INFORMATION, EFFICIENCY AND WELFARE IN AGRICULTURAL MARKETS

By

Robert Jensen

Presented at the 27th International Association of Agricultural Economists Conference
Beijing, China

August 16-22, 2009

INFORMATION, EFFICIENCY AND WELFARE
IN AGRICULTURAL MARKETS*

Robert Jensen

School of Public Affairs
UCLA

Watson Institute for International Studies
Brown University

and

NBER

Abstract: Information and communications technologies (ICTs) have spread rapidly in the developing world. There has been considerable interest in the potential role ICTs, particularly mobile phones, have begun to play in the marketing of agricultural outputs in these countries. In this paper, we discuss the potential impacts ICTs may have on welfare, both in terms of potential efficiency gains (via improved arbitrage), and welfare transfers among agents in the supply chain (via reduced informational asymmetries and market power). We also review the recent empirical evidence for such effects.

* I would like to thank Reuben Abraham, Christopher Avery, Nolan Miller, Mai Nguyen, and Richard Zeckhauser for valuable comments.

I. INTRODUCTION

The spread of information and communications technologies (ICTs), especially mobile phones, in developing countries has been both extensive and rapid. As of 2008, there were 364 million mobile phone subscriptions in Africa, 460 million in Latin America, and 1.8 billion in Asia (ITU 2008). These figures are all the more impressive in light of the fact that for quite a few developing countries, mobile phone service was not even available as recently as 10 years ago (see Figure I). The adoption of these technologies has not been limited to wealthy,[1] urban households. For example, mobile phone ownership among rural, farming households ranges to as high as 50-60 percent in countries such as the Dominican Republic, Guyana and Swaziland.[2]

As in wealthier nations, mobile phones and other ICTs are used for a number of purposes in the developing world, from personal to commercial. Recently, considerable attention has focused on the use of ICTs by farmers, fishermen and other agents in the agricultural supply chain, particularly in the marketing of output, such as obtaining price information or arranging sales. While much of the early evidence was largely anecdotal,[3] more quantitative studies have arisen as well (Abraham 2007; Jensen 2007; Aker 2009; Futch and McIntosh 2009; Goyal 2009; Muto and Yamano 2009; Svensson and Yanagizawa 2009). Most of these studies have built on the long-recognized role that information plays in the functioning of market economies (Hayek 1937, 1945; Stigler 1961; Geertz 1978), and the role that ICTs play in providing that information. However, there are many different ways in which information may be important, and different papers have focused on different aspects of the issue.

In this paper, we lay out a general framework for understanding the impacts ICTs may have on the functioning of agricultural markets.[4] We focus on two distinct channels: the role of information in enhancing arbitrage (and the resulting potential efficiency gains), and the role of information in market power (and the resulting potential transfers among agents in the agricultural supply chain). We also discuss the distribution of gains from information, and potential intervening factors such as barriers to trade, interlinked transactions and storage.

[1] The results of Jensen and Miller (2009) are particularly revealing in this regard: households in Hunan, China living below the urban poverty line and consuming far below the recommended caloric intake thresholds, respond to large rice subsidies not with additional food purchases, but with increased spending on communications.
[2] Author's calculations from various Demographic and Health Surveys (DHS), discussed in Section II.
[3] For example, see Arnold (2001), England (2004), LaFraniere (2005), Alam (2005) and Rai (2001).
[4] Many studies have focused on the economic impacts of mobile phones in developing countries in non-agricultural sectors, as well as a range of non-economic impacts. We do not discuss these impacts here; a discussion of the broader literature can be found in Donner (2008).

The remainder of this paper proceeds as follows. In Section II, we provide additional background data on access to mobile phones in the developing world. In section III, we outline the conceptual foundations for the welfare effects of information. Section III reviews the empirical evidence and section V concludes.

II. MOBILE PHONE PENETRATION IN THE DEVELOPING WORLD

We begin by documenting mobile phone penetration in low-income countries. Though below we will discuss a few studies using other ICTs, like radio and internet kiosks, most attention has focused on mobile phones, so it is worth exploring how widespread they are. The most comprehensive mobile phone database is the International Telecommunications Union's World Telecommunications/ICT Indicators Database. Table I and Figure I show data on mobile phone subscriptions across regions of the developing world (ITU 2008). As noted in the introduction, the growth of mobile phone subscriptions has been staggering. For Africa, the number of subscriptions increased by 7 times between 2003 and 2008, going from 53 to 364 million. In Latin America, subscriptions increased by a factor of 3.6, from 127 to 460 million, and in Asia (excluding Japan) they increased by a factor of 3.7, from 482 million to 1.8 billion. Subscriptions per 100 persons now stand at 39 in Africa, 78 in Latin America and 46 in Asia. The change is all the more impressive when viewed over the past decade, when subscriptions per 100 people was .5 in Africa, 3 in Asia and 24 in Latin America.

Our interest in mobile phones is due to the role they play in providing market information. In this regard, they are no different than landline phone connections (though in some cases the portability may matter, such as when critical marketing decisions are made while fishermen are still at sea, as in Abraham 2007 and Jensen 2007). However, due to the low cost of installing mobile phone towers relative to a network of telephone lines, mobile phones are the most relevant technology for almost all developing countries (particularly in rural areas). In 2008, there were only 32 million landlines in Africa (3 per 100 persons), 580 million in Asia (15 per 100) and 105 million in Latin America (18 per 100). Thus, the number of landlines is less than one-tenth the number of mobile subscriptions in Africa, less than one-third in Asia and less than a quarter in Latin America.

Of course, these regional figures mask substantial heterogeneity at the country level, as shown in Figure II. For example, while the lowest rate of subscriptions per 100 persons are found in Africa, countries such as Algeria, Gabon, Mauritius, Seychelles, South Africa and Tunisia have rates of 80 or more. Similarly, while the number of mobile subscriptions per 100 persons averages almost 50 in Asia, countries such as East Timor, Myanmar and Turkmenistan all have rates lower than 10 (although perhaps for different reasons).

Though informative, data on subscriptions per 100 persons are not ideal for measuring access, since for example some people may have more than one subscription, and since a single subscription in a household may effectively provide access to several people (plus, subscriptions per 100 people includes young children, who would not be expected to own phones themselves). Further, these aggregated data don't provide information on how access is distributed, such as among farmers. While there is no comprehensive database with such data available, some information is available from the Demographic and Health Surveys (DHS). Although focused primarily on population and health issues, recent versions of the survey ask whether the household owns a mobile phone. The advantage of these data is that they are carried out in a large number of developing countries (over 250 surveys in 75 countries since 1985); gather moderate to large samples (typically, 5,000-30,000); are nationally representative; and use a more-or-less standardized methodology and survey instrument, so the data are comparable across countries and over time. However, the collection of countries available is not a complete or representative sample of developing countries. Further, there is just one simple, yes or no question for both mobile phone ownership, and on agriculture (whether the household owns any agricultural land. We note that this will exclude farming households that rent land; these households are likely to be poorer, and to own less land and thus have less output that they may wish to market, which suggest lower mobile ownership rates. Further, some households owning land may not be farmers themselves and may simply rent out the land).

