



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Information and Firms' Search Behavior*

Jenny C. Aker¹ and Jesse B. Tack²

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011.

Copyright 2011 by Jenny Aker and Jesse Tack. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided this copyright notice appears on all such copies.

Abstract. Information and communications technologies (ICTs) have spread rapidly over the past decade. There has been considerable interest in the effect of such technology on search costs, search behavior and welfare outcomes, particularly in developing countries. This paper investigates the impact of a new search technology, mobile phones, on traders' search and marketing behavior in Niger. We construct a novel theoretical model of sequential search, in which traders engage in optimal search for the maximum sales price, net transport costs. The model predicts that the introduction of a new search technology, such as mobile telephones, will increase traders' reservation sales prices and the number of markets over which they search. To test the predictions of the theoretical model, we use a unique market and trader panel dataset from Niger. We show that the duration of mobile phone coverage increases the number of markets over which traders search and their number of market contacts. This result increases nonlinearly in the duration of mobile phone coverage in a particular market, suggesting that the relationship between mobile phone coverage and traders' search behavior is convex with larger effects accruing over time. This effect is also stronger for larger traders – namely those who trade over longer distances – but does not appear to have differential effects by gender, age, road quality or market size. These results provide important empirical evidence for search theoretic models that assume the existence of a causal link between search costs and search behavior and suggest potential welfare improvements.

JEL Codes: O1, O3, Q13

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

*This research was partially funded by Rocca Dissertation Fellowship, Catholic Relief Services, CARE, World Vision, the Ford Foundation, UC-Berkeley's CIDER, the World Bank and USAID. Jenny C. Aker is grateful to Ali Abdoulaye, Erin Baldrige, Ousseini Sountalma, Lisa Washington-Sow and the data collection team for their support and patience in Niger. We would like to thank Maximilian Auffhammer, Jeffrey LaFrance, John Morgan and seminar participants at Bates College, Boston College, the Center for Global Development, Fordham University, Tufts University, University of Delaware, University of California-Berkeley, University of California-Davis, University of Oxford, University of Virginia, Williams College, and the Bureau for Research and Economic Analysis of Development (BREAD), Center for the Study of African Economics (CSAE), Pacific Development (PACDEV) and Working Group in African Political Economy (WGAPPE) conferences for excellent comments on theoretical and empirical issues. All errors are our own.

¹ Economics Department and Fletcher School, Tufts University, Jenny.Aker@tufts.edu

² Department of Agricultural Economics, Mississippi State University, tack@agecon.msstate.edu

Introduction

Information and communications technology (ICT) has expanded considerably over the past decade. More than four billion individuals are connected to mobile phones, and developing countries represent some of the fastest-growing markets (ITU 2008). There has been recent interest in the use of such technology by producers, sellers and consumers in the developing world to obtain market information for their products. Qualitative and quantitative evidence suggests that mobile phones reduce search costs as compared to more traditional means, such as visits to markets (Jensen 2007, Aker 2010, Aker and Mbiti 2010). In this context, mobile phones could have important implications for firms' and consumers' search behavior, price dispersion and welfare in nascent markets.

Since the 1960s, a large literature on consumer search theory has emerged to explain how changes in search costs affect market actors' behavior and equilibrium price dispersion. The common thread among these models is the causal link between search costs, search behavior and equilibrium price dispersion, as identified in Stigler's (1961) seminal article. While the existing literature provides empirical evidence linking search costs and price dispersion (see Baye, Morgan and Scholten 2007 for a review, Aker 2010), to our knowledge, the linkage between changes in search costs, search behavior and agents' welfare has not been empirically tested.

The purpose of this paper is to examine the effects of a change in search costs, such as those induced by the introduction of a new information technology, on

sellers' search behavior. We first present a search model for the optimal sales price, net transport costs. Unlike most consumer search models, which assume that there are no additional costs incurred once the price quote is obtained, our model allows for the seller's expected benefits to be a function of price net transport costs. This aspect of the model brings theory closer to the realities of trade in a variety of contexts, especially in developing countries. The model predicts that a reduction in search costs will increase sellers' reservation prices and the number of markets over which sellers search.

We empirically test this theoretical prediction using novel data on grain traders in Niger, one of the world's poorest countries. Grains are central to producer and consumer welfare³, and traders play an important role in ensuring spatial and temporal arbitrage of agricultural commodities. With limited infrastructure, traders have physically traveled to potential markets to obtain market information. Between 2001-2007, mobile phone service was phased-in throughout the country. Given the high costs associated with personal travel, mobile phones reduced traders' marginal search costs, thereby allowing them to search over a larger number of markets more quickly. This fact was supported by the grain traders themselves, one of whom stated, "[With a mobile phone], I am now able to get information quickly and without moving."⁴

³Millet is produced in almost every agro-ecological zone of Niger and represents over 70 percent of daily caloric consumption.

