

# Improving Agricultural Productivity and Market Efficiency in Latin America and the Caribbean: How ICTs can make a Difference?

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**Abstract:** The rapid dissemination of ICTs in rural areas in LAC has been received with a lot of optimism, as these technologies are thought to be potentially effective tools of agricultural development. However, rigorous analyses of the impacts of ICTs on agriculture are still very scarce and lag behind the rapid penetration of these technologies. This paper is the first attempt to summarize recent findings from some of the few academic studies addressing this topic and complementing this analysis with anecdotal evidence and findings from case studies. Overall, the available evidence indicates that ICTs can play a major role in promoting agricultural productivity and rural development in LAC. By closing information gaps and reducing transaction costs, ICTs can improve the opportunities of farmers in agricultural markets and empower smallholders. ICTs can also foster productivity by facilitating the dissemination of technological knowledge and expand the access to financial and public services among the rural population by making service provision more affordable. Nonetheless, to the extent that the effective provision of ICTs has certain minimum requirements in terms of human and physical capital, many agricultural economies will be unable to reap the full benefits of these technologies.

**Keywords:** Agriculture, Rural Development, Technological Change, Information and Communications.

## 1. INTRODUCTION

In the last decade, mobile phone penetration in Latin America and the Caribbean (LAC) grew at an impressive pace. Between 1998 and 2008, the average number of mobile phone subscriptions increased from 3.4 to 86.3 per 100 people (IDB 2011). Other more costly information and communication technologies (ICTs) have also had a fast penetration<sup>1</sup>. For instance, in the 1998-2008 period, subscriptions to internet in the LAC region increased from 4.7 to 27.3 per 100 people and the number of personal computers doubled in the eight-year span between 1998 and 2006 (IDB 2011). The adoption of ICTs has not been limited to urban, wealthier households. For example, mobile phone ownership among rural households in the Dominican Republic and Guyana is as high as 50-60 percent (Jensen 2010).

The rapid adoption of ICTs in LAC has generated considerable optimism regarding its economic consequences. In the case of agriculture, ICTs are especially promising. To the extent that rural regions are sparsely populated and often have poor infrastructure and dispersed markets, the introduction

of technologies that reduce the cost of communication has the potential to lead to important transformations (Goyal 2010). However, there may also be reasons to expect limits to these potential benefits. The use and cost-effectiveness of ICTs may be small among poor farmers with little access to capital, electricity, and infrastructure. Moreover, whether the gains from the introduction of ICTs are scalable for a large and diverse rural population is not clear.

Given the excitement generated by the introduction of ICTs and the impressive pace at which they have spread in LAC, it is important to make a rigorous assessment of their economic consequences. However, the literature that tries to understand the impact of ICTs in rural areas in LAC is still very recent and is lagging behind the penetration of these technologies. The contribution of this paper is to present the first survey that summarizes the findings of the small and growing literature that studies the effect of ICTs in agricultural development in LAC. We outline the mechanisms through which the ICTs might have affected the agricultural sector and analyze the evidence of interventions in each of these areas. Whenever necessary, we complement our analysis with case studies and anecdotal evidence.

The results, thus far, are very promising and suggest that, by reducing disparities and gaps in information, ICTs can help farmers find and exploit the opportunities offered in the agricultural markets and increase their bargaining power. Moreover, ICT applications can help farmers meet the escalating

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<sup>1</sup>We use the standard definition of ICTs as any device, tool, or application that permits the exchange or collection of data through interaction or transmission. This is therefore an umbrella term that includes technologies ranging from radio, computers and television, to satellite imagery and electronic money.

demands in distribution and quality control in modern supply chains. ICTs can also play a role in the alleviation of credit and insurance constraints in agricultural economies by reducing the costs of rural service provision and of information. Finally, ICTs can influence the adoption of productive technologies in agriculture by reducing the costs of knowledge dissemination systems such as extension services.

However, the evidence reviewed in this paper also suggests that many agricultural economies may be unable to reap the benefits of these technologies, as they lack the minimum requirements of human and physical capital. First, the adequate use of ICTs, such as internet services, often demands a minimum infrastructure and education level. For instance, illiteracy is an impediment to the introduction of ICT-related technologies such as text messaging and internet. Second, the users of ICTs will not be able to benefit from these technologies in the absence of complementary investments. For instance, as shown in the evidence reviewed in this paper, farmers that gained greater access to price information were unable to arbitrage when the high transportation costs limited the access to alternative input and output markets.

