How Does Mobile Phone Coverage Affect Farm-Gate Prices? Evidence from West Africa

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Abstract. The expansion in mobile phone coverage has changed rural and urban populations' access to information within much of the developing world. In sub-Saharan Africa and Southeast Asia, mobile phone technology has reduced communication costs, thereby reducing search costs. Existing evidence suggests that information technology has decreased price dispersion across markets for either highly perishable commodities or for consumer prices. We use micro-level data to estimate the impact of mobile phone coverage on farmers' welfare. We merge panel data on producer prices, transport costs and rainfall with detailed data on mobile phone coverage location and dates. Using market pair fixed effects, we find that introducing mobile phone coverage reduces producer price dispersion for cowpeas by 6 percent. This result is robust to the use of alternative measures of the dependent variable. The effect is stronger for markets that are farther apart and for those linked by unpaved roads, but there is no strong seasonal effect. Unlike existing research on the impact of information technology, these effects do not translate into higher producer prices for farmers but do translate into lower intra-annual price risk. Supplementary farmer and trader-level data suggests that the limited welfare-enhancing effects for farmers are driven by relatively limited mobile phone coverage in remote rural areas during the period of analysis. (J*EL* O1, O3, Q13)

Key words: Africa, Information, Information Technology, Market Performance, Search Costs, Niger.

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"[With a mobile phone], no dishonest trader can cheat me when I buy and sell…."
Farmer in Maradi, Niger[1]

1. Introduction

Sub-Saharan Africa has some of the lowest levels of infrastructure investment in the world. Merely 29 percent of the roads are paved, barely a quarter of the population has access to electricity and there are fewer than three landlines available per 100 people (ITU, 2009; World Bank, 2009). Yet access to and use of mobile telephony on the continent has increased dramatically over the past decade. There are ten times as many mobile phones as landlines in sub-Saharan Africa (ITU, 2009), and 60 percent of the population has mobile phone coverage. Mobile phone subscriptions increased by 49 percent annually between 2002 and 2007, as compared with 17 percent per year in Europe (ITU, 2008).

Mobile phones are used for a number of purposes in sub-Saharan Africa, from staying in contact with family members and friends to calling for price information and organize supply chains. By reducing communication costs, they allow individuals and firms to send and to obtain information quickly and cheaply on a variety of economic, social and political topics (Aker and Mbiti 2010). Improved access to information can not only enhance arbitrage, but also change the structure of market power (Jensen 2010). An emerging body of research shows that the reduction in communication costs associated with mobile phones has tangible economic benefits, improving agricultural and labor market efficiency and producer and consumer welfare in specific circumstances and countries. Jensen (2007) shows evidence of reduced producer price dispersion and improved consumer and producer welfare in fish markets in India due to the introduction

[1]Based upon interviews with one of the authors in 2007.

of mobile phone coverage. Aker (2010) shows that mobile phone coverage reduced consumer price dispersion by 10-15 percent for millet in Niger. Whereas Goyal (2010) found that internet kiosks increased farmers' prices for soybean in Central India,[2] Fafchamps and Minten (2010) find no effect of a mobile-phone based price information service on the agricultural prices received by farmers in Maharashtra, India.

While existing research suggests that information and communications technology (ICT) can lead to improved market efficiency for specific commodities, it cannot tell us the extent to which these gains are distributed among traders, farmers and producers. To date, few of these studies have focused on the impact of ICT on producer price dispersion and farmer welfare, particularly for food and cash crops that are produced by a majority of the rural poor. This has important implications for understanding whether welfare gains will accrue to mainly consumers and traders, or whether they will also extend to farmers who live in more remote rural areas and are the primarily suppliers of such commodities. To the extent that these impacts primarily affect consumers' and traders' welfare, understanding the mechanisms behind these effects could be informative about policies that broaden the impacts of ICT into more remote rural areas.

This paper estimates the impact of mobile phones on farm-gate agricultural price dispersion in one of the world's poorest countries, Niger. Between 2001 and 2008, mobile phone service was phased-in throughout the country. In a country with poor road infrastructure, low population density and limited landline coverage, farmers and traders have traditionally traveled to markets to obtain price information for agricultural goods. Aker (2010) shows that the reduction in search costs associated with mobile phones in

[2] Muto and Yamano 2009; Svensson and Yanagizawa 2009

Niger reduced consumer grain price dispersion across markets, thereby leading to welfare gains for grain traders and consumers (Aker 2008, Aker and Tack 2010). This paper, by contrast, assesses the impact of mobile phone coverage on farm-gate price dispersion for a staple grain and cash crop, which are directly relevant for farm households' welfare.

For the empirical investigation, we use two primary datasets. In the first part of the paper we use a panel dataset of monthly producer prices, transaction costs, market location and rainfall from a variety of primary and secondary sources. The dataset includes monthly producer price data over a ten-year period (1999-2008) across 37 domestic markets. We combine this dataset with data on the location and date of mobile phone coverage, collected from the mobile phone service providers operating in Niger. The second dataset is a detailed panel survey of farmers and traders collected between 2005 and 2007, thereby allowing us to provide insights into the mechanisms through which mobile phone coverage affects producers' and traders' behavior.

We exploit the quasi-experimental variation of mobile phone rollout to identify its impact on agricultural market performance. This involves estimating a dyadic regression model with market pair level fixed effects. We find that the introduction of a mobile phone tower reduces producer price dispersion across markets for cowpeas, but does not appear to have a statistically significant effect on millet. As cowpea is a cash crop that is highly susceptible to post-harvest losses, this supports previous evidence that mobile phones are more useful for semi-perishable goods (Jensen 2007, Muto and Yamano 2009). The effect is larger for markets that are within a certain geographic range; we find that reductions in producer price dispersion are stronger for markets farther than 350 km and for those that are linked by unpaved roads. This is consistent with the results on the impact of mobile phone coverage on consumer price dispersion for millet in Niger (Aker 2010).

The primary issue with interpreting these results causally is the possibility that observable or unobservable characteristics could be correlated with mobile phone coverage and producer price dispersion. The inclusion of market-pair-level fixed effects addresses the concern that the introduction of mobile phone coverage is associated with some fixed area characteristic, but does not address the possibility that mobile phone coverage could have been introduced into areas that were experiencing a faster reduction in price dispersion, that mobile phone companies changed the timing and location of coverage rollout in response to agricultural market conditions, or that other infrastructure investments occurred simultaneously.[3]

To address these issues, we conduct a series of robustness checks. If mobile phone companies were targeting areas in response to agricultural market conditions, then mobile phone coverage should be correlated with pre-treatment price dispersion. We do not find any evidence that future mobile phone coverage is correlated with producer price dispersion across markets. Similarly, as we use a difference-in-differences estimator with fixed effects, we might be concerned that producer prices in mobile phone markets exhibit differential trends from non-mobile phone markets. Using data prior to the introduction of mobile phone coverage, we show that there are no statistically different pre-intervention

[3] We should note that we have no reason to think that the endogenous placement of mobile phone towers in Niger, beyond the first two years of mobile phone coverage, is common. Conversations with the mobile phone operators suggested that they chose the initial areas of coverage based upon urban centers and whether the location was located near the southern borders. Once these initial criteria were met, there was no mention of providing mobile phone coverage based upon agricultural markets or prices. As Niger is still strongly rural, and a majority of agricultural markets are located outside of urban centers, there does not appear to be a high degree of correlation between the two.

trends across mobile phone and non-mobile phone markets for either millet or cowpea prices.

Following our estimates of the overall impacts of mobile phone coverage on price dispersion, we explore whether these effects vary by distance, road quality or season. Most farmers in Niger sell their products in markets located near their home village, and primarily do so immediately after the harvest. We find that the impact of mobile phone coverage is stronger for markets located farther than 350 km apart and for those linked by unpaved roads. By contrast, we do not find a strong difference in the impact of mobile phones during different periods of the year.

These results point to a causal impact of mobile phone coverage on reducing producer price dispersion, but leave open the possibility that these impacts are due to traders' or farmers' selection into mobile phone markets or a greater consolidation of market power by traders (thereby leading to the monopoly price, rather than a competitive price). We argue that these factors do not explain our results. Farmers in mobile phone markets did not receive higher farm-gate prices than their non-mobile phone counterparts. But mobile phone coverage reduces the intra-annual coefficient of variation, suggesting that mobile phones reduce the price risk faced by farmers.