⁴Based upon interviews with the author during the trader survey of 2006. By 2006, 29 percent of traders surveyed used mobile phones for their commercial operations.

We exploit the spatial and temporal rollout of mobile phone towers to identify its impact on firms' search behavior. Our approach differs from the existing empirical literature on information technology and development outcomes in several ways. First, the nature of mobile phone rollout provides an opportunity to partially distinguish the impact of mobile phone coverage from potentially confounding omitted variables. Second, we control for potential selection of traders into mobile phone markets by bounding the effect of mobile phone coverage. And finally, as search behavior may be affected by the duration of mobile coverage in a particular market, we use both linear and nonlinear duration models to estimate the coverage effects.

The results indicate that mobile phone coverage has a statistically significant impact upon traders' search behavior, increasing the number of markets over which they search and the number of market contacts. The effect is stronger as the duration of mobile phone coverage increases and for larger traders, namely wholesalers and semi-wholesalers. However, there do not appear to be any differential effects by gender, age, market size or road quality. These results are robust to a variety of specifications, such as different functional forms and bounding the mobile phone coverage effect, thereby providing empirical evidence for the existence of the causal mechanism linking search costs to search behavior.

These findings are directly related to a growing body of research linking information technology and economic development outcomes. By far the most popular, and relevant, strain of this research examines the impact of information

technology on equilibrium price dispersion (Brown and Goolsbee 2002, Jensen 2007, Aker 2010). These papers assume that the casual link relating search costs to price dispersion is the number of markets over which an agent searches. Importantly, the empirical applications do not directly test whether search costs affect agents' search behavior.

In a companion article, Aker (2010) shows that the introduction of mobile phones is associated with a statistically significant decrease in grain price dispersion across markets in Niger. That result, coupled with the findings here, suggests that the mechanism behind the market-level decrease in price dispersion is due to changes in firms' search behavior. This therefore provides evidence of the causal link between information technology, search costs and price dispersion, which has not been empirically established in the economics literature.

The remainder of this paper proceeds as follows. Section 2 provides an overview of grain markets and traders in Niger and the introduction of mobile phones into the country. Section 3 describes the model and Section 4 presents the data. Section 5 presents the empirical strategy, and Section 6 presents the empirical results. Section 7 conducts robustness checks for potential threats to identification, and Section 9 concludes.

1. Mobile Phones and Market Agents in Niger

Niger, a landlocked country in West Africa, is one of the poorest countries in the world. The country is ranked last on the UN's Human Development Index (2009). 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, rice, fonio and maize, with cash crops including cowpea, peanuts, cotton and sesame. Among all of these crops, millet is central to producer and consumer welfare in the country, as it is produced in almost every agro-ecological zone of Niger and represents over 70 percent of daily caloric consumption (INS 2005).

A variety of market actors are involved in the grain trade, including farmers, traders, transporters and rural and urban consumers. There are four types of traders in Niger: retailers, who typically trade in small quantities (less than one 100-kg bag) in local markets and sell directly to rural and urban consumers; intermediaries, who buy from farmers in villages or markets and “resell” the commodity to semi-wholesalers and wholesalers; and semi-wholesalers and wholesalers, who typically trade in larger quantities (greater than one metric ton), over longer distances and engage in storage for a period of 1-2 months. As rainfall is unimodal in Niger, there is only one growing season per year, and so both traders and farmers engage in intra-annual storage. The duration of such storage is quite limited (an average of 7 days) and inter-annual storage is limited (Aker 2008).

Traders buy and sell grains through a system of traditional markets, each of which is held on a weekly basis. The density of grain markets varies considerably by geographic region, with inter-market distances ranging from 10 km to over 1,200 km. The number of grain traders per market ranges from 24 to 353, with retailers accounting for over 50 percent of all traders. While a market information system

has existed in Niger since the late 1980s, 89 percent of grain traders surveyed by the author stated that they primarily obtain price information through their personal and professional networks. This is due to the timing and quality of price information provided by the service: price data are primarily for consumer prices in particular markets, and are often disseminated only on a weekly basis.