This paper starts with an overview of the agricultural sector in LAC that highlights the potential mechanisms through which ICTs may improve agricultural productivity and market efficiency in this region. The paper then summarizes the evidence provided by studies that evaluate the impact of ICTs interventions, underscoring the causal channels that may be in place. While there is an emphasis on the studies that evaluate interventions in the LAC region, there are also references to studies in other developing economies whenever these are pertinent to the LAC context.

## **2. THE AGRICULTURAL SECTOR IN LATIN AMERICA AND THE CARIBBEAN**

As is characteristic of developing economies, there has been a long-run steady decline in the relative importance of the agricultural sector in LAC countries overall. The contribution of agriculture to GDP fell steadily from 17 percent in 1960 to 6 percent in 2008. Moreover, while the share of employment in agriculture amounted to 54 percent of the workforce in 1950, only 16 percent of workers were employed in agriculture in 2008 (World Bank 2011; Iglesias 1992). Despite these decreasing trends, agriculture remains a sector of great importance for many countries in the region. Indeed, aggregate figures at the regional level mask important

differences across countries. While in 2008, agriculture contributed at least 30 percent of total employment in Honduras, Guatemala, Bolivia and Paraguay, less than 1 percent of the workers in Argentina were employed in agriculture (World Bank 2011). The relative importance of agriculture also varies within countries. For instance, the Mexican states of Zacatecas and Sinaloa have the character of primarily being agricultural-based economies (World Bank 2008a).

Agricultural growth rates in the LAC region have been much slower than the rest of the developing world. In the regions of East Asia, South Asia and Middle East and North Africa, the annual growth of agricultural GDP in 1980-2004 exceeded 3 percent, while growth in Sub-Saharan Africa averaged almost 3 percent. In contrast, annual growth rates in Latin America's agricultural sector did not reach 2 percent. However, due to a decline in the agricultural population, the per capita annual growth of agricultural GDP averaged 2.8 percent (World Bank 2008b). Unfortunately, this growth in per capita agricultural income did not translate into benefits for much of the rural population. In fact, the limited impact of agricultural growth on the reduction of rural poverty has been a distinctive feature of Latin America's agricultural economy (World Bank 2008a). Over the years, the incidence of rural poverty has been surprisingly resilient, and has doubled the rate of urban poverty (Ravallion *et al.* 2007). The rate of rural poor has remained above 50 percent since the 1970s in countries like Guatemala and Honduras. Moreover, the number of rural poor has increased in most countries, with the exception of Brazil, Chile and Mexico (de Janvry and Sadoulet 2002).

In addition to a persistent rural poverty, the agricultural economies in LAC are characterized by a dual nature in which small traditional subsistence farms coexist with large corporate landholdings. In fact, the LAC region has the world's most unequal land distribution and those who have access to land often use it inefficiently (UN 2008). For example, in 2001, 90 percent of the total arable land in Latin America was in large farms that accounted for 26 percent of the total number of farms, and land in these farms was often under-used or idle. The 50 percent smallest farms, which accounted for 2 percent of the land, were subsistence farms in which land was generally overused (de Janvry *et al.* 2001). Such inequality in land ownership has not given rise to an active tenancy market, on the contrary to what would be expected. Despite having by far the world's most concentrated

land patterns, Latin America's land rental markets are surprisingly thin (de Janvry *et al.* 2002).

To support the more disadvantaged smallholders, many countries in the region have implemented social assistance programs that often take the form of cash transfers targeted at the rural poor. These cash transfers are often conditional on the beneficiaries taking certain long-run beneficial measures, such as enrolling their children at school or receiving vaccinations. In countries like Brazil, these cash transfers seem to have had a greater impact on rural poverty reduction than agricultural growth. Thus, in spite of a booming agriculture, Brazil's recent decline in rural poverty seems to be mostly driven by social assistance and non-farm employment, rather than increased agricultural earnings (World Bank 2008a).

Some countries are turning to an alternative approach in which poverty reduction can be diminished by the increase of agricultural incomes instead of the provision social assistance (World Bank 2008a). This requires measures to foster agricultural productivity in a way that enhances farm earnings among the poorest. Unfortunately, the performance of agricultural productivity in many countries has been unsatisfactory. With the exception of Costa Rica, countries in Central America and the Caribbean experienced very low productivity growth in the last decade. Instead, the largest countries in the region, such as Argentina, Brazil, Chile, Colombia, Mexico and Venezuela, made considerable improvements (IDB 2010).

