern, and create a world where information flows in all directions. For example, sellers of inputs, attentive to the possibility of new sales, learn about farmers' practices. They then purvey products, and sometimes call for new products, that boost agricultural productivity. At the same time, farmers scan the market to learn about potentially more profitable crops or new farming techniques. Thus, better information flows could promote technological adoption and innovation.

[9] Imai (2001) estimates the total resource transfer from urban and rural households to the Chinese government from price and wage controls to have amounted to 10.4% of GDP during the 15-year period before 1979.

Overall, then, it is possible that basic information and communication technologies could provide a higher path of income growth, not just a one-time income gain. This optimistic prediction has empirical support. Research shows that productivity flows from marketplace infrastructure and integration. Studying developing countries, Antle (1983) shows that poor transport and communication infrastructure constrains agricultural productivity. When markets function well, trade is abundant, and farmers reap the rewards of specialization, for instance producing a profitable cash crop rather than growing the main crop and others for their own subsistence. Additional gains from specialization include developing product-particular skills and knowledge, purchasing inputs in bulk, or reaching economies of scale. A whole region or economy benefits when improved information flow leads to more integrated markets that widely disseminate new techniques, fertilizers, and other inputs to agricultural production.

III. EVIDENCE ON THE TRANSFORMATIVE ROLE OF INFORMATION TECHNOLOGY

We have argued that integrated markets can significantly help the rural poor of developing nations, and that ICT's, even basic communications technologies, can play a major role in creating such markets. Moreover, we have posited that ICT's have the potential not just to provide a one-time lift to income in poor regions, but to accelerate the entire growth process by generally making it easier for isolated producers to improve their practices, in effect speeding innovation. What can we learn from the historical record?

Evidence on the impact of ICT's on economic growth mostly comes from study of high-income countries. Early studies, such as Hardy's (1980) examination of the role of the telephone in economic development, although pioneering and suggestive, are nevertheless plagued by problems of reverse causality. In other words, does a positive correlation between improved ICT's and economic growth reveal that (1) ICT's bolster growth, or that (2) growth nourishes improved ICT's, or both? Several researchers have attempted to disentangle these effects (e.g., Norton 1992; Greenstein and Spiller 1996). In a careful recent study, Röller and Waverman (2001) analyze 21 OECD countries over 20 years, finding evidence of a significant positive causal link between telecommunications infrastructure and economic growth.

Evidence on how advances in and the spread of ICT's spurred economic development in 19th century America is perhaps more germane to the world's poor today. Garbade and Silber (1978) find strong statistical support for the hypothesis that two innovations in communications technology—the telegraph (1840s) and the trans-Atlantic cable (1866)—led to significant and rapid narrowing of inter-market price differentials. Du Boff (1980) chronicles the growth of the telegraph in the US from the mid-1840s to 1860. In 1840, 63% of the American labor force worked on farms and only 9 percent in manufacturing, much like many developing countries today. After initial skepticism regarding the new

communications technology, the telegraph industry grew dramatically as the railroads, the press, other businesses and consumers began to capitalize on the advantages of instantaneous communication. Consistent with our argument on the high value on market integration through the flow of price signals, Du Boff reports that among the earliest and highest volume telegraph dispatches were communications of market prices in different areas to press outlets for wider dissemination. For example, a Pittsburgh newspaper in January 1848 announced 'the lightning brought us quite a budget of news last night,' listing the "going prices for cotton, flour, breadstuffs, wheat, rye, pork, southern oats; money market conditions in England; and railroad service connections for freight shipments"; "other newspapers in 'Telegraph Dispatches' showed the same predominance of financial and commercial items" (p.468).[10] Moreover, better communications propelled efficient production and reduced myriad transactions costs:

> The advent of the telegraph and associated growth in networks of exchanges "ensured the price differentials among markets would tend to narrow to the costs of transportation and transactions between places. These differential costs too were slashed through use of the telegraph. After the Civil War, impediments to direct transactions between producers and final consumers were removed as retailers, farmers and manufacturers discovered that they could now bypass the complex of intermediaries and save on commissions paid to wholesalers…. Steadier and more dependable prices and faster communication with suppliers also reduced both 'search' costs and the need to carry heavy inventories with attendant financing costs" (Du Boff 1980: 477).