Mobile phone service first became available in part of Niger in October 2001. Although private mobile phone companies initially intended to provide universal coverage, due to high fixed costs and uncertainty about potential customers, mobile phone service was introduced gradually. The initial criteria for introducing mobile phone coverage to a location were twofold: first, whether the town was an urban center; and second, whether the town was located near an international border.⁵ By 2006, 76 percent of grain markets had mobile phone coverage. By contrast, the number of landlines remained relatively stable during this period and were primarily concentrated in urban centers. As of 2006, 29 percent of grain traders surveyed owned a mobile phone for their trading operations, ranging from 18 to 40 percent in specific markets. Mobile phones were initially adopted by wholesalers, who were more likely to engage in inter-regional trade. Wholesalers were also more likely to be able to afford the phones, which initially cost US\$30.

2. Conceptual Framework of Firms' Search Costs and Behavior

⁵Based upon one of the author's personal interviews with mobile phone companies in Niger.

An extensive body of literature on consumer search theory has emerged since the 1960s, explaining how changes in search costs affect market actors' behavior and equilibrium price dispersion. The consumer search literature is dominated by two approaches: the “search-theoretic” approach, which assumes that it is costly for consumers to collect information about prices (Stigler 1961, Reinganum 1979, MacMin 1980, Stahl 1989, Janssen and Moraga-González 2004); and the “information clearinghouse”, which assumes that a subset of consumers can access price information via a clearinghouse (Salop and Stiglitz 1977, Varian 1980, Spulber 1995, Baye and Morgan 2001).

This paper builds upon the sequential search-theoretic models to develop a conceptual framework of trader sequential search. The framework presented here is novel for two reasons. First, it focuses on search from the seller's perspective, which has not been previously addressed in the search literature.⁶ Second, most consumer search models assume that there are no additional costs involved to purchasing the good once the minimum price quote is obtained. The framework presented in this paper relaxes this assumption by allowing expected benefits to be a function of the price net transport costs, reflecting the realities of grain trade in a variety of developing country contexts.

Assume that there is a homogeneous product (millet) and a finite number of traders (sellers) with strictly increasing concave utility functions over income.⁷

⁶In his work on the impact of mobile phones on the fisheries sector in India, Jensen (2007) proposes a two-market model of fishermen arbitrage in order to derive the decision rule for a fishermen's search technology and its impact on inter-market price dispersion.

⁷We assume throughout that grain traders buy in their home market and do not search for the best purchase price. This is consistent with models where an agent is simultaneously a producer and seller of the good.

Traders know the distribution of prices across all markets, $F(p)$ on the support $[\underline{p}, \bar{p}]$, but not the exact market for each price. There is a constant per-km (known) cost of transporting the good to the final sales market, so that each seller with home market $j, j = 1, \dots, J$, faces a well defined non-degenerate distribution of prices net transport costs $F_j(p)$ on the support $[\underline{p}_j, \bar{p}_j]$. Traders in home market j sequentially search for their optimum price net transport costs by repeatedly drawing from $F_j(p)$, but must pay a constant per-search cost, c .

Suppose that the trader has already searched an arbitrary number of markets, n , and has found an optimal price net transport cost z . The seller searches an additional time and realizes a price net transport cost of p_{n+1} . The seller “wins” if $p_{n+1} > z$ and “loses” otherwise. If the seller “wins”, his benefit is $u(p_{n+1}) - u(z)$. If the seller “loses” the gain in utility is zero, as he can simply sell at z . Consequently, the sellers’ marginal expected benefit function for the $n+1$ search is:

$$\begin{aligned} B_j(z) &= \int_z^{\bar{p}_j} [u(p) - u(z)] f_j(p) dp + \int_0^z [u(z) - u(z)] f_j(p) dp \\ &= \int_z^{\bar{p}_j} [u(p) - u(z)] f_j(p) dp \end{aligned} \tag{1}$$

where $(z, \bar{p}_j]$ is the range of winning. Since $u(\cdot)$ is strictly increasing and $1 - F_j(z) > 0$, it can be shown that the benefit function $B_j(z)$ is strictly positive and decreasing for $z \in [\underline{p}_j, \bar{p}_j]$.

The trader weighs expected marginal benefit with marginal cost of additional search, defined as the marginal net gain function: $h_j(z) \equiv B_j(z) - c$. If $h_j(z) \leq 0$, the

seller will not search again; if $h_j(z) > 0$, the trader will search until he finds a price net transport cost at or above his reservation price, r_j . Rearranging and substituting in the expression for $B_j'(r_j)$ implies

$$\frac{dr_j}{dc} = -\frac{1}{u'(r_j)[1-F_j(r_j)]} < 0 \quad (2)$$

for all traders with home market j . Equation (2) implies that a reduction in the seller's search cost leads to an increase in its reservation price r_j for $r_j \in [\underline{p}_j, \bar{p}_j)$.