At an aggregate level there has been a satisfactory growth in LAC's agricultural productivity since the 1960. The LAC region has outperformed all other regions in the world except for high income countries. These productivity gains have been entirely driven by technological improvements -- such as the adoption of more productive technologies and modern crop varieties-- as opposed to a more efficient use of the existing resources (Ludena 2010). Further gains in agricultural productivity are not only important for the creation of better-paid agricultural jobs in the rural economies. They are also important if the countries in the region want to respond to the worldwide increases in food demand without affecting domestic food security. It has been estimated that worldwide food production must increase by 70 percent in order to satisfy the global food demand in 2050. With the rising scarcity and degradation of arable land, fresh water reserves and biodiversity, the majority of the required increases in production should come from productivity

gains rather than an expansion in the use of natural resources (FAO 2009). Thus, to meet a rapidly increasing global food demand, farmers in the region should make an effort to increase their productivity. Transformations in the productive process may also be required if farmers want to take advantage of the opening of new markets for high-value primary and processed products (World Bank 2008a).

In order to find ways in which agricultural producers in the LAC region, including small holders, can increase their productivity and take advantage of the new opportunities brought by the expansion of agricultural markets, several structural issues should be tackled. These can be classified into three broad categories: i) agricultural marketing and supply chains; ii) agricultural insurance and credit; and iii) adoption of productive technologies.

## **2.1. Agricultural Marketing and Supply Chains**

The commercialization of agricultural products has suffered important transformations in recent decades, posing big challenges for farmers in the LAC region. First, there are challenges at the initial stage of marketing, when farmers are required to identify their potential buyers. There are also big challenges in distribution and quality control, to the extent that the food markets are being transformed by the procurement practices of the new supply chains. Finally, an effort should be made in terms of information and transaction costs in order to increase efficiency in the agricultural markets as well as the gains obtained by the producers. A more detailed description of these issues follows.

### **2.1.1. Finding the Right Buyers**

In the first stage of marketing, farmers are required to collect short-term information on the quality and quantity currently demanded as well as long-term information on future market trends. Moreover, as food distribution systems become more integrated and globalized, farmers not only require information on domestic consumers, but also on international markets. The collection of such information can be quite costly in rural areas of LAC. If no in-site sources of information are available, farmers may need to travel personally to collect information. This can involve significant costs due to the long distances in sparsely populated rural regions. Poor conditions of road infrastructure will worsen the situation. In this respect, the LAC region has a particularly poor record, lagging behind non-LAC middle income countries in terms of road infrastructure.

A third of the population in the region has poor road access, meaning they don't live within 2 km of an all-season passable road. In countries like Nicaragua, access to transport is particularly limited, reaching just over one-fourth of the population (Calderón and Servén 2010). Some evidence on the consequences of these high information costs has been collected for Colombia where, due to lack of information, many agricultural products are not produced or are inefficiently commercialized (Camacho and Conover 2011).

### **2.1.2. Delivering the Product on Time**

In the second stage of marketing, in which agricultural products are delivered to the consumers through supply chains, the role of transportation and logistics is decisive. Transformations in the procurement practices in the agricultural industry are posing important challenges to farmers in terms of supply chain logistics, quality assurance and process management. Indeed, in recent years, the food industry has been subject to significant changes due to the industrial deregulation in many developing nations, the lowering of trade barriers in many industrialized countries and the incorporation of private market agents. In this new industrial environment, private entrepreneurs lead expensive supply chains that link consumers to agricultural producers. Moreover, supermarkets and the food processing and food service industries play an increasingly important role (World Bank 2008b, Beaumont *et al.* 2011). By the early 2000s, in many Latin American countries retail food sales in supermarkets exceeded 50 percent of total retail sales (World Bank 2008b). The demand for food services is also growing rapidly, as "eating out" becomes increasingly popular in Latin American countries like Brazil, where spending on food services accounts for 22 percent of food budgets (World Bank 2008b).

If farmers want to participate in these new markets, their products must meet escalating safety, quality and distributional requirements. Indeed, agri-food systems in LAC are increasingly pervaded by food safety and quality standards from the private sector which, although not legally binding in the regulatory sense, may be *de facto* mandatory for farmers (IDB 2011). Adequate logistics are also essential to overcome common problems, such as the inability to communicate timely orders to producers, the incapacity to fully trace the production cycle for certification purposes and delays in the process of collection, delivery and payment (Beaumont *et al.* 2011). Meeting

the requirements of these value chains poses serious challenges to farmers in Latin America, especially to small holders who are often unable to cater to demanding supermarket standards (World Bank 2008a). Brehm *et al.* (2007) illustrate this point with a case study in Yucatán, México, where the US retail chain Wal-Mart and several national supermarkets have expressed interest in directly procuring chili habanero from small-scale growers. In spite of this, small-scale producers rarely distribute their output directly to these retailers because they lack the infrastructure and technology needed to comply with strict quality control standards. Another example is provided by Cavatassi *et al.* (2009), who describe how Ecuadorian small potato growers have been unable to meet the volume and quality requirements of the multinational food processor Frito-Lay.