The data are summarized in Table II. We have included in this table only surveys that both asked questions about ownership of mobile phones (which generally excludes surveys more than 5 years old) and ownership of land for agriculture.[5] The ownership rates vary considerably

[5] In all, these two criteria eliminated 20 of 38 surveys in the regions of interest conducted since 2004 (and for which data are currently available). However, most of the exclusions were due to not having data on land ownership, not mobile phones. Thus, there is no reason to believe the surveys chosen disproportionately represent countries with higher mobile phone ownership, as might be the case if the question were only asked where ownership is high. In

across countries. Ownership rates are extremely low, less than 10 percent, in 5 of the 18 cases (Ethiopia, Zimbabwe, Nepal, Haiti and Peru). In other cases, they are moderate to high, exceeding one-in-five for 8 of the 18 countries, with rates as high as 47 percent in Guyana, 54 percent in Swaziland and 64 percent in the Dominican Republic.

For comparison, column (2) shows the ownership rate for the total population.[6] Overall, in large part, ownership rates among farmers are low where ownership rates overall are low. In many cases, the ownership rates are not much lower for farming households than other households. Column (3) shows the ratio of farm household ownership to total ownership is high on average. In 12 of the 18 countries, the ratio is over two-thirds, which is all the more striking given that service is often not available in rural areas. Noticeably, in 6 of the countries (Bangladesh, Benin, the Dominican Republic, Guyana, Swaziland and Uganda) the rates are 80 percent or more of the non-rural rate. Bangladesh is in this regard an exceptional case where farmer ownership is greater than ownership among others, presumably due to at least in part to the Grameen Village Phone program, which makes service available in rural areas.

Of course, this does not mean that all farmer households use their mobiles for marketing purposes. And on the other hand, there may be many farmers who do not own a phone, yet at the appropriate time during harvesting and marketing may be able to borrow one from someone else. So, these data do not provide a precise accounting of the use of mobiles in agriculture. However, they do indicate that a significant fraction of farming households have access to mobile phones, which may be used in marketing.

Finally, a few micro-studies of specific markets do provide direct information on mobile phone penetration and use among agents in agricultural markets. Jensen (2007) finds that over 60 percent of fishermen in Kerala owned mobile phones by 2001 and used them for marketing. Aker (2009) notes that 29 percent of grain traders in Niger in 2006 own mobile phones for their business, compared to an average ownership rate in the country of only 4 percent. However, it should be kept in mind that the samples used in these studies focused on locations and economic sectors where mobile phones were available and in use, which may not be representative of the broader population of individuals involved in agriculture.

---

fact, the set of countries represented in Table II have lower average subscription rates per 100 inhabitants in 2008 according the ITU data than their corresponding regional averages in Table I.

[6] note, these data are not directly comparable to those in Table I, both because the ITU data represent subscriptions per hundred persons, whereas we are measuring the fraction of households that own a phone and because the DHS surveys are a few years older than the ITU data (and mobile growth has been extremely rapid over this period).

II. WHAT ARE THE GAINS TO INFORMATION IN AGRICULTURAL MARKETS?

There are a variety of channels through which information might influence consumer or producer welfare in the agricultural sector. We discuss two direct channels, arbitrage and market power, and three indirect channels that may follow from the first two (supply responses, reduced transportation, and reduced price variability).

II. A. Information, Arbitrage and Efficiency

Economists have long recognized the important role that information, specifically price, plays in the efficient functioning of markets. Hayek [1937, 1945] emphasized that in a market economy, price enables the efficient coordination of large numbers of consumers and producers, each acting only in self-interest and only with information about their own preferences, technology and constraints. Price differentials across markets in excess of transportation costs for example serve as signals to profit seeking agents to re-allocate goods towards the higher priced market.[7] In doing so, they also increase aggregate welfare. However, optimal arbitrage requires agents have full information on prices. Stigler (1961) suggested that such information is rarely perfect, noting that, "Price dispersion is a manifestation - and, indeed, it is the measure - of ignorance in the market." The possibility of welfare-enhancing arbitrage has been the emphasis in much of the literature on ICTs and market performance. This follows primarily from the large empirical literature documenting a lack of spatial integration among agricultural product markets in many developing countries (Delgado 1986; Heytens 1986; Ravallion 1986; Fafchamps and Gavian 1997; Palaskas, Hariss-White and Crowe 1997; Zhou, Wan and Chen 2000).

We focus this discussion by sketching out the welfare implications of limited information or costly search. We consider a simple model of arbitrage under exogenous supply, related to Jensen (2007). We first focus on the case of fixed supply; our main concern is how goods are allocated once they have been produced. When the average price change due to arbitrage is small because quantity variations across markets are small relative to the average quantity or because the demand curve is close to linear, this approximation will be fair for the short to medium term since supply will not be expected to change dramatically. We discuss supply responses below.

[7] Though price dispersion in excess of transportation costs and efficiency do not map perfectly to each other. For example, prices could be equalized across markets because of monoposny or collusion, rather than arbitrage.

Suppose there are two villages where a particular crop is produced. Yield for farmers in each village is random variable with an identical distribution across individuals and across villages, but there is some positive correlation in output within a village due to some common, exogenous shock. Specifically, assume that a farmer's yield depends on the rainfall, r, during the relevant phases of the cropping cycle (here, we think of r as the absolute deviation from the crop-specific optimum, since both too much and too little rainfall is bad for yields), as well as an idiosyncratic shock z. The output for farmer i in village v thus follows the distribution $f(x_i|r_v, z_i)$. We assume that $f(x_i|r_v, z_i)$ satisfies the Monotone Likelihood Ratio Property, so that the likelihood ratio $\frac{f(x_i|r_{v=1}, z_i)}{f(x_i|r_{v=2}, z_i)}$ is increasing in x if $r_{v=1} > r_{v=2}$.

Assume for simplicity that both villages surround an associated city or town with consumers. Each town has its own competitive market for the output, with many buyers and many sellers. The aggregate demand curve $P(Q)$ for the crop is known and identical for the two towns, where Q is defined as the per-capita supply per local farmer, with $P'(Q) < 0$.

Due to the supply shocks (though similar analysis would hold under demand shocks as well), prices will differ between the two markets when there is no trade between them. These price differences should induce arbitrage. However, farmers don't know the prices in either market. Each farmer's personal yield does contain information about aggregate local output due to the fact that $f(x_i|r_v, z_i)$ satisfies the Monotone Likelihood Ratio Property (alternatively, they may directly observe some common, yield-relevant shocks). For example, a farmer with a high yield can infer it is more likely that other farmers in his village also had a high yield, which might make it profitable to try to sell in the non-local market. However, the idiosyncratic supply shock makes it more difficult to identify the common shock. Further, they may know even less about output in the other village. These two effects create greater uncertainty about the potential value of selling in the non-local market and may limit arbitrage. Assume there is a transportation cost of τ per unit of output and a cost of searching for the price in the other market, Ψ. A farmer (or trader) will search for the price in the non-local market when the expected price difference net of transportation costs is greater than the cost of search, Ψ, i.e., $E[P(Q_v) - P(Q_{-v}) - \tau] > \Psi$. If search costs are sufficiently high, there will be no search and no arbitrage. This might be the case for example when there is no form of telecommunications available and markets are widely dispersed. Thus, one potentially significant contribution of mobile phones is to reduce the cost of search, which should lead to more arbitrage and lower price dispersion across markets.