Although the choice variable in this model is the reservation price (net transport costs), it is instructive to derive the trader's expected number of search markets. For sequential search with iid draws from the distribution $F_j(p)$, the constant probability of success $1-F_j(r_j)$ implies that the number of searches is a random variable from a geometric distribution (Baye, Morgan and Scholten 2007). Thus, the expected number of searches is given by $E_j[N] = \frac{1}{1-F_j(r_j)}$, which implies:

$$\frac{dE_j[N]}{dc} = \frac{dE_j[N]}{dr_j} \frac{dr_j}{dc} = -\frac{f(r_j)}{u'(r_j)[1-F(r_j)]^3} < 0 \quad (3)$$

for all $r_j \in [\underline{p}_j, \bar{p}_j)$. In other words, we expect that the number of markets over which traders search will increase as search costs fall. Equation (3) represents a testable hypothesis of Stigler's proposed causal mechanism.

Linking the model to the data is straightforward. Data from the trader survey in Niger suggests that the introduction of mobile phones decreased traders' per-

search costs as compared to personal travel.⁸ For example, an average trip to a market located 65 km away lasts 2-4 hours roundtrip, as compared to a two-minute call. Using a local daily wage of 500 CFA (US\$1) per agricultural laborer, the total costs of obtaining information from a market 65km away might have fallen by fifty percent between 2001 and 2006.⁹ Thus, we would expect that the introduction of mobile phones would increase traders' reservation prices, as well as the number of markets searched. We test the latter hypothesis in this paper.

3. Data and Measurement

This paper uses two primary datasets. The first is a census of all traders, including their gender and trader type, conducted in thirty-five markets across six geographic regions of Niger between 2000 and 2007. Census data were collected from the Agricultural Market Information Service (AMIS) between 2000 and 2004, and by one of the authors between 2005 and 2007. These data allow us to observe changes in the composition and size of markets during the period of mobile phone expansion and the survey period.

The second dataset is a panel survey of traders, transporters and market resource persons collected in Niger between 2005 and 2007. The survey interviewed 395 traders located in thirty-five markets across six geographic regions of Niger.¹⁰ Prior to the first round of data collection, a census of all grain markets was developed, and markets were randomly sampled based upon geographic location

⁸ In 2006, a two-minute call to a market located 65 km away cost US\$1, as compared US\$2 for roundtrip travel. Mobile phone usage rates were 160-195 CFA/minute (\$.35-.43/minute) and 35 CFA per text message (\$.07/minute).

⁹ Estimated search costs pre-mobile phones were US\$2.50, with US\$2 for travel and US\$.50 for opportunity costs. Estimated search costs post-mobile phones are US\$1.

¹⁰ The sample represents 12.5 percent of the total number of traders operating in the surveyed markets.

and market size. Within each market, a stratified random sample of traders was selected. Over 98.5 percent of traders interviewed during the first phase also participated in the second phase (with attrition primarily due to illness, death or travel to Mecca for the *Hadj*). Consequently, attrition is not a major concern.

The traders and market resource persons who participated in the survey provided detailed information about their demographic background and commercial operations during the 2005/2006 and 2006/2007 marketing seasons, as well as data on the 2004/2005 marketing season. The 2004/2005 data is sparse relative to the 2005/2006 and 2006/2007 data, so we concentrate on the latter two years here. We drop any observation with missing values for our variables of interest, which yields an unbalanced panel with 696 observations (358 traders) over two periods.

Table 1 reports summary statistics for the trader-level (Panel A) and market-level variables (Panel B). Grain traders are primarily male, from the Hausa ethnic group, are not formally educated and have a mean age of forty-six years. A majority of traders are retailers, representing over 53 percent of all traders in the sample. Traders follow prices in an average of four markets and consult 4.11 people for market information; however, there is significant variance for both of these variables.

The dataset includes data from collection, wholesale, and retail markets, and a majority of markets have access to some type of paved road (either paved, semi-paved or compressed dirt). Average market size (as measured by the number of traders operating within the market) is 98 traders, and ranges from relatively small

(25) to large (353). In general, markets are not within close geographic proximity, but are also not completely isolated. On average, there are less than two other markets within 50 km, but nearly five markets within 100 km. As mobile phone coverage was introduced into Niger in late 2001, some of the markets in our sample had coverage at the time of our survey; mobile phone coverage increased by 9 percentage points between the first and second year of our survey.