### **2.1.3. Getting the Best Price**

If farmers are to increase their profits from agricultural marketing ventures, it is necessary to reduce information and transaction costs that lead to inefficiencies and weaken their bargaining position. To take full advantage of the opportunities offered by markets, agricultural producers should have timely and accurate information on the prices paid by potential buyers, the costs of alternative distribution channels and the prices and outside options of input suppliers.

Unfortunately, due to high information costs, many farmers make their production and sales decisions in the absence of sufficient information. Some evidence of this issue has been gathered for the *department*<sup>2</sup> of Boyacá, in central Colombia. Camacho and Conover (2011) document how, in this region, 26 percent of the farmers don't know the price of their product if it is purchased at the farm, 43 percent don't know the price of their product at the municipal market and 63 percent don't know the price of their product in Bogotá.

Such lack of information has an adverse impact in terms of efficiency, to the extent that optimal arbitrage requires farmers to have full information on prices. Limited information can also have distributional consequences (Jensen 2010). As mentioned earlier, farmers rarely sell directly to consumers; instead, there is usually a supply chain composed of transportation agents, wholesalers, retailers and other intermediaries. These intermediaries can gain pricing power if the

<sup>2</sup>Departments are the largest subnational administrative units in Colombia, analogous to US states.

producers have limited information on alternative trading opportunities. In this way, information asymmetries lower the profits received by producers from agricultural sales.

## **2.2. Insufficient Availability of Insurance and Credit**

Agricultural producers in LAC are exposed to numerous sources of risk. Fluctuations in weather and in commodity prices translate into large shocks to agricultural income. Pests and disease outbreaks as well as risks related to health shocks can have major impacts on yields. To cope with these risks and uncertainty, agricultural households could resort to formal insurance arrangements that can cover natural, biological and health hazards. However, access to these products in the LAC region is still very limited. In Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Panamá, Paraguay and Venezuela, at most 4 percent of the cultivated area is covered with a formal insurance product. México is an exception to this low insurance coverage, with a share of insured farmland of 15 percent. The lack of coverage in the LAC region contrasts with access to formal insurance in the US, where 75 percent of the farmland under cultivation is insured (Werner 2005).

In the absence of formal insurance arrangements, farmers often resort to informal insurance networks composed by family or community members. They can also adopt alternative mechanisms to cope with risk. One alternative is taking steps to reduce their exposure to risk shocks before they occur. This is often achieved by adopting income smoothing strategies, such as engaging in conservative income activities or in crop diversification. To the extent that these production choices probably do not coincide with those taken on profit maximization grounds only, they will typically yield lower returns.

Households may also respond to risk shocks ex post, by depleting nonfinancial assets, adjusting their supply of labor or forgoing investment decisions. Thus, the ability of farmers to mitigate risk is affected by their access to financial services, which can be used to smooth consumption across different states of nature. Unfortunately, access to credit markets in rural areas in the LAC region remains fairly limited in spite of the increase in banking competition and the expansion of financial products that followed the wave of financial liberalization in the 1990s. While the financial markets in urban areas benefitted from such reforms, financial services in rural areas remain underdeveloped and non-competitive (IDB 2010). Thus, formal sources of

credit in rural areas are scarce. Some evidence of this is presented by Tejerina and Westley (2007), who review more than 400 household surveys that span 12 different countries in the LAC region. They report that only 8.4 percent of the surveyed rural households had savings in a formal institution and only 3.4 percent had accessed credit from a formal source.

Such constraints in the formal credit market have an especially high impact on the farmers' ability to engage in production ventures. Due to its seasonal nature, agricultural production often requires the payment of upfront costs in anticipation of future returns. To surmount the constraints faced in the formal credit market, many farmers resort to informal sources of loans. However, informal credits are often more expensive and can also be insufficient. In the absence of credit rating mechanisms and proper collateral, informal lenders often charge high interest rates to offset the risk of no repayment. These higher interest rates may perversely attract only those farmers who have no intention of repaying, driving the rates even higher and reducing the access to credit for small farmers. Tejerina and Westley (2007) document the insufficient supply of informal credit in 12 countries in the LAC region by reporting that, even when both formal and informal sources are considered, only 14.1 percent of rural households have access to credit.