Thus, ICT's did not merely improve prices for producers, they changed the whole nature of economic transactions. If anything, the potential for developing countries to utilize ICT's today is greater than it was for the United States then, since today's developing nations can draw on the models and technologies of more developed nations, and can sell outputs to those wealthier entities.

Will that potential be realized? Unfortunately, evidence on how ICT's affect development in poor nations is quite limited. Disentangling the impact of ICT's from those of other changes can be difficult, requiring good data (which is scarce) and careful attention to issues such as reverse causality. Torero (2000), concerned with poverty in Peru, finds that "access to a telephone is important in explaining why low income households do not drop into poverty, but it is not significant in explaining the transition between poor and non-poor status." Peruvian households that acquired a phone between 1994 and 1997 also increased their incomes and their access to financial savings and credit, although causality here is not clear.

[10] Statistics from a telegraph company for one month in 1856 confirm the salience of market information signals via the new communications technology: "Of the 20,400 messages transmitted, at least 57 per cent were unmistakably commercial in nature ('messages to buy and sell goods,' 'instructions to pay money and notes,' 'reports of markets,' 'messages respecting freight and shipping,' and 'general mercantile matters')" (Du Boff 1980: 470).

The Grameen Phone Village Pay Phone project in Bangladesh provides intriguing evidence on how ICT's provide benefits. This project leases cellular mobile phones to low-income women, who essentially provide a village pay phone. According to one study (Bayes, von Braun and Akhter 1999) close to half of all phone calls involved economic purposes such as discussing market prices of commodities, employment opportunities, land transactions, remittances, and other business items. Moreover, "the average prices of agricultural commodities (especially [rice] paddy and eggs) were higher in target villages (with phones) than in control villages (without phones)." Vegetable growers said that access to phones helped them to make more appropriate production decisions, and users of agricultural inputs benefited from a smoother and more reliable supply. Better information also improved the perception of some sellers' of their bargaining position vis-à-vis middlemen. Finally, village phones facilitated easier job searches, better access to emergency medical care and dealing with natural disasters, lower mortality rates for livestock thanks to more timely advice from extension workers, and better rates in foreign-exchange transactions.

Additional evidence on the effects of basic communications technologies can be obtained from analysis of the aforementioned CHNS data for China. During the period of market-oriented economic reforms covered by the survey, telephones service was expanded throughout rural areas. In 1991, approximately 40 percent of rural villages in the survey had phones. By 1993, however, that fraction had increased to over 60 percent. The household survey gathered information on a variety of economic activities, including agriculture (output and sales prices), wage labor (time worked—hours per day, days per month, months per year—and wage or salary received), and household businesses/enterprises. The hypotheses developed above predict that as information flows better and markets become more integrated, farmers or enterprise owners might, for example, receive more for their output or sell more output, and hours worked may increase due to better coordination of labor. We follow households over time to see what happens to incomes when villages add phones. Villages that did not get phones are the comparison group. Table 4 provides data on income for households from various sources.

Table 4. Sources of Income

	No Phone 1991 No Phone 1993			**No Phone 1991 Phone 1993**		
	1991	**1993**	**%Change**	**1991**	**1993**	**%Change**
Income from wages	326	342	.05	366	394	.08
Income from agriculture	1035	990	-.04	929	1091	.17
Income from business	332	351	.05	355	412	.16
TOTAL	1693	1683	-.01	1650	1897	.15

Note: All values deflated to 1991Rmb.

In the initial period, households in the villages that received phones between 1991 and 1993 had slightly higher incomes from wages and businesses and less from agriculture than villages that were still without in 1993. Overall, however, households living in villages that received phones in 1993 had incomes that were slightly lower in 1991 (about 2 percent). But between 1991 and 1993, there were dramatic changes in income for households in villages where phones were added. In particular, overall average household income grew 15 percent, with the largest increases in agricultural and business income. By contrast, households living in villages that did not add phones experienced slightly lower incomes in 1993 compared to 1991. This pattern is consistent with the predictions regarding information and markets discussed above. As with the analysis of prices above, there is concern that villages that received phones may be different in other ways that affect household income. However, statistical analysis that controls for differences (or changes) in numerous other factors, such as access to roads and transportation services, distance to nearest city and a variety of other factors, yields similar conclusions (results available from the authors). We also make use of the longer series of data, and find that there was no differential trend in income between 1989 and 1991 for villages that would receive phones in 1993, compared to those that wouldn't. Finally, we make use of a statistical technique that exploits the fact that phones were in part 'pseudo-randomly' assigned across villages in these years, so we can eliminate concerns about reverse causality or differences between villages that received phones and those that did not.[11]