We interpret these results as a consequence of the extension of mobile phone coverage into Niger. We explore the mechanism by which this occurs, distinguishing between two possibilities. The first is that the introduction of mobile phone coverage into a market may affect farmers' access to information, thereby allowing them to search over more markets, negotiate better prices, and thus reducing price dispersion. Alternatively, mobile phone coverage may improve traders' access to information on farm-gate prices, thereby allowing them to search for lower purchase prices from farmers and leading to a reduction in price dispersion. To disentangle the two mechanisms, we use trader and farmer survey data collected between 2005 and 2007. Consistent with the results of Aker and Tack (2010), we find evidence in favor of increased access to information and changes in search behavior by traders, rather than farmers.

This paper is related to the literature on the relationship between telecommunications infrastructure and market performance. Most of the existing papers have examined the impact of telecommunications on a specific perishable commodity (Jensen 2007), farmers' market participation (Muto and Yamano 2009) or producer price levels (Goyal 2010, Fafchamps and Minten 2010).[4] In contrast, this paper provides new evidence of the impact of mobile phone coverage on producer price dispersion and price levels, which is especially relevant for household welfare in rural sub-Saharan Africa. We also focus on a commodity, cowpea, which is produced in a variety of countries within sub-Saharan Africa.[5] Finally, we provide evidence of the impact upon farmers' welfare, which has not been addressed in related literature in sub-Saharan Africa (Aker 2010, Muto and Yamano 2009).

The rest of this paper proceeds as follows. Section 2 provides an overview of agricultural markets in Niger and the introduction of mobile phones into the country. Section 3 presents the conceptual framework, whereas Section 4 presents the data. Section

[4] Megumi Muto and Takashi Yamano (2009) examine the impact of mobile phone coverage on farmers' market participation for banana and maize in Uganda. Aparajita Goyal (2010) assesses the impact of internet kiosks on wholesale soybean price levels in India. Fafchamps and Minten (2010) evaluate the impact of agricultural price information delivered to farmers via SMS messages.

[5] It is estimated that cowpeas are produced on over 10 million hectares in West, Central and East Africa. Cowpeas are also produced in India, Australia, North America and Europe.

5 presents the empirical strategy, whereas Section 6 discusses the main empirical results and robustness checks. Section 7 discusses welfare effects whereas Section 8 presents the mechanisms. Section 9 concludes.

2. Agriculture and Mobile Phones in Niger

2.1. Agricultural Markets in Niger

With a per capita Gross National Product (GNP) of US$230 and an estimated 85 percent of the population living on less than US$2 per day, Niger is ranked last on the United Nations' Human Development Index (United Nations Development Program 2010). Agriculture employs more than 80 percent of the total population and contributes approximately 40 percent to Gross Domestic Product (GDP). The majority of the population consists of rural subsistence farmers, who depend upon rain-fed agriculture as their main source of food and income. The main grains cultivated are millet, sorghum and rice, with cash crops including cowpeas, peanuts and sesame.

Cowpea is the primary cash crop in Niger, grown in almost every agricultural zone in the country. Similar to staple grains such as millet and sorghum, it is produced annually (between October and November) and is primarily exported to Nigeria. Although cowpea and staple grains can be stored for several years in good conditions, over 90 percent of farmers and traders in the survey sample do not engage in inter-annual storage. Nevertheless, unlike grains, cowpea is highly susceptible to pest infestations during storage and is therefore considered a semi-perishable commodity.

A variety of market agents are involved in moving agricultural commodities from the farm to rural and urban consumers in Niger. Small-scale farmers typically sell their agricultural products to intermediaries in their village or in a nearby market. Intermediaries then sell to wholesalers in local markets, who in turn sell the commodity to other wholesalers, retailers or consumers in regional markets. As there is only one rainfed harvest per year, both traders and farmers engage in intra-annual storage, although the duration of such storage is limited (Aker 2008).

The purchase and sale of agricultural commodities in Niger takes place through a system of traditional markets, each of which is held on a weekly basis. The density of markets varies considerably by geographic region, with inter-market distances for which trade occurs ranging from 8 km to over 1,200 km. Farmers spend an average of 1.5 hours traveling from their village to their principal market, representing a distance of 7.5 km. The number of traders per market ranges from 24 to 353, with retailers accounting for over 50 percent of all traders. While an agricultural market information system has existed in Niger since the 1990s, 89 percent of traders and 75 percent of farmers surveyed stated that they primarily obtained price information through their own personal and professional networks.[6]

2.2. Expansion of Mobile Phone Coverage

Mobile phone service first became available in part of Niger in October 2001. Although private mobile phone companies intended to provide universal coverage, due to high fixed costs and uncertainty about demand, mobile phone service was introduced gradually. Based upon interviews with the mobile phone service providers, the initial criteria for introducing mobile phone coverage to a location were twofold: whether the

[6]While traders and farmers have stated that they do not depend upon prices from the agricultural market information system (AMIS) for their purchases and sales, this is primarily due to the type of data (only consumer prices are provided) and the timing of the data diffusion (the data is provided weekly, in some cases six days after a market).

town was an urban center, and whether it was located near an international border.[7] During the first three years of mobile phone expansion, the average distance between markets with coverage was 367 km.

Although landlines existed prior to 2001, Niger has the second lowest landline coverage in the world, with only 2 landlines available per 1,000 people, as compared to 113 landlines per 1,000 people in South Africa (World Bank 2005). Figure 1 shows the spatial rollout of mobile phone coverage by market and by year, whereas Figure 2 shows the number of mobile phone subscribers relative to the total number of landlines over the same period. Mobile phone coverage and subscribers increased substantially between 2001 and 2008, with 76 percent of grain markets and 44 percent of the population having access to mobile phone service by 2008. The greatest change occurred between 2008 and 2010, when mobile phone service expanded considerably into remote rural areas. By contrast, the number of landlines remained relatively stable during this period and their geographic coverage of grain markets did not change.[8]

Despite the increase in mobile phone coverage since 2001, as of 2008, Niger had the lowest adoption rate in Africa. There were an estimated 1.7 million mobile phone subscribers in 2008, representing 12 percent of the population. As of 2007, 32 percent of traders surveyed owned a mobile phone for their trading operations, ranging from 18 to 40 percent in specific markets. The percentage of adopters was considerably lower in rural areas during the same period, with estimated adoption at less than 10 percent during the

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[7]Based upon the author's interviews with mobile phone companies in Niger.
[8]Among all of the markets in the sample, only one market received new landline coverage between 1999 and 2008.

same period. Mobile phones were initially adopted by urban residents, functionaries and traders, who were more likely to be able to afford the handsets.

3. Information, Search and Producer Price Dispersion

There are a variety of channels through which information might influence consumer or producer welfare in agricultural markets. Jensen (2010) and Aker and Mbiti (2010) identify two potential direct channels through which mobile phones may affect market agents' behavior and agricultural market performance, namely arbitrage and market power. We will focus on the first channel in the main part of this paper, but provide some insights into the second channel in later sections.

In the Sahelian countries of sub-Saharan Africa, and Niger in particular, localized supply shocks result in price differences between markets in the presence of autarky. Such price differences should encourage arbitrage, but with high search costs and imperfect information, actual trade between markets may be sub-optimal. In Niger, farmers and traders have typically travelled to markets to learn about price information. A majority of farmers in our sample live 7.5 km away from their nearest market, or a 1.5 hour walk. This is a significant cost in terms of time and transport.[9]

The introduction of mobile phones in Niger decreased farmers' search costs across markets as compared to personal travel. Although mobile phones require an initial fixed cost, the variable costs associated with mobile phone use are significantly lower than

[9] Grain traders in Niger also typically relied upon personal travel to obtain price information prior to the introduction of mobile phones, thereby incurring high search costs.

equivalent travel and opportunity costs.[10] While mobile phone coverage did not expand into rural areas until 2008 – thereby limiting their use by farmers located in villages – they provided an alternative to obtaining price information once in the market. The total costs for a farmer for obtaining information from a market 10 km away might have fallen by 35 percent between 2001-2008; this is less than the decrease for traders, but still significant. Following the predictions in the consumer and labor search market literature, as well as the model developed by Aker and Tack (2010), we posit that the introduction of mobile phones will lead to an increase in the number of markets over which farmers' and traders' search and reduce producer price dispersion among markets with mobile phone coverage. This paper focuses on the latter hypothesis.