## **2.3. Limited Technological Adoption**

As was mentioned previously, the adoption of productive technologies explains the steady improvement in agricultural productivity in the LAC region since the 1960s. There are, however, important cross-country differentials in productivity trends. This reflects the fact that in many local agricultural economies in the region there are important constraints to technological adoption (IDB 2010). Technological adoption may be limited by credit and insurance constraints, which, as discussed previously, are prevalent in rural areas in LAC. Insurance and credit imperfections will constrain the adoption of technologies that require large upfront investment costs or whose returns are uncertain.

Limits to adopting new technologies may also arise from informational inefficiencies. Farmers may simply not know of a technology that is beneficial or have no information on how to use it. One of the more commonly used policies in LAC to diffuse the information on technological adoption is the provision of publicly-funded agricultural extension services (IDB 2010). However, despite decades of investment in

public extension programs, evidence of their impact in the LAC region is fairly limited (González *et al.* 2009).

In fact, rigorous impact evaluations of agricultural extension programs in other developing countries are also scarce. The existing evidence suggests that the effectiveness of extension services varies across settings and that the effects can be very weak. While this can be attributed to the methodological difficulties involved in performing a rigorous evaluation, the weak results can also be attributed to the quality of the agricultural extension systems themselves. In many developing countries agricultural extension systems are barely functioning. This is partly due to the problems of scale involved in the provision of extension services in small-farm agricultural economies in which farmers live in geographically dispersed areas. In this environment, the provision of extension systems becomes so costly that it may be financially unsustainable. Also, the weak performance incentives of field agents are often a barrier to efficient extension. Monitoring the performance of field extension agents can be quite costly given that they often work in geographically dispersed regions.

Agricultural technologies also remain at low levels of adoption if they generate positive externalities or spillovers that accrue to the wider community. For example, there is evidence that in developing countries, practices that control pests or reduce erosion will be adopted at a lower level than what is optimal from the point of view of the community. (Jack 2011) To overcome these externalities, arrangements that align the individual farmers' incentives can be developed. However, these may be ineffective if the actions that generate the externalities are costly to observe. For instance, Costa Rica's program of payments to reduce deforestation has had little impact on the actual deforestation rates because the majority of payments go to farmers that are unlikely to deforest in the absence of the program (Pfaff *et al.* 2008).

Finally, the adoption of agricultural technologies will also be constrained by insecure land rights. Investing in technologies with long-run returns will not be attractive if farmers are uncertain about their property rights in the future (Jack, 2011). This is certainly an issue in several countries in LAC, where land conflicts, expropriation and *de facto* ownership are common<sup>3</sup>.

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<sup>3</sup>In fact, some scholars have argued that insecure property rights have hindered the development of a land rental market in several countries in Latin America such as Brazil and the Dominican Republic. (See, for instance, Alston and Mueller, 2010; Macours *et al.* 2004).

### 3. POTENTIAL BENEFITS OF ICTS IN THE AGRICULTURAL SECTOR

The rapid spread of ICTs in developing countries offers an opportunity to tackle some of the problems afflicting agricultural economies in the LAC region. The most obvious impact that these technologies can have is the reduction in the information and communication costs in agricultural economies. This can be quite beneficial, given that rural regions are sparsely populated and often have dispersed, poorly connected markets. Indeed, by reducing information costs, ICTs can: i) increase the efficiency and producer surplus in agricultural markets; ii) strengthen the provision of rural services; iii) facilitate the adoption of agricultural technologies.

#### 3.1. Increasing Agricultural Market Access and Gains with ICTs

Research on the impact of ICTs on agriculture is fairly recent. Recent literature provides some new evidence indicating that ICTs can increase the farmers' access to markets and production profits mainly by reducing the costs of acquiring relevant market information (e.g., potential buyers, prices of inputs, distribution channels) and by supporting the logistics and quality control required to access more demanding markets.

##### 3.1.1. Lowering the Cost of Information

Consider, for instance, the case of mobile phones, which can significantly reduce the cost of acquiring market information in remote, rural areas. Once the initial fixed cost of installment is paid for, the variable costs associated with the gathering of information *via* mobile phones are significantly lower than the equivalent costs of travelling. Aker (2008) illustrates this point with a comparison of the per-search costs of searching for price information for different types of search mechanisms in Niger. While the approximate per-search costs of making personal visits are, \$USD 0.8, the cost of using mobile phones is \$USD 0.2. Mobile phones therefore allow people to obtain information on a more frequent basis and take a more active role in the process of searching for information. To the extent that farm producers can be better informed, they may be more able to make efficient production and sales decisions.