We now consider the welfare consequences of greater arbitrage. Let $\bar{x}(\Psi)$ be the amount of arbitrage that takes place when search costs are Ψ, and let Village 2 be the village with greater total output, and thus lower pre-arbitrage price. With arbitrage, consumers in Town 1 will gain,

$$(1) \qquad Q_1\big(P(Q_1) - P(Q_1 + \bar{x}(\Psi))\big) + \int_{Q_1}^{Q_1+\bar{x}(\Psi)} P(Q)\, dQ \; - \bar{x}(\Psi)P(Q_1 + \bar{x}(\Psi))$$

where the first term reflects the gain from the lower price paid for the Q_1 units of the good that would have been consumed in the absence of arbitrage, and the final two terms reflect the additional surplus from the consumption of $\bar{x}(\Psi)$ units of the good that is brought into the town that would otherwise have been consumed in Town 2. Consumers in Town 2 will correspondingly lose,

$$(2) \qquad (Q_2 - \bar{x}(\Psi))\big(P(Q_2 - \bar{x}(\Psi)) - P(Q_2)\big) + \int_{Q_2-\bar{x}(\Psi)}^{Q_2} P(Q)dQ \; - \bar{x}(\Psi)Q_2$$

where the first term reflects the loss due to a higher price paid for the $Q_2 - \bar{x}(\Psi)$ units consumed in the town, and the second term reflects the loss of surplus due to the reduced consumption of $\bar{x}(\Psi)$ in the town.

On the producer side, farmers in the low production Village 1 will lose,

$$(3) \qquad Q_1\big(P(Q_1) - P(Q_1 + \bar{x}(\Psi))\big)$$

due to the lower price they will receive for their output when more of the output is brought to the town via arbitrage. By contrast, producers in the high production Village 2 will gain,

$$(4) \qquad (Q_2 - \bar{x}(\Psi))\big(P(Q_2 - \bar{x}(\Psi)) - P(Q_2)\big) + \bar{x}(\Psi)\big(P(Q_1 + \bar{x}(\Psi)) - P(Q_2)\big)$$

with the first term representing the gain from higher prices for output sold locally and the second term reflecting the higher price for the $\bar{x}(\Psi)$ units of output sold in the higher price Town 1.

The combined change in consumer and producer surplus given by the sum of the four equations above reduces to,

(5) $$\int_{Q_1}^{Q_1+\tilde{x}(\Psi)} P(Q)\,dQ - \int_{Q_2-\tilde{x}(\Psi)}^{Q_2} P(Q)\,dQ$$

This expression is always positive provided only that the demand curve is downward sloping everywhere between Q_1 and Q_2. So with a reduction in search costs, the net welfare gain to society is always positive.[8] In effect, the gain arises from moving the good from where it is less highly valued on the margin, the market with high supply relative to demand and thus a low price (the second term in equation (5)) to where it is more highly valued on the margin, the market with low supply relative to demand and thus high price (the first term in equation (5)). The gain will exceed total search and transportation costs (since search and arbitrage would not be undertaken unless it were profitable).

These welfare gains can be significant, particularly when initial search costs are high and production shocks are both large and not highly correlated across villages. Further, any gains realized will be persistent, not one-time, since they reflect a permanent improvement in the functioning of markets. However, when $|P(Q_2) - P(Q_1)| < \tau$, there will be no arbitrage even with costless search, and thus no welfare gains to adding mobile phones.

Beyond at least weakly increasing welfare, the greater arbitrage induced by mobile phones also results in a set of transfers from consumers to producers or vice-versa. These transfer results from the fact that for the non-arbitraged crops, the price has changed. Thus, the $Q_2 - \tilde{x}(\Psi)$ units of the good consumed in the high output town would have been purchased by consumers at a price of $P(Q_2)$ if there were no arbitrage, but are now purchased at the higher price of $P(Q_2 - \tilde{x}(\Psi))$, a transfer from consumers to producers in that town. Similarly, the Q_1 units of output previously consumed in the low production town are now purchased at a lower price, transferring surplus from producers to consumers. In general, whether consumers or producers on net gain or lose is ambiguous. The direction of the transfer is given by,

(6) $$\left(P(Q_2 - \tilde{x}(\Psi)) - P(Q_2)P(Q_2 - \tilde{x}(\Psi))\right) - \left(P(Q_1 + \tilde{x}(\Psi)) - P(Q_1)\right)Q_1$$

[8] Note that since all that is required for equation (5) to be positive is that the demand curve be downward sloping, using Hicksian compensated demand curves (which are always downward sloping) will yield a similar conclusion, and thus the result will be robust to alternative measures of welfare such as equivalent or compensating variation.

and thus depends on the shape of the demand curves (in general, the greater the elasticity of demand, the smaller the gain (or greater the loss) for consumers and vice-versa for producers), the levels of output in the two villages and the amount of arbitrage.[9] Even the change in the average price at which the crop is bought/sold is also ambiguous.[10] Overall, it is important to note that we cannot examine welfare by focusing just on producers or just on consumers. It is quite possible for example that farmers' profits decline, while aggregate welfare increases. However, it is also possible for both groups to gain, especially (though not exclusively) when there is also a reduction in spoilage or waste due to more efficient arbitrage.

Finally, even when consumers or producers gain on average, there may still be winners and losers within these groups. As noted above, consumers in the town that had high production will lose (both in the form of higher prices and reduced consumption of the good), while those in the town with low production will gain. And producers in the low production village will lose (in the form of lower prices for their output) while producers in the high production village will gain. This suggests that the welfare changes of mobile phones can't be examined only by looking at the markets where mobile phones are newly introduced, since they may lead to welfare changes (possibly in the opposite direction) in other markets as well.

II.B Information, Market Power and Welfare Transfers

Producers rarely sell directly to consumers. There is often a long chain of intermediaries between the farm gate and the consumer, including traders, wholesalers, retailers and possibly other intermediaries. In understanding the potential effects of mobile phones, it is useful to consider the supply chain in more detail. The welfare gains documented above result from arbitrage across the two towns. What matters most is not which set of agents has information on prices in both towns, only that some agents do. Thus, even if farmers have no access to price information, the allocation of goods across the two markets may still be efficient if traders have the information and can engage in arbitrage; similarly, if wholesalers are able to engage in

[9] With a linear inverse demand curve and costless arbitrage, (6) reduces to $(Q_2 - Q_1) - \bar{x}(\Psi)$, which is always positive since the amount of arbitrage is always less than the initial difference in quantity between the two towns. For constant elasticity demand, (6) simplifies to $P(Q_2) - P(Q_1) - P(Q_2 - \bar{x}(\Psi)) + P(Q_2)$ which is always positive if there is any arbitrage since the price change in the high output town can't exceed the initial price difference between the two towns. However, we again note in general that the direction of the transfer cannot be signed (this is even more the case if we allow for demand shocks).