4. Data and Measurement

4.1. Producer Prices and Mobile Phone Coverage

This paper uses two primary datasets. The first includes detailed price and market-level data for 37 domestic markets over a ten-year period (1999-2008) provided from the Agricultural Market Information Service (AMIS). This dataset includes monthly farm-gate agricultural prices for millet and cowpea over a ten-year period (1999-2008). Farm-gate prices in this context represent the average price that farmers received for selling a commodity on a given market for that day. We also collected data on market-level factors that could potentially affect arbitrage and hence prices, including petrol prices, transport

[10] In 2008, a two-minute call to a market located 10 km away cost US$.50, as compared US$1 for roundtrip travel using a market truck or via cart.

costs, road distances, market latitude and longitude and rainfall.[11] We combine this dataset with data on the exact location and date of mobile phone coverage in each market, collected from the three primary mobile phone service providers operating in Niger.

These data have several limitations. First, although it provides price data from medium and large agricultural markets in Niger, it does not cover data from small (e.g., less than 20 traders) and remote agricultural markets. Therefore, if the markets that we observe are different from the markets that we do not observe, our results may have limited generalizability.

A second issue is that the current dataset focuses on producer prices. While demand for millet and sorghum (and hence consumer price data) is relatively constant throughout the year, producers do not necessarily have sufficient stocks to sell year round. Consequently, producer price data are not available on some markets during certain periods of the year. This means that we have an unbalanced panel. To econometrically deal with the missing data problem, we estimate the results using a balanced panel and by Heckman two-stage selection procedure.

4.2. Trader and Farmer Survey Data

To provide insight into the mechanisms behind the treatment effect, we match the price dataset with a dataset of traders and farmers in Niger collected between 2005 and 2007. The survey includes 415 traders and 215 farmers in 35 markets and villages across 6 geographic regions of Niger. Table A1 provides summary statistics of traders' characteristics. A majority of traders in Niger are male, from the Hausa ethnic group and

[11] Other secondary data were obtained from the *Syndicat des Transporteurs Routiers* for transport cost data; the *Direction de la Météo* for rainfall data; and the mobile phone service providers for mobile phone coverage.

have never attended school (Aker 2008, Aker and Tack 2010). Traders search for price information in an average of 3.8 markets, and buy and sell commodities in 4 markets. Traders have an average of 16 years' of trading experience, and only 10 percent changed their market since they began trading.

Table 1 provides summary statistics for farmers. Despite low levels of production, on average 25 percent of households sold millet and 75 percent sold cowpeas over two marketing seasons. Farmers are located 7.5 km from the nearest market, representing 1.5 hours' walk. In contrast with traders, farmers operate over a smaller geographic region for their trading activities: They sell in 1.46 markets and search for price information in 1.5 markets only.

5. Empirical Strategy

5.1. Empirical Strategy

The consumer search literature typically uses three measures of price dispersion: the sample variance of prices across markets over time (Pratt, Wise and Zeckhauser 1979), the coefficient of variation (CV) across markets (Eckard 2004, Jensen 2007), and the maximum and minimum prices across markets (Pratt, Wise and Zeckhauser 1979, Jensen 2007). The international trade literature uses measures of price dispersion between market pairs, such as the log of the price ratio between two markets or the standard deviation of price differences across markets (Engel and Rogers 1996, Parsley and Wei 2001, Ceglowski 2003). Mobile phone coverage in Niger was phased in throughout the country, with distances between mobile phone markets ranging from 8 km to 1,262 km in a single year. Our primary measure of spatial price dispersion is the absolute value of the difference in logs of producer prices for commodity i between markets j and k. Our basic regression is shown in Equation (1):

$$Y_{jk,t}^{i} = \beta_0 + \beta_1 mobile_{jk,t} + X'_{jk,t}\gamma + \alpha_{jk} + \theta_t + \mu_{jk,t} \quad (1)$$

where $mobile_{jk,,t}$ is a binary variable equal to one in month t if both markets j and k have mobile phone coverage, and 0 otherwise.[12] The α_{jk}'s are market-pair fixed effects, controlling for geographic location, urban status and market size. The θ_t's are a vector of date controls. These date controls include monthly fixed effects, as well as monthly fixed effects interacted with market-pair fixed effects. This allows the monthly fixed effects to differ by market pair and by the variables that could potentially affect mobile phone coverage. In addition to these fixed effects, we include a set of market-pair specific time-varying controls ($X_{jk,t}$) that affect spatial price dispersion, such as transport costs and the occurrence of drought. The parameter of interest β_1 captures the effect of mobile phone coverage in both markets on price dispersion across markets. This coefficient is identified off of the market pairs which receive mobile phone coverage between 2001 and 2008. The key identifying assumption of equation (1) is common trends across treated and untreated market pairs, as well as conditional independence between potential outcomes and the treatment variable.

As equation (1) is a time-series dyadic linear regression, we also include market-specific fixed effects and cluster by quarter, which corrects for spatial dependence and allows for some dependence between months.[13] We also estimate several variations on this regression, including alternative specifications of the dependent variable (such as the

[12]In all specifications, "treatment" is defined as the presence of a mobile phone tower, rather than mobile phone adoption.
[13]In future work, we will correct for potential serial correlation using the Newey-West correction.

max-min spread across markets within a particular region and the coefficient of variation among markets within a region) and the treatment variable.[14]

5.2. Endogenous Placement of Mobile Phone Towers

A central issue in our analysis is the concern that the factors that determine mobile phone coverage are correlated with our outcome of interest. Our analysis exploits the variation in mobile phone coverage across markets, thereby controlling for any fixed differences across markets over time. However, it remains important to understand what drives placement.

As a first approximation, we undertake two strategies. First, we attempt to understand the magnitude of this threat based upon interviews with the mobile phone operators about their choice of locations for mobile phone coverage. The mobile phone operators cited two issues when targeting locations, especially in earlier years: namely, whether the area was located in or near an urban center (greater than 35,000 people) and whether it was located near a southern border (Benin, Burkina Faso and Nigeria). After these initial criteria, the mobile phone companies considered cost factors, such as access to a paved road. While these discussions do not suggest that mobile phone coverage was randomly assigned, these demographic and infrastructure characteristics in Niger are relatively constant over time.

We are also able to test for this endogenous placement statistically using our data. To do so, we estimate the market-level determinants of having mobile phone coverage by

[14] Equation (1) can either be estimated via fixed effects transformation or first differencing. While both will be unbiased and efficient under standard assumptions, first differencing will be more efficient than fixed effects in the presence of a serial correlation problem. We estimate equation (1) using fixed effects, but also use first differences as a robustness check.

the end of the sample in 2008. We include variables cited by the mobile phone operators, including a location's urban status, road quality, latitude and longitude, elevation and slope, as well as regional fixed effects.

The results from these regressions are shown in Table 2. In general, the results support the interview evidence. More urban areas are likely to have mobile coverage, at least in the initial years, as are areas with paved roads; this is primarily due to the high correlation between urban status and road quality. We also see evidence that locations in the southern areas of the country were more likely to receive mobile phone coverage earlier, consistent with their focus on the southern borders. We see limited evidence that elevation, slope or latitude matters, suggesting that cost considerations were not a primary factor for consideration. It also suggests that mobile phone coverage was dispersed fairly evenly from the West to East of the country.

The inclusion of market-pair and market-level fixed effects means that any differences in price dispersion associated with these variables will not affect our results. However, if there are differential trends in producer prices across markets associated with these variables, this could impact our results. We deal with these issues in more detail in Section 6.2.

6. The Impact of Mobile Phones on Producer Price Dispersion

This section presents our results of the impact of mobile phone coverage on producer price dispersion across markets. In the first subsection we present our basic results by commodity and report variations in the effect by different specifications. The second subsection discusses whether our results are driven by differences in pre-treatment trends or observable characteristics. The third subsection presents the heterogeneous treatment effects, breaking down the effect by distance, road quality and period of year. The fourth subsection assesses the impact on farmers' welfare, using alternative measures of the dependent variable.