If the introduction of ICTs allows farmers to operate more efficiently and take advantage of the existing opportunities for arbitrage, there should be a reduction

in price dispersion across markets and time. An emerging body of research has provided direct evidence of this effect in developing countries. In an influential paper, Jensen (2007) exploits exogenous variation in the introduction of mobile phones in the state of Kerala, India and finds that access to mobile phones leads to a sizeable decline in the price variability of fresh fish across markets and over time and to the complete elimination of waste. The results of Goyal (2010) point to the same direction. She finds evidence of a reduction in the spatial dispersion of the price of soybeans in the state of Madhya Pradesh in India, where the introduction of internet kiosks allowed farmers to bypass intermediaries and obtain daily information of wholesale prices. Evidence of a similar effect of ICTs in the LAC region is provided by Camacho and Conover (2010). They implement an experiment that randomizes the price and weather information provided to farmers through text messages (SMS technology) in the department of Boyacá, Colombia. They find that, relative to the control group, farmers who received the text message had a smaller dispersion in the expected crop price and a significant reduction in crop loss.

The gains in efficiency from the introduction of ITCs can translate into an increase in the welfare of agricultural producers. ICTs may also increase the farmers' surplus if a greater access to information increases their market power. Goyal (2010) provides suggestive evidence of these welfare effects in Madhya Pradesh, India, where the introduction of the internet kiosks allowed for the bypassing of intermediaries and the creation of a direct marketing channel. As a result, there was not only a reduction in price dispersion but also an increase in the average soybean price received by farmers and an increase in the area of soy under cultivation suggesting the existence of net welfare gains for farmers. Jensen (2007) also finds positive welfare effects from ITC's, to the extent that the introduction of mobile phones increased the profits of fishermen in Kerala.

The evidence of increases in welfare effects for farm producers in the LAC region is still very limited. A few studies in rural Peru provide evidence in this direction. Beuermann (2010) takes advantage of exogenous variation in the timing of the provision of at least one public (satellite) payphone to rural villages in rural Peru that previously had neither landlines nor cell phones. Results show an increase in agricultural profitability in 19.5 percent which the author attributes to an increase in the farmers' bargaining power. Chong

*et al.* (2009) also study the impact of the introduction of payphones in rural Peru. They exploit quasi-experimental variation in the installation and operation of public payphones in small rural towns in Peru and find a sizable positive impact on agricultural income. Finally, the study of Beuermann, McKelvey and Vakis (2012) show that household real consumption in rural villages in Peru increased in 11 percent as a result of the exogenous expansion of mobile phone coverage.

However, the empirical literature has not always found a welfare enhancing effect of ICTs on farmers. Aker and Fafchamps (2010) exploit the quasi-experimental nature of mobile phone rollout in Niger and find that, while mobile phone coverage reduces producer price dispersion, it does not increase producer prices. Suggestive evidence indicates that the limited welfare-enhancing effects could be driven by insufficient mobile phone coverage in remote areas. In the LAC region, Camacho and Conover (2010) present experimental evidence in the same direction. In a randomized experiment, they find that sending text messages with price and weather information to farmers in Boyacá, Colombia, has no significant impact on agricultural prices, revenues or household expenditures. The authors argue that the lack of effects could be explained by the short duration of the intervention.

While the absence of ITC on farmers' welfare could be associated to the characteristics of the program, the results of Camacho and Conover (2010) and Aker and Fafchamps (2010) also suggest that there are intervening factors that may hinder the possible impact of ITCs on the market efficiency and the producer welfare. First, even in the presence of greater information, farmers may be unable to arbitrage in response to the additional information if the high transportation costs limit the access to alternative input and output markets. This, as discussed previously, is an important limitation in the LAC region. Also, even after obtaining additional information and learning of better market opportunities, farmers may continue to trade with the marketing agents with whom they have repeated interactions. This will be the case if there are interlinked transactions in which, for instance, traders extend credit to farmers in return for the exclusive rights to purchase their output (Jensen, 2010). Coon *et al.* (2010) provide some illustrations of this kind of relationships in Central America. For example, they describe how NicFoods, a Nicaraguan company dedicated to process and export tubers, has acted as a guarantor for plantain farmers to access loans at a

local bank. A second example is the case of Parmalat, a multinational dairy corporation that provides credit to dairy farmers in Nicaragua when they are unable to pay the upfront operation costs of milk refrigerators.