[10] In the linear demand case, the average price increases, even though the market-clearing price in the low output town decreases by the same amount as the price increases in the high output town, since the price increase applies to more of the output than the price decrease.

arbitrage, the efficient allocation may arise even if both farmers and traders have no information. Such cases may be common even without mobile phones, since many traders and wholesalers are located in larger towns or cities where landlines have long been available. Thus, there need not be widespread penetration of landlines on a national scale, as in Table I, since those who stand to gain the most from them may be among the few that have them (and even when they do not have a personal dedicated landline, phone service may still be available for purchase at booths, kiosks or shops). Where price information is available through other channels, we would not expect the introduction of mobile phones in rural areas, making service available to traders or farmers, to have an impact on aggregate welfare generated in agricultural markets.

However, mobile phones may still result in transfers of welfare among agents, even when there is no net welfare change (though as discussed below, these transfers could in turn lead to other behavioral changes that do impact total welfare). In particular, if there are significant barriers to entry in becoming a trader or a wholesaler (such as high fixed costs, including a vehicle for transportation, storage facilities or access to credit for making large purchases in advance of sales), localized monopsonies may arise for traders or wholesalers. They may even represent cases of natural monopsonies, if the costs of entry and market participation are sufficiently great. In these cases, the farmer may receive a lower price for their output.

There are a few reasons why information could lead to farmers receiving a higher price for their output. First, by lowering search costs, phones may reduce the market power of traders. Consider a simple, Hotelling-like set-up, where a set of farmers is located along a unit interval [0,1] representing physical distance, with one town located at either end (for example, see Goyal 2009). As above, a given farmer's output is a random variable. Within each town is a single, profit maximizing trader (traders visit farmers for purchases rather than vice-versa, perhaps because transportation costs are non-linear in quantity). Traders face both search and transportation costs, each increasing in distance. Both traders choose which farmers to visit along the interval to learn their output and what price to offer (assume the marginal cost of additional search is increasing in distance, for example where the trader has to return to the town after each farm they visit, perhaps due to limits on the quantity of the good they can transport at one time).

In equilibrium, each trader will only visit farmers out to a certain distance from the town, both because marginal search and transportation costs increase in distance and because the further away they go the more likely it is the other trader will also visit the farmer, which requires them to offer a higher price due to increased competition. By lowering marginal search costs, mobile phones increase the range of farmers over which the two traders potentially compete. More generally, reducing search costs should at least weakly increase the amount of competition among traders, which leads to higher prices offered to farmers.

A second reason why farmers may gain with mobile phones comes from providing them direct information on prices. In many cases, while each farmer may face a locally monopsonistic trader, most goods are sold to wholesalers in competitive, open outcry auctions in large towns. In this setting, the trader must offer a price that makes the farmer indifferent between selling to the trader and bringing their goods to a market for sale themselves. Thus, the price offered to the farmer must be such that total revenue for the farmer exceeds the farmers' expected price in the market times quantity, minus search and transportation costs. Greater uncertainty on the market price, greater search costs (for example, the farmer may need to actually transport their grains to the market before learning the price) and greater risk aversion among farmers allows traders to offer a lower price. Reductions in search costs that can reveal the market price with certainty increase the price the trader must offer to keep the farmer from selling the good in the market themselves; in effect, this is also a form of reduced market power, as at some sufficiently low price the farmers would find it profitable in expectation to serve as their own intermediary.

There are a few additional points worth making. First, we note again that if the market for traders is competitive, farmers should achieve the full, optimal-arbitrage price for their output. Even if the farmer had no information on the wholesale market price, if any trader offered a lower price to the farmer than the full-arbitrage equilibrium price, another trader could offer a slightly higher price and capture the entire market. The only equilibrium price offer for traders should be the competitive, optimal-arbitrage price. We note also that mobile phones may in fact affect the competitiveness of the market for intermediaries, either by increasing the area over which existing traders compete as noted above or by lowering the costs of entry (though it should also be noted that mobile phones could also make it easier for traders to collude, by making it both easier to coordinate and set prices, and to monitor compliance).

Second, we also note that providing farmers with price information should cause traders to raise their offer price, rather than farmers transporting and selling the good themselves without the trader. The possibility of eliminating intermediaries in the supply chain or "cutting out the middleman" is among the most often cited anecdotal examples of the potential gains to mobile phones for farmers. However, middlemen perform importation intermediation tasks, such as sorting and verifying quality, transportation, storage, assuming and/or pooling risk, or supplying credit (see for example Biglaiser 1993; Li 1998; Van Raalte and Webers 1998). As discussed by Eggleston, Jensen and Zeckhauser (2001), there are likely to be gains to having these tasks performed by traders rather than farmers themselves, since they are likely to be more efficient, so the equilibrium will not involve removing intermediaries, only increases in offer prices.

Third, and perhaps most importantly, the change in offer prices and the gains to farmers represent pure transfers from traders to farmers, not a net gain in welfare. Traders extract excess profits due to market power and informational asymmetries, and mobile phones will simply transfer some of those profits back to farmers. However, arbitrage may have been socially efficient once the goods left the farmers' hands. Thus, while there may be reasons to believe the transfers are still desirable, especially on distributional grounds, they are not a direct, social efficiency gain (though below we discuss potential follow-on gains).

II.C. Other Efficiency Gains

Both the cases of enhanced arbitrage and reduced market power by traders could result in net efficiency gains through three additional channels. First, to the extent that either leads to an increase in prices for outputs, the increased profitability for farmers may lead to supply changes as well (though these are likely to take a longer time). This can work in two ways. First, an increase in output prices may lead to farming existing land more intensively or moving more marginal land out of other non-agricultural uses (or from not being used at all) and into production. Note, this may drive down the gains to arbitrage among existing producers, and potentially result in a net transfer to consumers. In addition, increased arbitrage may change the composition of crops grown. While mobile phones can used by farmers and traders equally for all goods, it may be for example that the prices of different crops respond differently to mobile phones, either because of differences in the demand curves for these goods or because of initial differences in the amount of arbitrage that takes place (for example, there may have initially been more efficient arbitrage of storable goods such as grains, but little trade in highly perishable foods). To the extent that mobile phones facilitates trade in some of these goods more than others and increases their price, producers may switch across crops. There will be a net gain to society from producing more goods that on the margin are more highly valued than goods that are less highly valued on the margin. However, as above, how the gains are distributed between consumers and producers is ambiguous, and subsets of consumers or producers may gain at the expense of others (for example, those producing the good that was previously more highly valued on the margin will lose from the increased supply, while those who continue to produce the less highly valued good will gain from reduced supply due to switching).

Second, even conditional on supply, there may be gains via reduced transport. Figure III provides a simple depiction of the agricultural supply chain. Before mobile phones, arbitrage between Towns 1 and 2 might have had a particular set of output travelling from a farmer in Town 1 to a Trader in town 1 and then on to a trader in Town 2, following the paths A and B. However, if the farmer in Town 1 can now directly communicate with the trader in Town 2, they might be able to market the product directly to Town 2 when that price is higher. As a result, their output will travel a much shorter distance, along path C. There will be net gains to society via reduced transport, potentially lowering price for consumers or increasing profits for farmers or traders, and freeing up additional resources, previously used for transporting goods the additional distance, that can be used elsewhere in the economy. The potential for marketing directly to the other town may also result in more arbitrage, leading to efficiency gains. In the case without mobile phones, arbitrage will continue until the price difference between the two markets is the cost of transportation along segments A and B, whereas with mobile phones arbitrage will continue further, until the price difference is only the cost of transportation along segment C. Thus, there will be an additional net welfare gain from greater arbitrage.