4. Empirical Strategy

4.1. Estimation

The theoretical framework suggests that the reduction in search costs associated with the introduction of mobile phones will increase traders' reservation prices and the number of markets over which they search. To empirically test the latter prediction, we exploit the spatial and temporal variation in the rollout of mobile phone towers to examine the change in trader-level outcomes before and after the introduction of mobile phone towers in each market. We estimate the following reduced form equation:

$$y_{ij,t} = \alpha + d_{j,t}\tau + \mathbf{x}'_i\boldsymbol{\beta} + \mathbf{z}'_j\boldsymbol{\delta} + \theta_t + u_{ij,t} \quad (4)$$

where $y_{ij,t}$ is the outcome variable of interest, either the number of markets followed or the number of people consulted by trader i with home market j during year t . $d_{j,t}$ is a scalar binary variable that takes on a value of one if market j had mobile phone coverage during period t , and zero otherwise. \mathbf{x}_i is a vector of time-invariant trader-level fixed effects, whereas \mathbf{z}_j is a vector of market-level fixed effects. The scalar parameter θ_t is a periodic intercept shifter that is invariant across traders and

markets. The parameter of primary interest is τ , which represents the impact of mobile phone coverage. Equation (4) is a two-period difference-in-differences specification. Identification primarily relies upon the assumption of parallel trends across mobile phone and non-mobile phone markets, as well as conditional independence.

Equation (4) implies a constant mobile phone coverage effect. Yet the duration of mobile phone coverage in a particular market could have important impacts upon traders' search behavior as traders become more accustomed to the new technology. We therefore modify equation (4) to measure the impact of the duration of mobile phone coverage on traders' search behavior:

$$y_{ij,t} = \alpha + d_{j,t}^1 \tau + \mathbf{x}'_i \boldsymbol{\beta} + \mathbf{z}'_j \boldsymbol{\delta} + \theta_t + u_{ij,t} \quad (5)$$

where $d_{j,t}^1$ measures the number of marketing seasons that market j has had mobile phone coverage. Specifically, if market j received mobile phone coverage for the first time in period t , then $d_{j,0}^1 = \dots = d_{j,t-1}^1 = 0$, $d_{j,t}^1 = 1$, $d_{j,t+1}^1 = 2$, $d_{j,t+2}^1 = 3$, etc. This is a linear duration model, whereby τ reflects the impact of mobile phone coverage that increases linearly in the duration of the coverage.

We modify equations (4) and (5) in a variety of ways. Assuming that the impact of mobile phone coverage might not be the same for all groups, we interact mobile phone coverage with trader- and market-level characteristics. We then allow the effect to be nonlinear in the duration of coverage. These generalizations are more fully discussed in Section 6.

4.2. Dealing with Endogenous Selection into Mobile Phone Markets

As mobile phone coverage in Niger was not randomly assigned, we are concerned that observed or unobserved characteristics might be simultaneously correlated with mobile phone coverage and our outcomes of interest. For example, mobile phone companies could have targeted specific markets based upon criteria that are also correlated with traders' search behavior. Conversely, traders might have self-selected into a particular market after the introduction of mobile phones, thereby biasing our results.

The market- and trader-level data suggest that traders' selection into mobile phone markets does not seem likely. First, in related work, Aker (2010) shows that the mobile phone companies used specific criteria for mobile phone rollout, namely urban status and a market's location near the southern border. These criteria were not determined by nor strongly correlated with market-level or trader characteristics. Second, based upon the annual trader census data, the number of traders per market did not vary significantly on an intra- or inter-annual basis between 2000 and 2007.¹¹ This coincides with the period of significant expansion in mobile phone coverage, and one during which we would expect to find trader sorting if it occurred.

Finally, according to the trader panel data, only ten percent of all traders surveyed changed their principal market since they began trading. Compared to

¹¹ Trader censuses were conducted on each market between 2004 and 2007, with data from 1999-2001 collected from secondary sources. There was a moderate amount of entry and exit during this time, and there does not appear to be a correlation between the number of traders per market and the introduction of mobile phone coverage into a market.

the average number of years of experience among traders (16 years), this suggests that traders do not quickly or easily change their principal markets. This is not surprising, as most traders operate in the market that is closest to their village and are reluctant to change villages during their lifetime. Among those traders who did change their principal market, there is no statistically significant difference in means between traders located in mobile phone and non-mobile phone markets.

The trader survey data appear to support these claims. Table 2 presents trader- and market-level time-invariant variables that would likely be correlated with mobile phone coverage if self-selection into covered markets were taking place. For the trader-level characteristics (Panel A), the covariates are reasonably well-balanced; none of the difference in means are statistically significant. For the market-level covariates (Panel B), we also fail to reject the equality of means for all of the covariates. Overall, these results suggest that there is balance between traders in mobile phone and non-mobile phone markets. Nevertheless, we condition on these covariates and bound the coverage effect as additional robustness checks.