### 3.1.2. Supporting Logistics and Quality-Control

ICT applications can also help farmers meet the escalating demands in terms of distribution and quality control posed by modern supply chains. An interesting example for the LAC region is the TRAZ.AR program in Argentina. This program provided small and medium cattle farmers with internet-connected software that allowed them to track each animal from the time of its delivery until the meat is distributed and thus follow the evolution of the stock and the sanitary situation of the animals. Since tracking is an essential quality requirement in many international value chains, the use of TRAZ.AR strengthened the competitiveness of cattle farmers in the global meat market (IDB 2011). Moreover, through the use of this program farmers improved reproduction selection, reduced animal stress and improved sanitation. Galiani and Jaitman (2010) find that, relative to a control group with similar characteristics, farmers in the TRAZ.AR program were less affected by a severe drought experienced during the period and were able to sell at better prices.

ICT applications that provide similar services for farmers in the developing world are becoming more common. Choudhary and Sen (2011) describe several software applications that have helped overcome supply chain problems in countries like Kenya, India and Bangladesh. These systems typically support the communication of orders to farmers, the coordination of storage and distribution logistics, the tracking of the produce along the supply chain for quality control purposes and the process of payment. While some of these software applications are sophisticated and costly, there is also a supply of cheaper systems that are affordable for small holders since they rely on lower-cost ICT devices such as, for example, mobile phones or PDAs.

Choudhary and Sen (2011) note how many of the ICT applications for supply chain management are provided by the private sector. To the extent that private companies support the operations with a viable business model, these interventions are likely to be sustainable. In this regard, an interesting example is the ICT intervention led by ITC Limited, a large buyer of soybeans in India. In order to bypass intermediaries and lower the transaction costs, ITC Limited set up

internet kiosks in rural villages that enabled farmers to access daily information on wholesale prices of soybeans in local markets as well as the price offered by ITC. As discussed by Goyal (2010), this intervention was financially sustainable, for it was profitable both for farmers and for ITC. In contrast, similar efforts undertaken by NGOs or governments to remove intermediaries and provide information to farmers have not had the same success due to their lack of sustainability.

### 3.2. Strengthening Financial Services and Mitigating Risk with ICTs

ICTs can facilitate the provision of services in agricultural economies by reducing the costs of reaching and servicing scarcely populated rural areas. In the case of banking, a very successful innovation has been the introduction of mobile financial applications (a.k.a. "m-banking"). These systems facilitate the operation of a variety of financial transactions *via* mobile phones, such as the payment of bills or the transfer of money among bank accounts.

M-money technologies have been adopted throughout the developing world, in Asia, Africa and LAC region. Particular attention has been given to the Kenyan m-banking service, M-Pesa, which has had a dramatically rapid penetration, attracting one million subscribers in the first ten months after its introduction. There are currently 9.5 million subscribers (23% of the population) which implies a remarkable achievement in terms of financial inclusion since only 4 million people own a bank account in Kenya (IDB 2011). However, even though this technology has provided "banking for the unbanked", it should be noted that most of the transactions occur within urban areas. In Colombia's coffee sector m-banking services have also been introduced. In a very recent pilot project, coffee growers have been given access to mobile phones with which they can perform financial transactions including the purchase of inputs (IDB 2011).

ICTs have served a similar function by reducing the cost of providing public services to the rural poor. An example is the electronic implementation of the conditional cash transfer programs in Colombia and Mexico (*Familias en Acción* and *Oportunidades*, respectively). The subsidies are being transferred through electronic payments to individual and collective bank accounts (IDB 2011). The Bhoomi project in the state of Karnataka, India, is also an interesting example. In this project, several million land records were

computerized and made publicly available through a network of rural land-record kiosks. To the extent that public officials were bypassed, this process reduced the opportunities for corruption and eased farmers' access to documentation needed for land transactions and loans. (McNamara 2009).

ICTs can also have an impact in the exposure to risk of agricultural households. As discussed earlier, agricultural economies are inherently risky and, in the absence of formal insurance mechanisms, farmers often resort to members of their social network for informal insurance. To the extent that ICTs improve communications among the social network, they can increase the effectiveness of these informal insurance arrangements. For example, mobile phones can increase the speed of information flows within the network, allowing them to respond more rapidly to shocks. However, the evidence on the effect of mobile phones on social networks is limited, but the topic has been extensively studied in the field of sociology.

ITCs may also facilitate the transmission of information on potential shocks. This was the goal of the randomized intervention in Boyaca, Colombia, in which farmers were provided with price and weather related information *via* text messages (Camacho and Conover 2010). An improved system of alerts natural disasters are also a good example of the role of ITCs in reducing risks. In response to the 2010 earthquake, the Chilean government initiated an SMS earthquake alert system program that, by 2012, should have incorporated all mobile phones in the country (IDB 2011).