The third additional net gain to highlight is reduced price variability. For products such as dairy, fruits and vegetables, fish and others for which there are frequent markets, when arbitrage is limited, the local price will vary with local supply, whereas under perfect arbitrage, the primary source of price fluctuations will be changes in aggregate supply. Thus, local supply shocks will be largely arbitraged away, leaving more stable prices. Newbery and Stiglitz (1981) and Wright and Williams (1988) review a related theoretical and empirical literature on the producer and consumer gains to commodity price stabilization.

Of course, it is also possible that mobile phones will lead to some adverse outcomes that may counteract some of the potential gains. First, the breakdown of long term relationships between specific farmers and traders as farmers begin to sell to whoever offers the greatest price may lead to a reduced willingness of traders to provide important services such as credit. The lack of repeated interactions may also lead to greater default or fraud, and the associated loss of trust may even lead agents to forgo potentially profitable transactions. Finally, if phones only provide prices but do not "lock in" transactions, problems of herding may arise. For example, if farmers learn that one market is paying a higher price, this may lead to a rush to that market and oversupply causing a sharp price decline. This could also lead to "cobweb"-like behavior (Kaldor 1934), where the lag time between price quotation and arrival of goods at the market causes farmers to repeatedly move from one market to another, creating sharp price fluctuations. However, this would only occur if we assume farmers do not form price expectations taking the potential responses of other farmers into account, which seems unlikely.

II. D. Intervening Factors

While the general theory predicts that reducing search costs will lead to greater arbitrage and welfare gains, or reduced market power and welfare transfers, there are many reasons why in practice, the introduction of mobile phones may not in many cases have these effects, due to a range of intervening factors. First, as noted above, agents may already have access to some form of information technology for marketing, such as landlines. Second, there may be other barriers to arbitrage, including high transportation costs (especially where roads are poor, fuel and other costs are high, or security concerns arise), formal government restrictions on cross-regional trade, or market power. Third, in the presence of storage, prices may not vary significantly across markets even without arbitrage, as supply or demand shocks are met with changes in stocks by intertemporally optimizing farmers, traders or wholesalers. Related, goods that are highly perishable may be most likely to experience gains. If goods are easily storable and transportable, even time-intensive search should eventually lead to more efficient arbitrage. On the other hand, for goods that spoil easily, such as some fruits and vegetables, dairy or fish, the speed with which price information is transmitted and thus the speed of arbitrage are important factors.

In addition, even with information, farmers may continue to sell to those with whom they have repeated interactions. There may for example be interlinked transactions, such as traders extending credit to farmers for fertilizer, equipment or labor in exchange for the exclusive right to purchase their output (for example, see Bardhan 1989 and Bell and Srinivasan 1989). In these cases, unless similar relationships can be formed with new buyers, there may be no transfers from traders to farmers. Molony (2008) documents that mobile phones do not enable potato and tomato farmers in Tanzania to find new buyers for this very reason.

III. EMPIRICAL EVIDENCE

There is significant evidence that arbitrage is often among the earliest uses for information technologies. For example, Du Boff (1980) notes that a significant volume of early telegraph use in the United States was for commodity price quotes in distant markets, and suggests that this resulted in reduced inter-market price differentials. For example, he notes reports from a Pittsburgh newspaper in January 1848 announcing that telegraph messages included the "...going prices for cotton, flour, breadstuffs, wheat, rye, pork, southern oats..." Similar evidence of the use of phones for arbitrage comes from Bayes (2001) and Bayes, von Braun and Akhter (1999). Studying the Grameen Village Phone in Bangladesh, they report that close to half of all phone calls were for economic purposes, including (though not limited to) market prices of commodities. Consistent with enhanced arbitrage, they report that farmers received higher prices for rice and eggs in villages with phones. Overå (2006) also reports that traders use mobile phones to get information on prices in Ghana.

None of the studies above use detailed quantitative data, nor do they treat concerns about the endogenous placement of mobile phones that may confound the relationship between phones and the outcomes of interest. More recently, however, a number of studies have gathered extensive quantitative data and dealt with identification concerns using both panel data and more plausibly exogenous variation in access to phones.

Jensen (2007) studies the market for sardines in the southern Indian state of Kerala. In the initial state, none of the agents had price information and arbitrage across markets was close to zero, consistent with the case above suggesting welfare gains. In addition, fish are a highly perishable good, making rapid dissemination of information all the more critical. Exploiting the staggered roll out of mobile phones reveals a tight correspondence between the timing of the introduction across three regions and sharp, sudden changes in market outcomes, suggesting a lack of pre-existing differential trends or other omitted variables. Mobile phones led to significant increases in arbitrage, declines in price dispersion across markets, and waste (unsold fish in markets with high supply, averaging about 6 percent of daily catch prior to mobile phones) was completely eliminated. On net, fishermen's profits increased by 8 percent, consumer prices declined by 4 percent and consumer surplus increased by 6 percent. These results are consistent with the more in-depth, qualitative analyses of Abraham (2007) for the same sector.

Aker (2009) also exploits panel data and the staggered introduction of mobile phones across various regions in studying millet markets in Niger. In this case, mobile phones were primarily taken up by traders, not farmers. If the traders did not have market information before, this should still lead to a more efficient allocation of resources across markets, some of which could pass through to farmers. She finds that mobile phones increased the number of markets over which traders searched. There was significantly reduced price dispersion (10-30 percent), a 29 percent increase in trader's profits (though unfortunately, there are no data on farmers), and improvements in consumer welfare (including a consumer price decline of 3.5-4 percent). She also suggests that the enhanced market performance attributable to mobile phones is likely to have mitigated the consequences of a food crisis in 2005. These results are all the more important in that they show gains even for a grain, which is not as perishable as fish.

In a sense spanning the spaces of goods from these other two studies, Muto and Yamano (2009) study the introduction of mobile phones in rural villages in on the marketing of bananas and maize in Uganda. They find that phones lead to increases in the prices farmers received for bananas, but not maize. They argue that the greater perishability likely limited arbitrage in bananas when information was limited, but not maize, since it is easily transportable and the speed of information transmission is less important. They also find that mobile phones lead to increases in farmer's incomes, particularly for farmers further from larger towns.

By contrast, Futch and McIntosh (2009) find no effects of the introduction of a village phone program in Rwanda on the prices received by farmers (though they do not track the impacts on consumer food prices or consumer welfare). Their paper has the advantage of exploiting what was originally designed as a randomized trial. While the actual implementation deviated from the initial design, this could not explain the absence of an impact, and if anything suggests they would overestimate the effects. In terms of comparability of their results with the others above, they note that one possible explanation is that most of the villages they study were already covered by mobile phone service, and in particular, there already existed a very similar product to the new product being introduced. Thus, they identify at most the effect of a reduction in the cost of service, rather than the introduction of new service. Though it certainly cannot be ruled out that the effects found by the other authors do not arise in all cases, due perhaps to other barriers to arbitrage discussed above.