6.1. Average Effects of Mobile Phone Coverage on Producer Price Dispersion

Table 3 presents the regression results of equation (1) for cowpeas Controlling for monthly and market pair fixed effects, Column 1 shows that mobile phone coverage reduces producer price dispersion for cowpeas by 6.3 percent. These results are robust to the inclusion of additional covariates that also affect price dispersion across markets, such as transport costs and drought (Column 2). The standard errors increase when including market fixed effects and clustering by quarter, but the results are still statistically significant at the 1 percent level (Column 3).[15] We also redefine the treatment by including a binary variable equal to 1 when only one market in a pair has mobile phone coverage (Column 4). The effect of mobile phones in both markets is still negative and statistically significant on cowpea producer price dispersion, reducing price dispersion across markets by 7 percent. Estimating the regressing with an alternative specification of the dependent variable (the max-min price spread and the coefficient of variation across markets in a region) yields similar results (Table A2).[16]

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[15] Transforming the dependent variable using the absolute value of the price difference, mobile phones reduce price dispersion across markets by 11 CFA/kg as compared with a pre-treatment price dispersion of 140 CFA/kg.

[16] In order to account for missing data in some markets during periods when farmers are not selling cowpea, we employ two techniques. We first use a two-stage Heckman procedure, estimating the Mills' ratio for each market separately (Table A3) and then constructing the sum or product of the inverse Mills' ratio and including this as a separate regressor. We also use market pairs that have a full set of price data for all time periods in the sample, or a balanced panel. The results are provided in Table A4. Results are similar in magnitude and statistical significance when using the inverse Mills' ratio. The regression results when using the balanced panel suggest that mobile phone coverage reduces price dispersion by 4 percent, and this result is statistically significant at the 1 percent level.

While not the primary focus of this paper, Table A5 presents the regression results of equation (1) for millet, which is more easily stored and sold less frequently by farmers. The coefficient on mobile phone coverage is negative but not statistically significant at conventional levels (Columns 1-4). This is in contrast to the results of Aker (2010), which found that mobile phone coverage reduced consumer price dispersion for millet by a minimum of 10 percent (Aker 2010). This suggests that mobile phone coverage is more useful for more perishable traded commodities in Niger, such as cowpea. This also suggests that information for millet farm-gate prices could be strongly localized or useful for only certain segments of the population, a hypothesis that we will test in Section 6.3.

6.2. Threats to Identification of Mobile Phone Coverage

As initial mobile phone coverage in Niger was not randomly assigned, current market outcomes could be the result of differences in markets prior to the placement of mobile phone towers. The main concern is the possibility that current producer price dispersion is due to pre-treatment time-invariant or time-varying characteristics that led to the placement of mobile phone towers. Table 4 shows the differences in means for pre-treatment outcomes and covariates at the market (Panel A) and market pair level (Panel B).[17] The difference in average producer price levels for millet and cowpea in the pre-treatment period (1999-2001) is small and not statistically different from zero. In looking at market pairs, there is not a statistically significant difference in producer price dispersion for millet or cowpea during the pre-treatment period. However, as price

[17]As mobile phone coverage was phased in over time, we also test for differences in pre-treatment trends in market outcomes. The trends are not statistically different from zero, except for the market pair treated in 2001.

dispersion is lower in non-mobile phone markets during the pre-treatment period, this suggests that our results might be a lower bound of the treatment effect.

A majority of the differences in means for other pre-treatment covariates are not statistically significant from zero, with the exception of a market's urban status. This is expected, as a market's probability of receiving mobile phone coverage, at least initially, depended upon whether it was located in an urban center. Overall, the results in Table 4 suggest that there were no statistically significant differences in pre-treatment characteristics between the two groups.[18]

Identification of equation (1) relies upon the assumption of similar trends across mobile phone and non-mobile phone markets. While we cannot directly test for parallel trends, we can use data prior to the introduction of mobile phones in 2001. If trends across treated and control markets were the same during the pre-treatment period, then they are more likely to have been the same in the post-treatment period in the absence of expansion in mobile coverage. Table 5 presents the results of a regression of price levels and differences on interaction terms between the year of coverage during the pre-treatment periods (1999-2001). Overall, the results suggest that the assumption of parallel trends might be valid. The pre-intervention trends for the log of millet prices (Column 1), millet price dispersion (Column 2) and cowpea price dispersion (Column 4) are not statistically different from zero for markets and market pairs that received mobile phone coverage during different periods. The sole exception is for cowpea price levels (Column 3)

[18]This assertion is supported by using pre-treatment covariates to predict the onset of mobile phone coverage. Regressing mobile phone coverage in market i at time t on time-varying and time-invariant characteristics (ie road quality, drought, latitude and longitude, market size and urban status) suggests that the probability of mobile phone coverage is strongly positively correlated with urban status and road quality at time t, but not correlated with latitude, longitude, drought or the number of traders operating on the market. Overall, however, the pre-treatment characteristics do not strongly predict *eventual* coverage in a particular market. Results are available in Table A1.

and price dispersion for those markets treated during the first year of coverage (2001/2002). This raises some concerns with respect to the validity of the assumption of parallel trends for those market pairs. As a robustness check, we estimate the regressions in Table 3 by dropping market pairs that received mobile phone coverage during the first year and find that the results are unchanged.

As a final test, we conduct a falsification check by estimating the impact of mobile phones on producer price dispersion for millet and cowpeas during the pre-treatment period (1999-2001). For all specifications, the estimated effect is close to zero and not statistically significant at conventional levels (Table 6). The results suggest a lack of direct evidence of selection on unobservable characteristics.

6.3. Heterogeneous Effects of Mobile Phone Coverage

The evidence above suggests that price dispersion of farm-gate prices for cowpeas decreases in response to the introduction of mobile phone coverage. Here we attempt to assess these effects by distance between markets, road quality and the period of year. Cowpea in Niger is actively traded throughout the country and is sold by a majority of farmers, as it is the primary cash crop in Niger. The period of heaviest trade for cowpea occurs immediately after the harvest, as the crop is highly susceptible to pest infestations, thereby suggesting that the cowpea market is relatively "thick" during the post-harvest period. Given these characteristics of the cowpea market, we would expect a stronger impact of mobile phone coverage for markets that are farther apart and during periods of the year when trade is somewhat thin.

Table 7 summarizes the effect of mobile phone coverage by distance, road quality and period of the year. Columns 1 and 2 show the impacts of mobile phone coverage by distance, including an interaction term between mobile phone coverage and distance between markets (Column 1), as well as a binary variable for markets that are located more than 350 km apart (Column 2). Both interaction terms are negative and statistically significant at the 1 percent level, suggesting that mobile phone coverage is more effective in reducing producer price dispersion for markets that are located farther apart. Mobile phone coverage reduces price dispersion by 11.5 percent for markets located more than 350 km apart, as compared with a reduction of 3.5 percent for markets in closer proximity.

Column 3 presents the results by road quality, including an interaction term between mobile phone coverage and paved roads. The coefficient on the interaction term is positive and statistically significant, suggesting that mobile phone coverage is less useful in reducing price dispersion for markets that are connected by paved roads. This suggests that mobile phone coverage, to some extent, is a substitute for road quality. [19]

Column 4 presents the results by period of the year, including an interaction term between mobile phone coverage and the harvest period. The coefficient on the interaction term is positive and statistically significant, suggesting that mobile phone coverage reduces producer price dispersion during periods of the year other than harvest time.[20]

7. Mobile Phones and Farmers' Prices

[19] Similar regressions for millet are provided in Table A4. The results suggest that mobile phone coverage does not have a differential impact on markets that are less than 350 km apart (Column 2), but that it does have a negative and statistically significant impact on markets that are less than 100 km apart (not shown). This suggests that information and trade for millet is more localized. Mobile phone coverage only reduces millet producer price dispersion during the non-harvest period, reducing price dispersion by 2 percent.

[20] As cowpeas are primarily traded during the harvest period, markets are primarily "thick" and more closely integrated during this time. Outside of the harvest period, thin markets imply less integration, and hence mobile phone coverage can reduce costs and reduce price dispersion.