Another example of how the adoption of ICTs can affect risk exposure is presented by Muto and Yamano (2009), who use panel data to study the impact of a large expansion in mobile phone coverage in Uganda. After the expansion of the coverage, there was an increase in the sales of banana but not of maize. The authors argue that the greater impact on banana is due to the fact that, as opposed to maize, banana is a perishable product whose price depends heavily on freshness at the time of sale. The new flow of information made available by the mobile phones allowed the farmers to reduce the risks of producing bananas by facilitating a timely coordination in production and transportation that avoided spoilage.

### **3.3. How ICTs can Increase the Adoption of Agricultural Technologies**

One of the main policies put forth by many countries to promote the adoption of agricultural technologies is

agricultural extension. Extension services were conceived of and developed in response to the limited access that farmers often have information on farming technologies. To the extent that ITCs reduce the costs of communication, they can ease the provision of effective extension services.

“Traditional” ICTs such as television and regular radio broadcasts have been used for long to support the service of agricultural extension. Governments around the world are now incorporating new versions of extension services that are supported on more “modern” ICTs, such as voice-based information systems, SMS and e-learning. The voice-based information systems primarily consist of call-in centers and hotlines that provide information on farming methods and market access. SMS-based extension services essentially use text-messages *via* mobile phones to disseminate information. E-learning programs usually consist of internet kiosks or centers that allow farmers to access agricultural information on the internet. While the introduction of these new technologies can prove beneficial, there are challenges to supporting the diffusion of agricultural extension *via* ICTs. On the one hand, the effectiveness of the technology is highly dependent on the type of information provided. For example, while the information on crop prices can be easily transmitted by text messages, these may prove inadequate to disseminate more nuanced, complex information about agricultural practices. Also, some of these technologies require users to have some literacy level and technological knowledge.

From a different standpoint, ICTs can also improve the effectiveness of agricultural extension. In particular, they can be used to improve the accountability of extension services by facilitating the collection of agricultural information. For example, instant messaging systems can be used to collect information on technological adoption and use of inputs on a more frequent basis than the regular agricultural surveys. Mobile phones may also be used to verify the extension agents visits (Aker, 2008).

ICTs can also be beneficial to the adoption of agricultural technologies by strengthening social ties and the diffusion of private information on technologies. The adoption of productive technologies can be sped up if there is increased communication between farmers and other technological adopters. The economics literature provides interesting evidence on the role of peer effects, knowledge spillovers and

learning externalities on the adoption of agricultural technologies. In an influential paper, Foster and Rosenzweig (1995) provide evidence of learning spillovers in farming technologies in rural India. They find that farmers with neighbors that have adopted new technologies (i.e., high-yielding seed varieties) devote more land to the new technologies and have more profitable farms. Conley and Udry (2010) exploit a rich set of data on the communication patterns of pineapple farmers in Ghana and provide evidence of social learning. Specifically, they show that farmers align their level of fertilizer input with the amount used by farmers in their information neighborhood who were successful in the previous season.

Finally, by facilitating the degree of cooperation among economic agents, ICTs may also influence the adoption of technologies with spillovers and externalities. Evidence of this type of effect is quite scarce. There is, however, anecdotal evidence from the Huaral Valley in Perú indicating that the installation of telecommunication information centers improved the distribution of water from irrigation sources and helped the communities coordinate its use in times of water scarcity (IDB 2011).

#### 4. CONCLUSIONS

The rapid dissemination of ICTs in rural areas in LAC has been received with a lot of optimism, as these technologies are thought to be potentially effective tools of agricultural development. Moreover, ICTs can become sustainable development interventions to the extent that they can be delivered as viable businesses for the private sector. However, rigorous analyses of the impacts of ICTs on agriculture are still very scarce and lag behind the rapid penetration of these technologies. This paper summarizes recent findings from some of the few academic studies addressing this topic. The analysis is complemented with anecdotal evidence and findings from case studies. Overall, the available evidence indicates that ICTs can play a major role in promoting agricultural productivity and rural development in LAC. By closing information gaps and reducing transaction costs, ICTs can improve the opportunities of farmers in agricultural markets and empower smallholders. ICTs can also foster productivity by facilitating the dissemination of technological knowledge and expand the access to financial and public services among the rural population by making service provision more affordable.

Nonetheless the evidence also indicates that many agricultural economies will be unable to reap the full benefits of these technologies unless there are complementary investments in physical or human capital. Given the speed of innovation in the ICT industry and the diversity and complexity of its applications, there is an urgent need for more analyses on their potential benefits and pitfalls. More rigorous evidence is necessary to guide development practitioners and policy makers on how to harness the opportunities that ICTs can bring to the agriculture sector in Latin America.

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