Goyal (2008) studies the soybean market in the Indian state of Madhya Pradesh. Farmers sold their soybeans to traders in local wholesale markets. Traders had access to information across markets, but farmers did not. A soybean processor (a large purchaser of soybeans) put internet kiosks in villages that allowed farmers to both access daily prices across the various wholesale markets and to sell directly to the company. Since traders already had price information, this represents a case where the allocation across markets may have been efficient, but that information simply increased competition, as in Section II.B. Overall, the introduction of the kiosks was associated with a 1-3 percent increase in soybean prices for farmers. Farmers' profits increased by 33 percent profit, most of which was a redistribution away from traders.

Related, though not focusing on mobile phones, Svensson and Yanagizawa (2009) use panel data to examine the impact of a project in Uganda that provided farmers with market price data for 19 agricultural commodities via radio (including both a weekly 15 minute program and a 2-4 minute daily bulletin). They find that the project lead to 10-15 percent increase in the prices received by maize farmers, which they attribute primarily to greater bargaining power on the part of farmers once they had access to market price information.

Beyond these arbitrage and market power effects, there is some evidence of the follow-on effects discussed above, whereby price changes influence production decisions. For example, Muto and Yamano (2009) find that cell phone coverage increases the production of bananas but not maize, suggesting a supply response due to the increased profitability of banana production when mobile phones are introduced (though it does not appear this was the result of substitution out of maize and into bananas). Goyal (2009) similarly finds that the increased profitability of soybean production after internet kiosks were introduced lead to significant increases in soybean production in Andhra Pradesh. Qualitatively similar results are reported in Bayes (2001) and Overå (2006) who find that improved information on market prices affect production and harvesting decisions for vegetable growers. By contrast, Jensen (2007) finds that increased profitability of fishing did not lead to a supply response, due primarily to high barriers to entry (high costs of equipment and gear, and the concentration of fishing among only a few castes).

V. CONCLUSION

ICTs have had a dramatic impact on the marketing of output in the forestry, fishery and agricultural sectors in developing countries. We identify five primary impacts: two direct channels (efficient arbitrage and reduced market power) and three channels following from the first two (supply responses, reduced use of transportation, and reduced price variability). Most empirical studies have found significant gains in consumer and/or producer welfare, particularly when there was no previous source of information available. Just as importantly, any gains observed are likely to be permanent, since they represent a structural improvement in the efficiency of market functioning.

The discussion in Section II suggests six significant caveats in assessing the impact of mobile phones. First, changes in price dispersion alone do not capture the welfare effects. Second, the analysis can't focus just on producers or consumers in isolation, since one or the other may lose while the other gains, even when there is a positive net effect (the same holds for looking just at consumer or producer prices). Third, some of the gains may come through increases in production; in fact, the theory suggests any average profit gains from mobile phones should be eliminated by entry. Fourth and related, some of the gains may come through changes in the mix of crops produced. For these last two reasons, we can't just focus on average profits in the market for one particular good. Fifth, the analysis can't focus just on those villages that get phones, since one town may gain while another loses; for example, if a rural village gets mobile phones and farmers begin to supply the regional center, they may gain while farmers nearer the center lose. Overall, assessing the impact of mobile phones requires a comprehensive approach spanning many agents, sectors and regions.

We have focused only on the effects via marketing and production. There may be many other effects as well. For example, ICTs may increase the efficiency of production, such as by remotely providing extension services. In this spirit, Bayes, von Braun and Akhter (1999) report lower mortality rates for livestock in Bangladesh due to more timely advice from extension workers where village phones are available. Related, the kiosk program discussed by Goyal (2009) provided not just price information, but information on cropping techniques. At present however, it is unclear whether such effects will be large or widespread, due to costs or technological constraints.

There may also be benefits in the form of a reduction in lost productivity due to equipment failures. For example, Jensen (2009) finds that fishermen's lost fishing time in Kerala declined due to shorter repair durations for outboard motors when repair companies adopt mobile phones. There may also be improvements in the market for agricultural inputs. Bayes (2001) and Bayes, von Braun and Akhter (1999) note that mobile phones in Bangladesh villages lead to a smoother and more reliable supply of inputs such as fertilizer and diesel fuel. Other effects, for which there is even less evidence, include ICT-linked sensors that can provide real time data on soil conditions to farmers who can then adjust levels of inputs; improving safety (such as rescue services for fishermen at sea (Abraham 2007) or security on the road when transporting goods (Overå 2006)); or improved productivity such as using phones for communicating to other fishermen the location of a school of fish (Abraham 2007).

While we have focused primarily on mobile phones, any technology that provides market price information could in principle have the same effects; as Jensen and Zeckhauser (2001) put it, it is the "I" and the "C" that are important, not the "T." For example, Goyal (2009) showed gains from village-based internet kiosks, while Svensson and Yanagizawa (2009) find effects from radio. There certainly may be some advantages to these other technologies over mobile phones, such as the ability to centralize information, providing information on all markets at once. However, radio does not allow for negotiation of sales, and computers and internet connectivity remain expensive (and in many places connectivity is simply not available). For the foreseeable future, mobile phones are likely to play the more important role in agriculture.

REFERENCES

Abraham, Reuben (2007). "Mobile Phones and Economic Development: Evidence from the Fishing Industry in India," *Information Technologies and International Development*, 4(1), p. 5-17.

Aker, Jennifer (2008). "Information From Markets Near and Far: Information Technology, Search Costs and Grain Markets," mimeo, Tufts University.

Alam, Shafiq (2005). “Mobile Rings Changes for World’s Poor,” Sydney Morning Herald, April 22.

Arnold, Wayne (2001). “Cell Phones for the World’s Poor,” The New York Times June 29, p. BU4.

Bardhan, Pranab (1989). The Economic Theory of Agrarian Institutions. Oxford: Oxford University Press.

Bayes, Abdul (2001). "Infrastructure and Rural Development: Insights from a Grameen Bank Initiative in Bangladesh," *Agricultural Economics*, 25, p. 261-272.

- -, Joachim von Braun, and Rasheda Akhter (1999). “Village Pay Phones and Poverty Reduction: Insights from a Grameen Bank Initiative in Bangladesh." Center for Development Research (ZEF), Universität Bonn, Discussion Papers on Development Policy No.8.

Bell, Clive and T.N. Srinivasan (1989). "Interlinked Transactions in Rural Markets: An Empirical Study of Andhra Pradesh, Bihar and Punjab," *Oxford Bulletin of Economics and Statistics*, 51, p. 73-83.

Biglaiser, Gary (1993). "Middlemen as Experts," *RAND Journal of Economics* 24: 212-223.

Delgado, Christopher L. (1986). "A Variance Components Approach to Food Grain Market Integration in Northern Nigeria," *American Journal of Agricultural Economics*, 68(4), p. 970-979.

Donner, Jonathan (2008). "Research Approaches to Mobile Use in the Developing World: A Review of the Literature," *The Information Society*, 24(3), p. 140-159.

Du Boff, Richard B. (1980). "Business Demand and the Development of the Telegraph in the United States, 1844-1860," *Business History Review* 54, p. 459-479.