As is typical in many agricultural markets in sub-Saharan Africa, there is often a chain of intermediaries between the farm gate and the consumer, including traders, wholesalers and retailers. As a result, farmers rarely sell directly to consumers, but rather sell to traders located within the village or market. While mobile phones may lead to a reduction in search costs and price dispersion across markets, thereby resulting in a net welfare gain to society, how these gains are allocated among consumers, traders and farmers remains ambiguous.[21] In addition, mobile phones may lead to welfare transfers among agents, even when there is no net welfare change. For example, if there are significant barriers to entry in becoming a trader, they may act as local monopsonies vis-a-vis farmers, thereby resulting in a lower farm-gate price for farmers. As a result, the lower search costs associated with mobile phones may reduce traders' market power, which could lead to higher prices offered to farmers (Jensen 2010).

In related work, Aker (2010) tested for the degree of competition on local markets with respect to consumer prices in Niger, and found little evidence of uncompetitive markets. Following Jensen (2007) and Goyal (2010), we attempt to measure the impact of mobile phones on farmers' welfare by assessing its impact on producer price levels and the coefficient of variation. This involves estimating the following equation:

$$Y_{jt}^{i} = \beta_0 + \beta_1 mobile_{j,t} + X_{j,t}'\gamma + \alpha_j + \theta_t + \mu_{j,t} \quad (2)$$

where $Y_{j,t}^{i}$ represents either the log of farm-gate prices or the intra-annual coefficient of variation of farm-gate prices of commodity i on market j at time t, $mobile_{j,t}$ is a binary

[21] As Jensen (2010) points out, the "welfare 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) to where it is more highly valued on the margin (the market with low supply relative to demand and thus high price)."

variable equal to one in month or year t if market j has mobile phone coverage, and 0 otherwise. $X_{j,t}$ is a vector of variables that affect producer price levels or the coefficient of variation on market j, such as the occurrence of drought. The α_j's are market fixed effects, including controlling for geographic location, urban status and market size, and θ_t are monthly fixed effects. Similar to the previous specification, the parameter of interest is β_1.

Table 8 presents the results of the impact of mobile phone coverage on producer price. Columns 1-3 present a regression of the log of cowpea prices on mobile phone coverage, controlling for time fixed effects, market fixed effects and time-varying covariates. Contrary to existing research of the impact of information technology on fishermen (Jensen 2007) and soybean producers in India (Goyal 2010), mobile phone coverage does not appear to have a positive effect on producer cowpea prices in Niger. While the effect is positive for all specifications, it is not statistically significant at conventional levels.

While mobile phone coverage did not increase cowpea prices, it does have an impact on the intra-annual price risk faced by farmers. Using the intra-annual coefficient of variation, the introduction of mobile phone coverage reduced the coefficient of variation by an average of 6 percent. As compared with an average coefficient of variation of 26 percent during the pre-treatment period, this is a potentially significant reduction in producers' price risk.

Although assessing producer welfare involves more than the change in producer prices or the coefficient of variation, we do not have the data to undertake a full welfare analysis. Consequently, we provide a rough approximation. Prior to the introduction of mobile phones, consumers faced an intra-annual distribution of millet prices, $F(p) \sim p_F, \sigma_F^2$ After the introduction of cell phones, producers faced a distribution of $G(p) \sim p_G, \sigma_G^2$, where $p_F > p_G, \sigma_F^2 > \sigma_G^2$. This suggests that $\int_0^{\bar{p}} G(p)dp \leq \int_0^{\bar{p}} F(p)dp \quad \forall p \in [0, \infty]$, implying that *G(p)* second-order stochastically dominates *F(p).* A simple graphical analysis of the density functions of cowpea prices by mobile phone coverage supports these assumptions (Figure 3). Consequently, risk-averse, expected profit-maximizing producers would prefer *G(p),* assuming that farmers are net sellers of cowpea. While the welfare analysis would differ if farmers consumed the good (Fafchamps 1992), the assumption that farmers are net sellers of cowpea is a valid one in the Nigerien context.

8. Mechanisms

We draw several conclusions based upon the results in Sections 6 and 7. First, the introduction of mobile phone coverage into agricultural markets in Niger resulted in a decrease in producer price dispersion for cowpeas but not for millet, suggesting that information technology is more useful for semi-perishable commodities. This effect seems to be concentrated in markets that are more than 350 km apart, for those that are linked by unpaved roads and outside of the harvest period. The observed reduction does not appear to be driven by changes in observable or unobservable characteristics. Finally, mobile phone coverage does not appear to have an impact on producer price levels, but does appear to reduce the intra-annual coefficient of variation.

In this section we provide some initial evidence on the mechanisms that drive this effect. We distinguish between two possibilities. The first is that the introduction of mobile phone coverage into a market may affect *farmers*' access to information, thereby allowing them to search over more markets and better take advantage of arbitrage opportunities, thereby reducing price dispersion. Alternatively, mobile phone coverage may improve *traders'* access to information on farm-gate prices, thereby leading to a reduction in price dispersion but not necessarily leading to higher farm-gate prices. To disentangle the mechanism, we use trader and farmer survey data collected between 2005 and 2007.

8.1. Evidence on Traders' Access to Information

Aker and Tack (2010) find evidence in favor of increased access to information and changes in traders' search and marketing behavior as a result of mobile phone coverage. Using the trader-level dataset, they find that mobile phone coverage was associated with an increased probability of traders' searching for price information, a 25 percent increase in the number of search markets and a 22 percent increase in the number of people contacted for price information. In addition, mobile phone coverage was associated with a change in arbitrage behavior: traders in mobile phone markets increased the number of markets where they bought and sold agricultural commodities by 25 percent. The results do not appear to be driven by traders' selection into mobile phone markets or changes in the composition of traders on local markets.

8.2. Evidence on Farmers' Access to Information

Table 9 provides some initial evidence of the impact of mobile phone coverage on farmers' behavior. While the survey did not collect detailed information on farmers' search behavior, it did collect data on whether farmers' searched, the mechanisms used and their marketing behavior. As none of the villages in our sample had mobile phone coverage between 2005 and 2007, the primary independent variable of interest is a binary variable for whether the nearest market to the farmers' home village had mobile phone coverage during year *t*, 0 otherwise.

Similar to the traders' results, the introduction of mobile phone coverage is associated with an increase in farmers' probability of searching for price information, increasing a farmers' probability of searching for price information by 20 percent. However, unlike traders, farmers do not appear to increase the number of markets where they search for price information, nor do they appear to change their arbitrage behavior in response to increased search. This suggests that there could be other factors, such as farmers' access to credit or bargaining power vis-à-vis traders, that affect farmers' arbitrage behavior.

9. Conclusion

This paper provides some evidence of the impact of mobile phone technology on producer price dispersion for agricultural commodities in Niger. Although mobile phone coverage did not reach remote rural areas during the period of our analysis, the introduction of mobile phone coverage reduced price dispersion in farm-gate prices for cowpeas over the period of our sample. The effect was much stronger for markets located farther apart and for those linked by unpaved roads. Unlike other studies, the results suggest that mobile phones did not increase the prices that farmers' received, but it did reduce the intra-annual coefficient of variation.

Overall, these results suggest that information technology resulted in net welfare gains to society, but that these effects primarily benefitted traders and consumers, consistent with previous research. This could be due to several factors, such as limited mobile phone coverage in remote rural areas during the period under consideration, localized trader monopsonies or missing credit markets that potentially affect farmers' ability to engage in optimal arbitrage. Such results suggest that future analyses of rural infrastructure investments, particularly in the telecommunications sector, need to carefully assess the distribution of welfare gains among different agents and complementary public or private goods that might be required.