5. Results

5.1. Impacts of Mobile Phones on Traders' Search Behavior

Table 3 presents the regression results for equations (4) and (5) using the number of markets searched as the dependent variable. Using a simple DD specification (Columns 1-3), mobile phone coverage in year t has a positive effect on the number of markets over which traders search (Column 1), but this effect is not statistically significant at conventional levels. These results do not change when we

include market-level fixed effects (Column 2), trader-level fixed effects (Column 3) or when using a negative binomial specification to account for the limited count dependent variable (Column 4). Overall, these results suggest that mobile phone coverage does not have a significant effect on traders' search behavior during that marketing year.

Columns 5-8 use the duration of mobile phone coverage, rather than mobile phone coverage in the same period, as the independent variable. The duration of mobile phone coverage has a positive and statistically significant impact on a traders' number of search markets, suggesting that a trader increases his or her average number of search markets by 5 percent (Column 5) for each year of coverage. The results are robust to including market-level fixed effects (Column 6), trader-level fixed effects (Column 7) and using a negative binomial specification (Column 8).¹²

Table 4 presents the regression results for equations (4) and (5) using an alternative measure of search behavior, namely, the number of people consulted for price information. The pattern of results are quite similar to those presented in Table 3. Mobile phone coverage in year t has a positive but not statistically significant impact upon a traders' number of market contacts (Column 1). There also is not a statistically significant impact when controlling for market-level fixed effects (Column 2), trader-level fixed effects (Column 3) or a negative binomial specification. However, once including the duration of mobile phone coverage

¹²The results are also robust to using a random effects estimator with unobserved heterogeneity modeled at the trader-level, and a Poisson count model.

(Column 5), there is a positive and statistically significant impact of the duration of mobile phone coverage on traders' behavior. This is robust to the inclusion of market-level fixed effects (Column 6), trader-level fixed effects (Column 7) and a negative binomial specification (Column 8). As is evident in the negative binomial specification, the duration of mobile phone coverage increases the number of market contacts by 6 percent for each year of coverage.

Overall, the results in Tables 3 and 4 suggest a dynamic effect of mobile phone coverage on traders' search behavior. The positive coefficients in Columns 5-8 suggest that mobile phone coverage increases a traders' search behavior, and that this effect increases each year by between 5-6 percent. Assuming a linear impact of mobile phone coverage on search behavior, traders in mobile phone markets would increase their search markets by 35 percent over a six-year period.

5.2. Nonlinear Effects of Mobile Phone Coverage

The estimates presented in Tables 3 and 4 suggest that traders' search behavior increases in the duration of mobile phone coverage, and that this relationship is linear. Nevertheless, it is reasonable to assume that some traders might initially increase their search behavior in the initial years of mobile phone coverage, but then reduce this behavior once more markets have coverage. Alternatively, smaller traders might engage in little search during the early years of mobile phone coverage and then increase this search behavior once a critical mass of traders are searching.

To investigate potential curvature in the duration effects, we relax the linearity assumption by modifying equation (5) to allow for a nonlinear effects. In particular, we are interested in determining regions of concavity or convexity for search behavior as a function of the duration of mobile phone coverage. We therefore employ a flexible functional form that takes on a value of zero when duration is zero, is monotonically increasing in coverage duration and permits a concave and/or convex relationship:¹³

$$y_{ij,t} = \alpha + B(d_{j,t}^2, \tau^1, \tau^2) \tau + \mathbf{x}'_i \boldsymbol{\beta} + \mathbf{z}'_j \boldsymbol{\delta} + \theta_t + u_{ij,t} \quad (6)$$

where $B(d_{j,t}^2, \tau^1, \tau^2)$ is the incomplete beta function with argument $d_{j,t}^2$ and two strictly positive shape parameters, τ^1 and τ^2 .¹⁴ The argument of the incomplete beta function is defined as $d_{j,t}^2 = d_{j,t}^1 / \max(d_{j,t}^1)$, which necessarily restricts the domain to $[0, 1]$. The parameters of this model can be consistently estimated using nonlinear least squares. This specification is flexible enough to nest a variety of curvature conditions, while still imposing a strictly positive duration effect which is consistent with findings from the linear duration model.

Figure 1 provides some stylistic evidence of this model's flexibility. Panel (1) shows curves for $\beta = .3$ and different values of α (0.3, 0.5, 1, and 5). Panels (2) – (4) show curves for $\beta = .5$, $\beta = 1$, and $\beta = 5$, respectively, for the same values of α .