Eggleston, Karen, Robert Jensen and Richard Zeckhauser (2002). "Information and Communication Technologies, Markets and Economic Development," in The Global Information Technology Report 2001-02: Readiness for the Networked World, Geoffrey Kirkman, Peter K. Cornelius, and Jeffrey D. Sachs, eds., Oxford University Press, p. 62-74

England, Andrew (2004). "African Farmers Discover Technology's Benefits," Financial Times November 24, London Edition: Middle East & Africa, p.9.

Fafchamps, Marcel, and Sarah Gavian, (1997). "The Determinants of Livestock Prices in Niger," *Journal of African Economies*, 6(2), p. 255-295.

Futch, Michael and Craig McIntosh (2009). "Tracking the Introduction of the Village Phone Product in Rwanda," *Information Technologies and International Development*.

Garbade, Kenneth D., and William L. Silber (1978). "Technology, Communication and the Performance of Financial Markets: 1840-1975," *Journal of Finance* 33(3): 819-831.

Goyal, Aparajita (2009). "Information Technology and Rural Markets: Theory and Evidence from a Unique Intervention in Central India," mimeo, University of Maryland.

Hayek, Friedrich A. (1937). "Economics and Knowledge," *Economica*, New Series, IV, p. 33-54.

--, (1945). "The Use of Knowledge in Society ," *American Economic Review*, XXXV, p. 519-530.

Heytens, Paul J. (1986). "Testing Market Integration," *Food Research Institute Studies*, 20(1), p. 25-41.

International Telecommunications Union (2008). Yearbook of Statistics: Telecommunications Services. Geneva: ITU.

Jensen, Robert T. (2007). "The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector," *Quarterly Journal of Economics*, 122(3), p. 879 – 924.

-- (2009). "Cell Phones, Supply Chains and Efficiency: Evidence From the Marine Repair Services Sector," mimeo, UCLA School of Public Affairs.

-- and Nolan Miller (2009) "Do Consumer Price Subsidies Really Improve Nutrition?" mimeo, John F. Kennedy School of Government, Harvard University, Cambridge, MA

-- and Richard Zeckhauser (2001) "What Information Technology Can Do for the World's Poor," The Economic Times (India), July 27.

Kaldor, Nicholas (1934). "A Classificatory Note on the Determination of Equilibrium," *Review of Economic Studies*, I, p. 122-36.

LaFraniere, Sharon (2005). "Cellphones Catapult Rural Africa to 21st Century," The New York Times August 25, p. A1.

Li, Yiting (1998). "Middlemen and Private Information," *Journal of Monetary Economics* 42(1): 131-159.

Molony, Thomas (2008). "Running Out of Credit: The Limitations of Mobile Phone Telephony in a Tanzanian Agricultural Marketing System," *Journal of Modern African Studies*, 46(4), p. 637-58.

Newbery, David M.G. and Joseph E. Stiglitz (1981). The Theory of Commodity Price Stabilization: A Study in the Economics of Risk (Oxford: Clarendon Press).

Muto, Megumi and Takashi Yamano (2009). "The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda" *World Development*.

Overå, Ragnhild (2006). "Networks, Distance, and Trust: Telecommunications Development and Changing Trading Practices in Ghana," *World Development*, 34(7), p. 1301-1315.

Palaskas, T. B., Barbara Harriss-White and Trevor Crowe (1997). “The Evolution of Local Market Commodity Price Behaviour in South India, 1972-92,” *Journal of International Development*, 9(1), p. 101-115.

Rai, Saritha (2001), “In Rural India, A Passage To Wirelessness,” The New York Times August 4, p. C1.

Smith, David (2009). "Mobiles give Africa's Farmers the Chance to Set Out Their Stall," The Observer (England), January 4, 2009, p. 16.

Svensson, Jakob and David Yanagizawa (2009). "Getting Prices Right: The Impact of the Market Information Service in Uganda," *Journal of the European Economic Association*, 7(2-3), p. 435-445.

Stigler, George J. (1961). “The Economics of Information,” *Journal of Political Economy* 69(3): 213-225.

Van Raalte, Chris, and Harry Webers (1998). “Spatial Competition with Intermediated Matching,” *Journal of Economic Behavior & Organization* 34(3), p. 477-488.

Wright, Brian, and Jeffrey C. Williams (1988). “Measurement of Consumer Gains from Market Stabilization,” *American Journal of Agricultural Economics*, LXX, 616-27.

Zhou, Zhang Y., Guang H. Wan, and Liang B. Chen (2000). “Integration of Rice Markets: The Case of Southern China,” *Contemporary Economic Policy*, 18(1), p. 95-106.

Table I. Mobile Phone Subscriptions in the Developing World

	MOBILE PHONES				LANDLINES	
	Number of Subscriptions (Millions)		Subscriptions/ 100 people		Number of Subscriptions (Millions)	Subscriptions/ 100 people
	2003	2008	2003	2008	2008	2008
Africa	53	364	6	39	32	3
Asia	482	1,791	13	46	580	15
Latin America	127	460	23	78	105	18

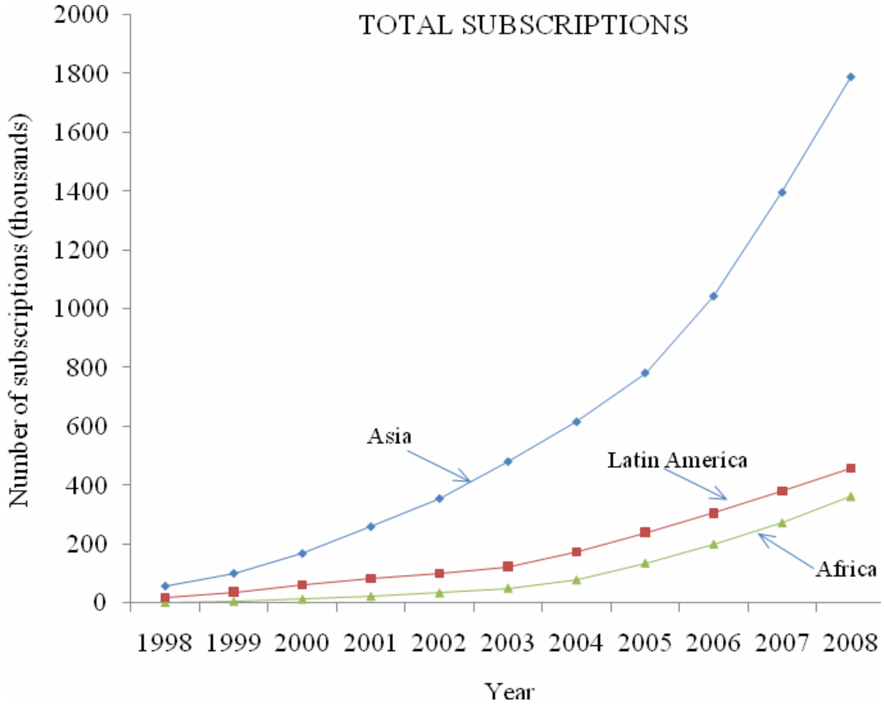
Source: ITU World Telecommunication/ICT Indicators Database 2008. Asia includes the Middle East and excludes Hong Kong, Japan and Macao.