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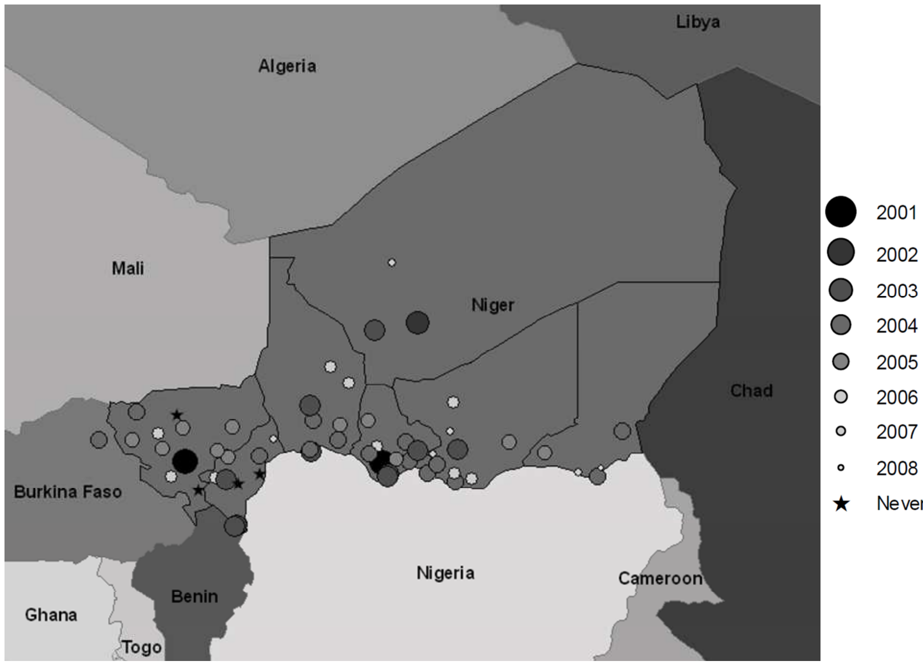
<u>Figure 1. Mobile Phone Coverage by Market and Year, 2001-2008</u>



Notes: Data collected by the author from the mobile phone companies in Niger (Celtel/Zain, Telecel and Sahelcom). The map shows mobile phone coverage for grain markets between 2001 and 2008.

Figure 2. Mobile Phone Subscriptions and Landline Subscriptions in Niger, 2001-2008

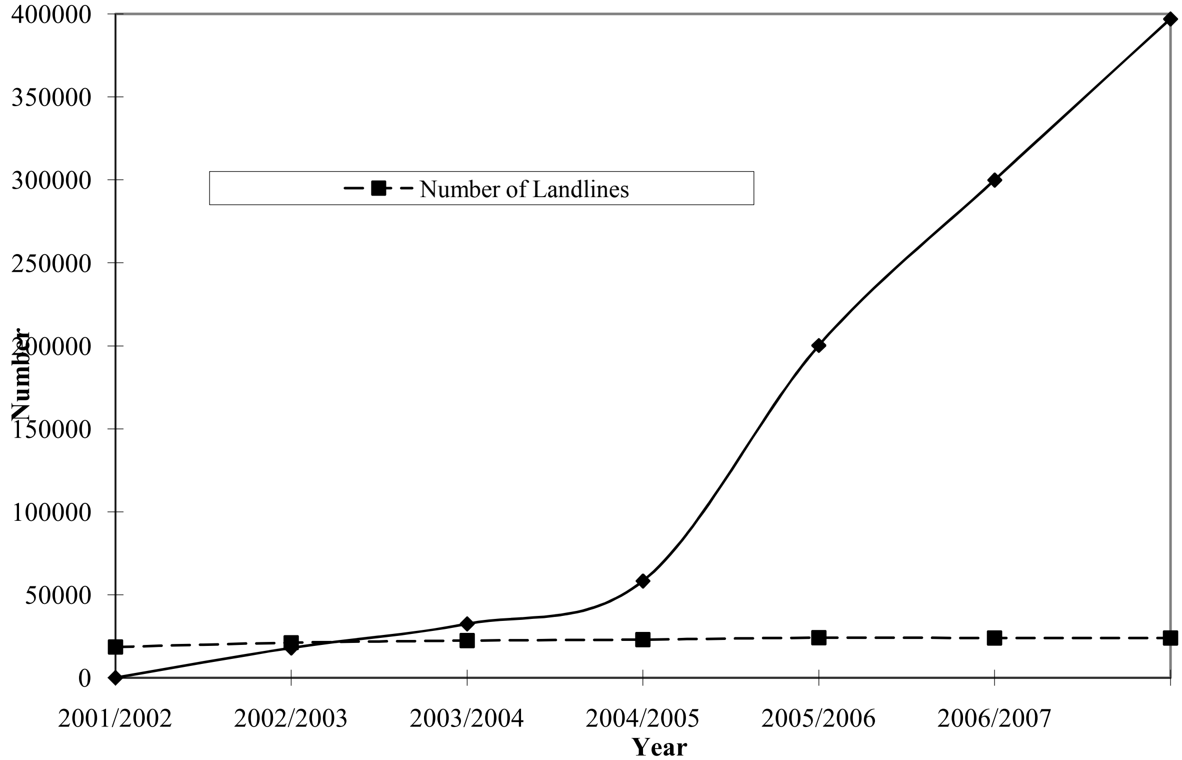


Figure 3.

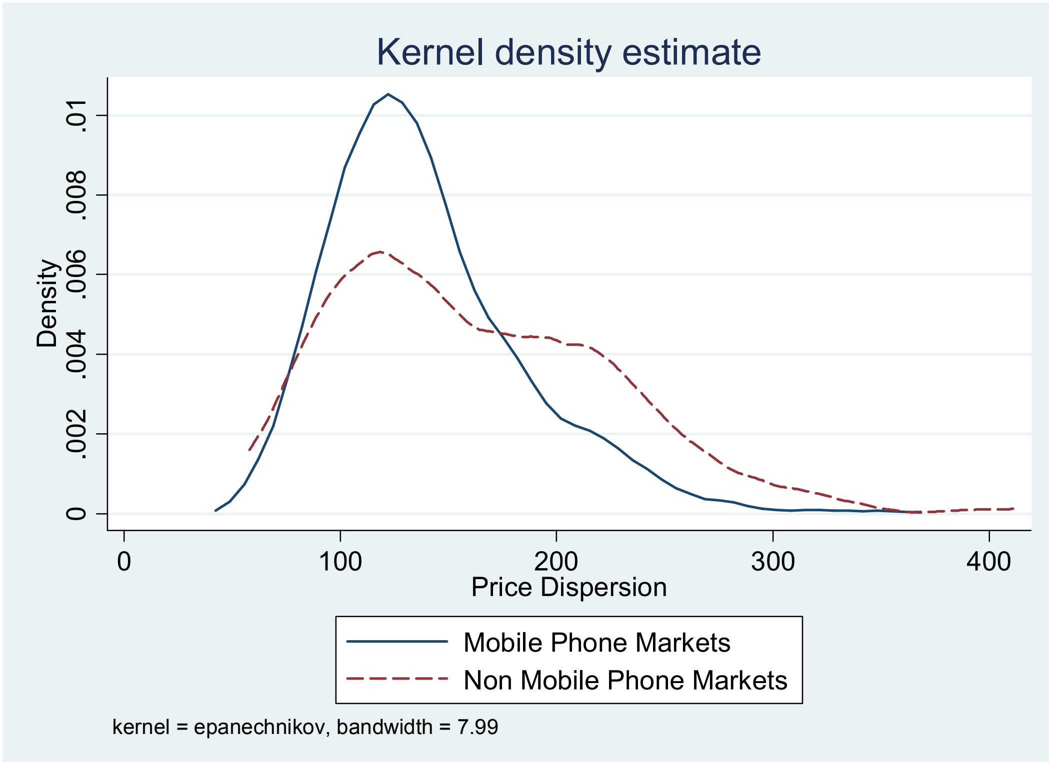

Kernel density estimate
Density
0
.002
.004
.006
.008
.01
0
100
200
300
400
Price Dispersion
Mobile Phone Markets
Non Mobile Phone Markets
kernel = epanechnikov, bandwidth = 7.99

Table 1. Description of Key Variables: Farmers

Variable Name	Sample Mean (s.d.)
Panel A: Farmer-Level Characteristics	
Socio-Demographic Characteristics	
Household head	.915(.279)
Member of hausa ethnic group	.675(.469)
Age	49(16)
Gender(male=0, female=1)	.01(.09)
Education (0=elementary or above, 1=no education)	.85(.35)
Household size	12.6(7.92)
Panel B. Agricultural Marketing Activities	
Sold millet in the past year	0.25
Sold cowpea in the past year	0.75
Purchased millet since the previous harvast	0.91
Number of hours walking to principal market	1.53
Access to a paved road	.269(.444)
Number of purchase and sales markets	1.46(.670)
Member of a producers' association	0.22
Sold to intermediary since the last harvest	0.45
Bought agricultural products on credit in the past year	0.41
Received payment in advance for harvest	0.16
Responsible for transport if sell product	0.64
Access to market information	
Personal conversations with traders and farmers	0.75
Radio (MIS)	0.09
Other	0.14
Primary marketing constraints	
Price levels	.
Transport/poor roads	0.18
Price instability	0.13
Access to credit	0.05
Others	0.14

Notes: Data from the Niger farmer survey collected by Aker between 2005 and 2007. Sample means are weighted by inverse sampling probabilities.