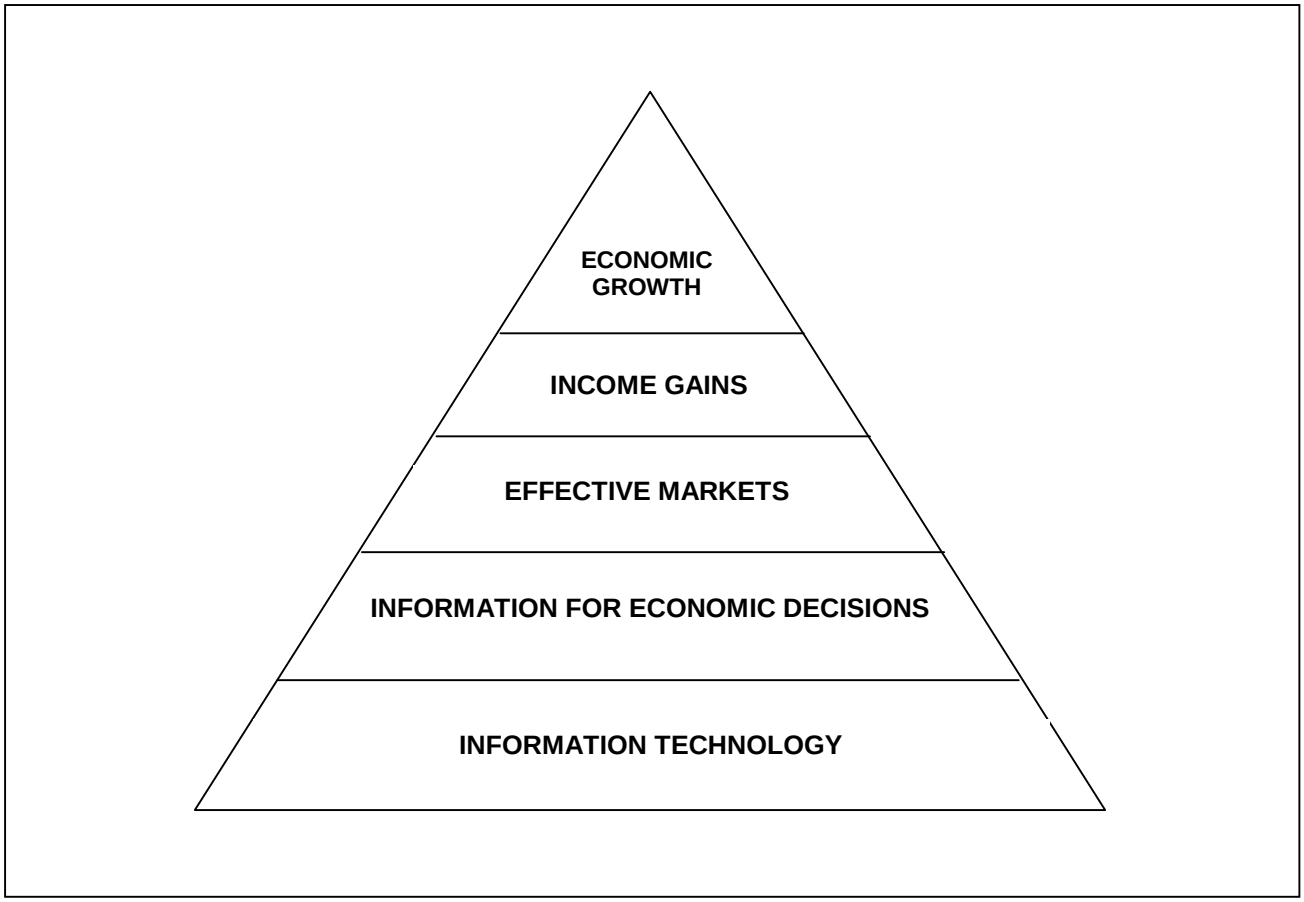
IV. CONCLUSION

The theory of information and market signals, and the available evidence on the relationship between market integration and economic development, suggest that greater access to ICT's, starting with basic communications infrastructure, could significantly improve the living standards of the world's rural poor through enhancing the functioning of relevant markets. The only sustainable way to end deprivation is to enhance earnings possibilities. Appropriately designed ICT interventions can help do exactly this, using the invisible hand of the market as a helping hand to the world's poor. But it is important to emphasize that the greatest value of ICT's derives from the 'I' and the 'C': Information and