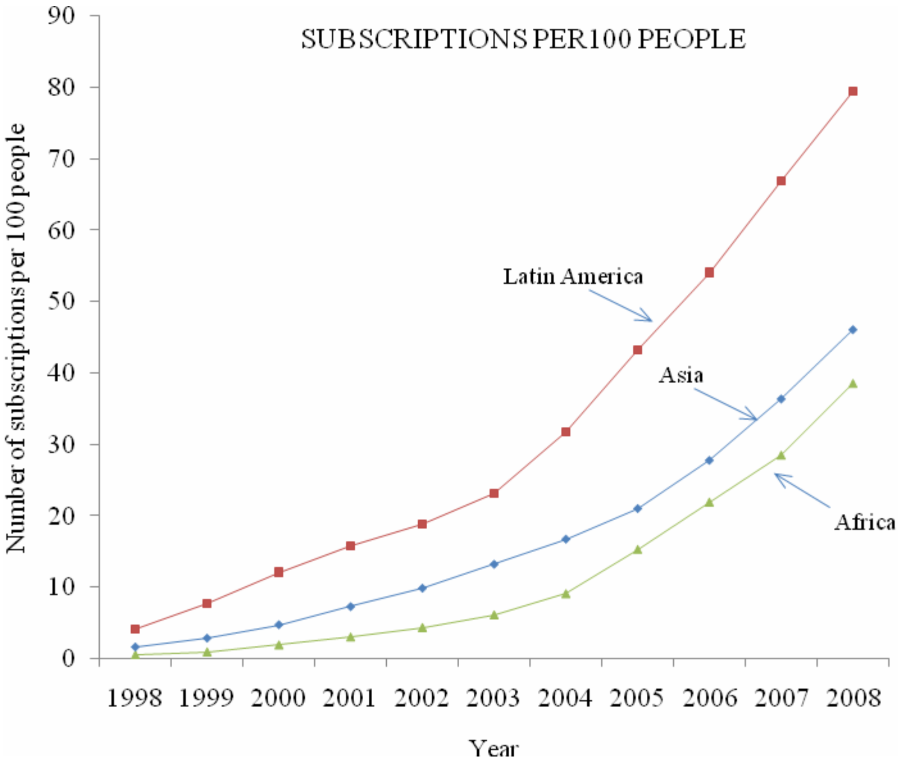
Table II. Mobile Phone Ownership for Select Developing Countries

	% Households that own mobile (Total)	% Households that own mobile (Farming)	Ratio (Farm Ownership/Total Ownership)
Africa			
Benin	24	21	.88
Ethiopia	2	0	.00
Namibia	52	35	.67
Swaziland	60	54	.90
Tanzania	28	19	.68
Uganda	16	13	.81
Zambia	28	16	.57
Zimbabwe	15	8	.53
Asia			
Bangladesh	32	41	1.28
Cambodia	20	12	.60
India	17	13	.76
Nepal	6	4	.67
Latin America			
Dominican Republic	71	64	.90
Guyana	55	47	.85
Haiti	17	8	.47
Honduras	36	24	.67
Peru	22	7	.32
Middle East/North Africa			
Egypt	41	32	.78

Source: Author's calculations from various Demographic and Health Surveys.

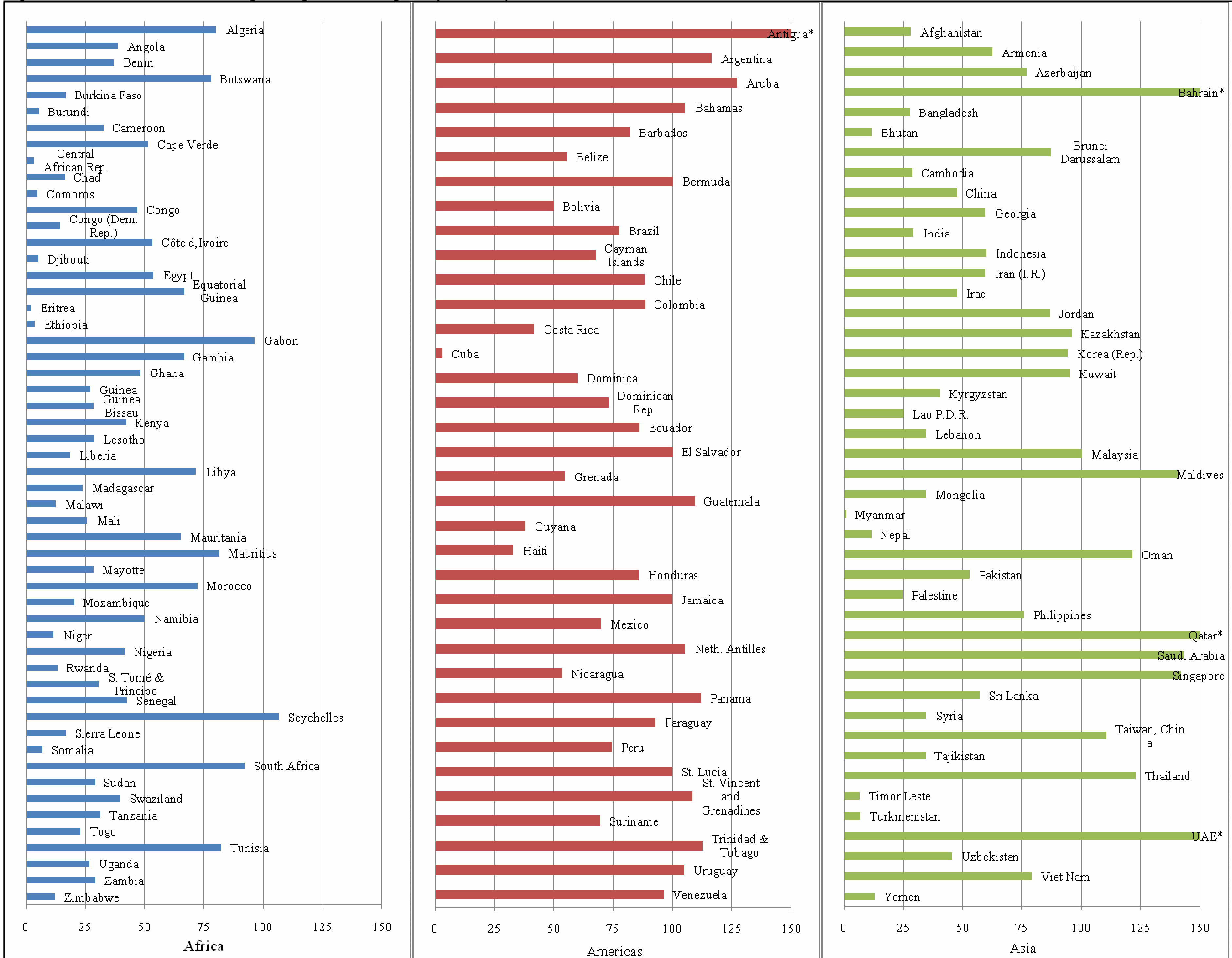
Figure I. Mobile Phone Subscriptions (Total and per 100 persons), by Region and Year





Notes: Data from ITU (2008).

Figure II. Mobile Phone Subscriptions per 100 People, by Country 2008



Notes: Data from ITU (2008).

Figure III. Transportation, Arbitrage and Efficiency