Table 2. Determinants of Mobile Phone Coverage in Niger

	(1)	(2)
Log(elevation)	-.011 (.044)	-.041 (.129)
Dummy slope	.019 (.035)	.070 (.107)
Urban center	.279*** (.018)	.754*** (.051)
Road quality	.036** (.017)	.121** (.055)
Latitude	-.012 (.023)	-.027 (.025)
Longitude	.010*** (.004)	.031*** (.011)
Constant	.360 (.272)	-.339 (.515)
Region fixed effects	No	Yes
R^2	0.0852	0.0663
No obs	4032	4032

Notes: Data collected by one of the authors from the mobile phone companies in Niger between 2001-2008. The slope dummy is equal to 1 if the location is steeply sloped, 0 otherwise. Urban center is equal to 1 if the location has a population greater than 35,000 people, 0 otherwise. Road quality is equal to 1 if the location has access to a paved road, 0 otherwise.

Table 3. Impact of Mobile Phones on Farm-Gate Price Dispersion for Cowpea

Dependent variable: $\|\ln(P_{it}\text{-})\text{-}ln(P_{jt})\|$	**(1)**	**(2)**	**(3)**	**(4)**
Mobile coverage both markets	- 0.0631***	- 0.0622***	- 0.0630***	-0.0733***
	-0.007	-0.006	-0.013	-0.008
Mobile coverage one market				-0.0119**
				-0.005
Drought both markets		- 0.0548***	-0.0535**	-0.0567***
		-0.01	-0.022	-0.01
Transport costs between markets		0.0113***	0.006***	0.011***
		-0.001	-0.001	-0.001
Monthly fixed effects	Yes	Yes	Yes	Yes
Market pair fixed effects	Yes	Yes	Yes	Yes
Number of observations	39120	39120	39120	39120
R-squared	0.154	0.165	0.382	0.165
Number of market pairs	970	970	970	970

Notes: Robust standard errors are in parentheses. *** denotes signficant at 1 percent level, ** denotes significant at .05 percent level and * denotes significant at .10 percent

Table 4. Comparison of Observables by Mobile Phone Coverage in the Pre-Treatment Period (1999-2001)

	Unconditional Mean		Difference in Means
Pre-Treatment Observables	Mobile Phone Mean (s.d.)	No Mobile Phone Mean (s.d.)	Difference in Means s.e.
Panel A. Market Level Data			
Millet Farm-Gate Price level (CFA/kg)	120.76(27.9)	118.48(29.28)	2.27(9.68)
Cowpea Farm-Gate Price level (CFA/kg)	174.07(43.8)	178.22(41.64)	-4.14(3.82)
Road Quality to Market (1=paved)	.659(.474)	.5(.503)	.159(.268)
Market Size (More than 100 traders=1)	.5(.503)	.341(.474)	-.159(.269)
Hausa ethnic group (Hausa=1)	.620(.486)	.75(.435)	-.130(.238)
Drought in 1999 or 2000	.058(.234)	.062(.243)	-.004(.035)
Distance (km) to international border	91.32(64.96)	92.39(54.06)	-1.07(29.90)
Urban center(>=35,000)	.349(.477)	0(0)	.349***(.090)
Panel B. Market Pair Level Data			
Millet farm-gate price dispersion (CFA/kg)	15.53(14.29)	12.54(8.98)	2.99(1.97)
Cowpea farm-gate price dispersion (CFA/kg)	30.45(25.69)	27.39(17.49)	3.05(2.27)
Distance between markets (km)	371.57(225)	379.50(245)	-7.93(71.10)
Road Quality between markets (both paved=1)	.397(.489)	.5(.501)	-.103(.145)
Transport Costs between Markets (CFA/kg)	10.80(6.00)	11.01(6.53)	-.209(1.87)

Notes: Data from the Niger trader survey and secondary sources. In Panel A, "mobile phone" market pairs are pairs where both markets received mobile phone coverage at some point between 2001-2008; "no mobile phone" market pairs are those pairs where either one or both markets never received mobile phone coverage during this period. In Panel B, "mobile phone" markets are those that received coverage at some point between 2001-2008, whereas "no mobile phone" markets are those markets that never received coverage. The number of markets is 37. Huber-White robust standard errors clustered by market (Panel A) and by market pair (Panel B) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. Prices are deflated by the Nigerien Consumer Price Index.

Table 5. Differences in Pre-Treatment Farm-Gate Price Trends by Treatment Period

Dependent Variable	Millet $\ln(P_{it})$ (1) Coef. (s.e.).	Millet $\lvert\ln(P_{it})-\ln(P_{jt})\rvert$ (2) Coef. (s.e.).	Cowpea $\ln(P_{it})$ (3) Coef. (s.e.).	Cowpea $\lvert\ln(P_{it})-\ln(P_{jt})\rvert$ (4) Coef. (s.e.).
Markets Treated Year 1*Change in Pre-Treatment	.113 (.096)	.442*** (.012)	.107* (.055)	.201*** (.039)
Markets Treated Year 2*Change in Pre-Treatment	.092 (.101)	-.279 (.221)	.048 (.092)	-.045 (.040)
Markets Treated Year 3*Change in Pre-Treatment	.124 (.101)	-.290 (.218)	.248 (.171)	.007 (.039)
Markets Treated Year 4*Change in Pre-Treatment	.143 (.100)	-.277 (.217)	.113* (.066)	-.041 (.036)
Markets Treated Year 5*Change in Pre-Treatment	.188 (.116)	-.217 (.217)	.078 (.079)	.013 (.036)
Markets Treated Year 6*Change in Pre-Treatment	.006 (.102)	-.251 (.211)	-.023 (.066)	-.008 (.036)
R^2	0.3677	0.1711	0.1597	0.1133
# of observations	423	7190	408	6696

Notes: Data from the Agricultural Market Information Services (AMIS) and mobile phone service providers in Niger. Each row represents the year in which a specific market first received coverage, interacted with the change between the pre-treatment years (1999/2000 until 2000/2001). *E.g.,* "markets treated year 1" represents the market that received mobile phone coverage in 2001, the first year of mobile phone coverage. Huber-White robust standard errors clustered by market are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are in 2001 CFA.

Table 6. Tests of the Conditional Independence Assumption

Dependent Variable: Cowpea *Price Dispersion in 1999-2001*

	Coeff(s.e.)	Coeff(s.e.)	Coeff(s.e.)
Ever received mobile phone coverage	.004(.017)	-.006(.015)	-.006(.013)
Monthly fixed effects	Yes	Yes	Yes
Other covariates	No	Yes	Yes
Market-pair specific time trend	No	No	Yes
R-squared	0.2904	0.3164	0.3164
Number of observations	6696	6696	6696

Notes: Data from the Nigerien Agricultural Market Information System, mobile phone companies and from other primary and secondary sources in Niger. Mobile phone dummy =1 for those market pairs that ever received mobile phone coverage between 2001-2008, 0 otherwise. Pre-treatment period is the period prior to the introduction of mobile phone coverage in Niger. Huber-White robust standard errors clustered by quarter are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are deflated by the Nigerien Consumer Price Index.