¹³ The first property simply insures a zero duration effect for uncovered markets. The monotonicity assumption is motivated by the results of the linear duration model, which can be thought of as a first order approximation of the nonlinear model derived here.

¹⁴ The incomplete beta function is a component of the cumulative distribution function (cdf) for the beta distribution, which for a random variable x on support $[0, 1]$ is given by $F(x; a, \beta) = B(x; a, \beta) / B(a, \beta)$, where $B(x; a, \beta)$ is the incomplete beta function and $B(a, \beta)$ is the complete beta function. The cdf of the beta distribution includes two strictly positive shape parameters and takes on a variety of shapes between the points (0,0) and (1,1), as evidenced by Figure A1. While the range of the beta distribution cdf is fixed at $[0, 1]$, we can omit the normalizing constant $B(a, \beta)$ and work directly with the incomplete beta function, which has range $[0, \infty]$.

Table 5 presents the regression results of equation (6) for both the number of search markets and the number of market contacts, controlling for year, market fixed effects and trader fixed effects. The magnitude of the duration effect is entirely driven by the two shape parameters. Overall, the results show a positive and statistically significant impact of the duration of mobile phone coverage on traders' search behavior, and one that is strongly nonlinear in nature

Figure 2a graphs the predicted values corresponding to Column (1). The graph shows that the relationship is convex, with the number of markets followed increasing at an increasing rate. Compared with the mean among traders in non-mobile phone markets, mobile phone coverage increases a traders' number of search markets by 2.40 percent the first year, 6.18 percent the second year, on up to 11.2 percent the sixth year. Although the linear duration model estimated a constant percentage increase per year, the results in Figure 2a suggest that the nonlinear duration effect is similar in magnitude. Nevertheless, the nonlinear model suggests that the smallest gains occur during the first few years of coverage. The results are similar when graphing the results for the alternative dependent variable (Figure 2b).

5.3. Heterogeneous Effects

While all traders within a mobile phone market received coverage simultaneously, certain traders might have adopted the technology earlier or at a faster rate. Similarly, certain markets – such as those located near a higher percentage of markets – might have been able to make use of the technology more quickly. Table

6 presents the heterogeneous linear duration effects, interacting mobile phone coverage with trader-level (gender, age and trader type) and market-level characteristics (road quality and distance to a paved road).

Among all of the trader-level interaction terms, only trader type is positive and statistically significant. The coefficient on the interaction term for gender and mobile phone coverage is negative, suggesting that mobile phones are more useful for male traders (Column 1). The interaction term is not statistically significant, which is not surprising, as there are few female agricultural traders in Niger (less than 11 percent). Controlling for interactions between age and mobile phone coverage (Column 2) yields similar results, suggesting that mobile phone coverage is not necessarily more useful for younger (or older) traders. Yet the interaction term for the trader type – retailer, intermediary, semi-wholesaler or wholesaler – is positive and strongly statistically significant, as is the joint effect. This suggests that mobile phone coverage was more useful for larger traders – namely wholesalers and semi-wholesalers – who typically trade larger quantities and are more likely to engage in spatial arbitrage.

Columns (4)-(5) include interaction terms for market-level characteristics. The interaction term between mobile phone coverage and road quality (Column 4) is negative, suggesting that mobile phone coverage is more useful for traders that are in markets near unpaved roads, consistent with Aker (2010). However, the results are not statistically significant at conventional levels. Including an alternative measure of isolation, namely, a binary variable for distance to an unpaved road,

suggests that mobile phone is more useful for markets that are more than 10 km away from an unpaved road (Column 5): the coefficient on the interaction term is negative and statistically significant. This suggests that mobile phone coverage can, to some extent, serve as a substitute for unpaved roads in allowing farmers to get access to price information. Using an alternative dependent variable (the number of market contacts) mirrors previous results.

6. Threats to Identification

Table 2 suggests that there was little evidence of trader sorting between mobile phone and non-mobile phone markets based upon observable characteristics. Similar, outside of a market’s urban status, Aker (2010) and Aker and Fafchamps (2011) show that neither market nor trader-level characteristics are strongly correlated with the geographic location or timing of mobile phone coverage. Nevertheless, there could be unobserved covariates affecting mobile phone coverage and traders’ behavior simultaneously. To address this, we construct bounds on the duration effect, calculating upper and lower bounds for differential selection by trimming the distribution (Manski 1990, Rosenbaum 2002, Lee 2005, Blattman and Annan 2010). The “best-case” bound is constructed by dropping the worst-performing “sorting” traders with lower values of the outcome, and then calculating the trimmed effect. The “worst-case” bound is calculated by dropping the “best-performing” traders who changed their principal market.