[11] In particular, we undertake a limited instrumental variables strategy; under such a strategy, if we can find a factor that predicts whether a village receives a phone, but is uncorrelated with *changes* in income, or other factors that affect income, then this factor can be thought of in some way as pseudo-randomly allocating phones across villages (as far as income is concerned). If we can statistically exploit this pseudo-randomization in phone allocation, we can in effect purge the results of unobservable factors, and overcome the problem of reverse causality, because we are only looking at differences in receipt of phones that is uncorrelated with income changes. Since much of the spread of the telephone in China during this time was based on fixed-line technology, the spread was generally radiating out from major cities; thus, the distance to the nearest city, for which we have data in the CHNS, is a good predictor of whether the village received a phone during the survey, but in general should be uncorrelated with *changes* in

Communication. The kernel of our argument is presented in Figure 4, which shows how ICT's can create a "Digital Provide" that boosts incomes and ultimately leads to economic growth. ICT's have the ability to disseminate information to isolated, information-deprived locales. Those receiving this information, predominantly farmers and laborers, as both producers and consumers, will for the first time be able to participate in effective markets. The immediate consequence should be income gains for participants, and the ability to better spend their incomes. Over the long term, enhanced access to information should enable producers to significantly improve their practices. Such improvement lays the path to economic growth.

Figure 4. The Digital Provide



Of course, there are other barriers to market functioning, such as transportation infrastructure, and at times counterproductive government interventions, e.g., price controls, and granting of monopolies. But

income over this time. Results from this limited strategy yield similar results to those shown in the main text; again, this allays concerns about reverse causality or differences between villages that receive phones and those that do not.

by emphasizing the importance of markets for helping the poor, market-oriented ICT interventions and applications help identify the costs of these barriers.

Our analysis has largely made use of reference and examples using the telephone. More advanced technologies such as internet-enabled kiosks, could provide even greater benefits. For markets, a single mouse click could instantaneously and simultaneously reveal market prices in numerous locations, rather than contacting each directly, as with a phone. Further, technologies such as kiosks could provide numerous additional benefits. While our argument has been to show the role of markets for improving living standards, the poor need more than just markets. Health and education, for example, are important priorities. But it need not be not an 'either-or' proposition, because ICT's can provide in these areas as well. For instance, many public health problems can be prevented or treated through information dissemination, e.g., through remote diagnostics, often at lower cost than treating the problem afterwards. There are equally valuable potential applications for education, including distance access to libraries, textbooks and instruction. ICT's are the gift that keep on giving; once in place, they can be used to transmit information for a variety of uses, at little additional cost.

Recent advances have dramatically lowered the costs of providing access to a range of information technologies. These advances, plus the perceived benefits they have brought to the developed world (though still difficult to quantify, and subject to debate), have fueled optimism for the potential to help the world's poorest. The goal of this paper was to provide a theoretical argument for such optimism, as well as provide what empirical evidence can be mustered. Policymakers in developing countries face the daunting challenge of deciding how to allocate often extremely limited resources among many important alternative priorities. When selecting which set of projects will yield the largest benefit for citizens, decision-makers need information about the relative cost-effectiveness of various proposed projects. Will better transportation infrastructure yield greater development outcomes than better access to telecommunications, or is a basic level of both necessary for significant progress? Unfortunately not enough careful analysis of ICT's in developing countries has yet been done to answer these pressing policy questions. While there have been numerous studies of the benefits and cost-effectiveness of other infrastructure investment projects, such as road building or dam construction, similar efforts for ICT's are only now just beginning.[12] What is clear, however, is that the potential for ICT's to alleviate poverty and promote economic growth in developing countries justifies greater attention and systematic analysis.

[12] For one example, see the Sustainable Access in Rural India (SARI) project, which the authors are involved with, http://edevelopment.media.mit.edu/SARI/mainsari.html.

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