Table 7. Heterogeneous Impact of Mobile Phones on Cowpea Producer Price Dispersion

Dependent variable: $\|\ln(P_{it})-\ln(P_{jt})\|$	**(1)**	**(2)**	**(3)**	**(4)**
Mobile coverage both markets	-.024*** (.007)	-.049*** (.006)	-.067*** (.007)	-.074*** (.007)
Mobile coverage*distance	-.0001*** (.000)			
Mobile coverage*distance binary variable (distance=1 if greater than 350 km)		-.033*** (.008)		
Mobile coverage*road quality (Paved=1)			.012*** (.005)	
Mobile coverage*harvest (Harvest=1)				.024*** (.006)
Joint effect significant	Yes	Yes	Yes	Yes
Monthly fixed effects	Yes	Yes	Yes	Yes
Market pair fixed effects	Yes	Yes	Yes	Yes
Other covariates	Yes	Yes	Yes	Yes
Number of observations	38820	38820	38820	38820
R-squared	0.2443	0.2518	0.2542	0.2566
Number of market pairs	970	970	970	970

Notes: Robust standard errors are in parentheses. *** denotes signficant at 1 percent level, ** denotes significant at .05 percent level and * denotes significant at .10 percent

Table 8. Impact of Mobile Phones on Cowpea Producer Welfare

Dependent variable:	*ln(P_{it})*			*Coefficient of Variation*		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Mobile phone coverage	.007 (.033)	.009 (.034)	.009 (.034)	-.062*** (.020)	-.062*** (.021)	-.062*** (.020)
Other covariates	No	Yes	Yes	No	Yes	Yes
Monthly fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Market fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Market-specific fixed effects	No	No	Yes	No	No	Yes
R-squared	0.617	0.628	0.628	0.216	0.216	0.216
Number of observations	2,132	2,132	2,132	3,033	3,033	3,033
Pre-treatment mean	131(37)	131(37)	131(37)	.264(.06)	.264(.06)	.264(.06)

Notes: Standard errors are in parentheses. *** denotes signficant at 1 percent level, ** denotes significant at .05 percent level and * denotes significant at .10 percent

Table 9. Impact of Mobile Phone Coverage on Farmers' Behavior

Dependent variable:	**(1) OLS Estimate**	**(2) Poisson QMLE Estimate**	**(3) Probit MLE Estimate**
	Coeff (s.e.)	**Coeff (s.e.)**	**Coeff (df/dx) (s.e.)**
Searched for price information (1=yes)	.074** (.035)		.074** (.031)
Use personal contacts to obtain market information	.108 (.247)		.115 (.249)
# of Purchase and Sales Markets	.188 (.209)	.079 (.114)	

Notes: Data from the Niger trader survey and secondary sources collected by one of the authors. The number of observations is 200 farmers across two years. Each entry represents a separate regression. Controls in the OLS, Poisson and probit regression include time-invariant farmer and market characteristics. Weighted by inverse sampling probability. Huber-White robust standard errors clustered by market are in parentheses for the OLS estimates. "adj s.e." refers to robust standard errors corrected for heteroskedasticity, clustering and Poisson regression (underdispersion) are in parentheses for the Poisson estimates. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level.

Appendices

Table A1. Description of Key Variables: Grain Trader and Market Baseline Characteristics

Variable Name	Mean (s.d.)
Panel A: Trader-Level Characteristics	
Socio-Demographic Characteristics	
Ethnicity	
Hausa	0.65
Zarma	0.17
Other	0.18
Age	45.71(12.2)
Gender(male=0, female=1)	0.11(.32)
Education (0=elementary or above, 1=no education)	0.62(.48)
Trader type	
Wholesaler	0.17
Semi-wholesaler	0.15
Intermediary	0.15
Retailer	0.53
Years' of Experience	16.0(10.2)
Commercial Characteristics	
Engage in trading activities all year round	.94(.22)
Trade in agricultural output products only	0.98(.02)
Engage in activities outside of trade	0.92(.28)
Co-ownership of commerce	.19(.40)
Changed "principal market" since he/she became a trader	.10(.31)
Number of markets where trade goods	4.42(2.84)
Number of markets where follow prices	3.87(3.0)
Number of days of storage	7.14(9.8)
Own cell phone	.29(.45)
Own means of transport (donkey cart, light transport)	.11(.32)
Panel B. Market-Level Characteristics	
Type of market	
Collection	0.19
Wholesale	0.36
Retail	0.30
Border	0.15
Number of traders	137(99.6)
Road quality (1=paved road, 0=otherwise)	.71(.45)
Market located more than 50 km from paved road	.07(.26)
New paved road in past 5 years	.15(.37)

Notes: Data from the Niger trader survey collected by one of the authors. Sample means are weighted by inverse sampling probabilities.

Table A2. Impact of Mobile Phones on Farm-Gate Price Dispersion for Cowpea

Dependent variable:	ln(Max-Min) Price Spread		Coefficient of variation	
	(1)	(2)	(3)	(4)
Percentage of markets with mobile phone coverage in region j at time t	-.458***	-.505***	-.057***	-.060***
	(.104)	(.105)	(.014)	(.014)
Additional covariates	No	Yes	No	Yes
Monthly fixed effects	Yes	Yes	Yes	Yes
Market fixed effects	Yes	Yes	Yes	Yes
Number of observations	2503	2503	2503	2503
R-squared	0.2607	0.2651	0.2841	0.2625
Number of market pairs	30	30	30	30

Notes: The max-min price spread is the difference between the maximum and minimum producer price for cowpea among markets in a given region at time t. The coefficient of variation is the standard deviation of producer prices among markets in a region a time t divided by the mean of producer prices for markets in a region at time t. Robust standard errors are in parentheses. *** denotes significant at 1 percent level, ** denotes significant at .05 percent level and * denotes significant at .10 percent

Table A3: First Stage of Mills Ratio

	Dependent variable: Price Data Available in Market *i* at time *t*
Drought both markets	-.096***
	(.038)
Urban center (1=yes)	-.112***
	(.015)
Road quality (1=paved)	.184***
	(.008)
Period of year (1=harvest)	.208***
	(.055)
Monthly fixed effects	Yes
Number of observations	114048
Chi-squared	13913.08
Pseudo R^2	.0949

Notes: A binary variable for whether price data are available for a given market during a given month is regressed on exogenous variables. ***, **, * denote statistically significance at 1, 5, 10 percent, respectively. Robust standard errors clustered at the market pair level.

Table A4. Impact of Mobile Phones on Farm-Gate Price Dispersion for Cowpea

	Inverse Mills' Ratio				Balanced Panel			
Dependent variable: $\|\ln(P_{it}\text{-})\text{-}ln(P_{jt})\|$	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Mobile coverage both markets	-.063***	-.062***	-.063***	-.076***	-.039***	-.039***	-.041***	-.062***
	(.007)	(.006)	(.012)	(.014)	(.009)	(.009)	(.017)	(.011)
Mobile coverage one market				-.014**				-.048*
				(.005)				(.025)
Inverse Mills' Ratio	Yes	Yes	Yes	Yes	No	No	No	No
Additional covariates	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Monthly fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market fixed effects	No	No	Yes	Yes	No	No	Yes	Yes
Number of observations	39120	39120	39120	39120	8890	8890	8890	8890
R-squared	0.0786	0.2614	0.382	0.382	0.1961	0.2625	0.322	0.3232
Number of market pairs	970	970	970	970	96	96	96	96

Notes: Robust standard errors are in parentheses. *** denotes signficant at 1 percent level, ** denotes significant at .05 percent level and * denotes significant at .10 percent

Table A5. Impact of Mobile Phones on Farm-Gate Price Dispersion for Millet

Dependent variable: $\lvert \ln(P_{it-})-ln(P_{jt}) \rvert$	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Mobile coverage both markets	-.001	-.001	-.002	-.003	-.003	.008	-.012	-.018***
	(.003)	(.003)	(.011)	(.004)	(.013)	(.009)	(.013)	(.005)
Mobile coverage one market				-.001				
				(.004)				
Mobile phone coverage*distance					-.000	-.020		
					(.000)	(.014)		
Mobile phone coverage*harvest							.028*	
							(.016)	
Mobile phone coverage*road quality								.035***
								(.005)
Joint significance					No	No	No	Yes
Additional covariates	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monthly fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	36436	36436	36436	36436	36436	36436	36436	36436
R-squared	0.0497	0.0536	0.316	0.316	0.076	0.0938	0.0877	0.085
Number of market pairs	858	858	858	858	858	858	858	858

Notes: Robust standard errors are in parentheses. *** denotes signficant at 1 percent level, ** denotes significant at .05 percent level and * denotes significant at .10 percent