Bounds for each outcome are provided in Table 7. Similar to Lee’s approach, we compare the “untrimmed” effect (Column 1) to the upper and lower bounds

(Columns 2 and 3). Among all traders, only 10.5 percent had moved markets at some point prior to the 2005/2006 marketing season, and no traders changed markets in between the first and second round of the sample.¹⁵ For each dependent variable, we trimmed out the lower 25th percentile of the empirical distribution to calculate the best-case scenario, and the upper 25th percentile for the worst-case scenario.¹⁶

In general, the duration effects under all three scenarios are statistically significant at conventional significance levels, and the 95 percent confidence intervals have a large amount of overlap. These results suggest that even under strong trader selection, mobile phone towers still have a statistically significant effect on traders' search behavior.

7. Conclusion

This paper investigates the impact of a reduction in search costs on sellers' search behavior in a developing country, providing empirical evidence of Stigler's (1961) causal mechanism. Starting from the sequential consumer search models of Reinganum (1979) and Stahl (1989), we develop a simple framework to analyze the impact of the introduction of a new search technology on firms' behavior. We posit that the introduction of mobile phone technology will increase traders' reservation prices and the markets over which they search, thereby leading to a reduction in price dispersion.

¹⁵ No trader reported moving between the 2005/2006 and 2006/2007 marketing seasons.

¹⁶ Performance was measured as an average of the dependant variables across the two observed marketing seasons.

We test these latter two predictions in the context of grain traders in Niger, a landlocked country located in sub-Saharan Africa. The results are consistent with the theoretical model: Mobile phone coverage reduces search costs and increases traders' search behavior. The cumulative effect of mobile phone coverage does not occur instantaneously, but rather unfolds dynamically over a period of at least six years. Furthermore, we find that there is a convex relationship between the duration of mobile phone coverage and traders' search, with the largest effects occurring in later years. The results also provide some evidence of stronger effects for larger traders and for more isolated markets.

Table 1. Grain Trader and Market Characteristics

Variable Name	Sample Mean (s.d.)	Min	Max	# of obs
Panel A: Trader-Level Characteristics				
<i>Socio-Demographic Characteristics</i>				
Gender (Male=0, Female=1)	.095(.30)	0	1	696
Ethnicity				696
<i>Hausa</i>	0.65	-	-	454
<i>Zarma</i>	0.16	-	-	112
<i>Other</i>	0.19	-	-	130
Age	45.88(12.22)	17	82	696
Education (1=some education)	0.18(.38)	0	1	696
<i>Commercial Characteristics</i>				
Number of markets where prices followed	3.97(2.90)	0	30	696
Number of people consulted for prices	4.11(3.73)	0	20	696
Trader type				696
<i>Wholesaler</i>	0.16	-	-	109
<i>Semi-wholesaler</i>	0.15	-	-	106
<i>Intermediary</i>	0.16	-	-	115
<i>Retailer</i>	0.53	-	-	366
Have bank account (Yes=1)	0.11(.32)	0	1	696
Member of traders' association (Yes=1)	0.34(.47)	0	1	696
Panel B. Market-Level Characteristics				
Type of market				32
<i>Collection</i>	0.22	-	-	7
<i>Wholesale</i>	0.44	-	-	14
<i>Retail</i>	0.34	-	-	11
Market located near border (Yes=1)	0.25(.44)	0	1	32
Road quality (1=Paved road)	0.63(.49)	0	1	32
Size of Market (Number of traders)	98.44(76.25)	24	353	32
Number markets within 50 km	1.41(1.41)	0	6	32
Number markets within 100 km	4.94(2.95)	0	12	32
Mobile phone coverage 2005/2006 (Yes=1)	0.66(.48)	0	1	32
Mobile phone coverage 2006/2007 (Yes=1)	0.75(.44)	0	1	32

Notes: Data collected from the Niger trader survey and from the mobile phone companies.

Table 2. Comparison of Trader- and Market-Level Covariates by Mobile Phone Coverage

Trader- and Market-Level Fixed Effects	Mobile Phone Markets	Non-Mobile Phone Markets	Difference in Means
	Mean(s.d.)	Mean(s.d.)	Coefficient (s.e.)
<i>Panel A. Trader-Level</i>			
Gender (Male=0, Female=1)	0.096(.295)	0.091(.289)	0.005(.050)
Education (0=No education)	0.171(.377)	0.206(.405)	-0.035(.056)
Age (Years)	46.6(12.7)	43.8(10.5)	2.77(1.65)
Hausa ethnic group (Yes=1)	0.693(.462)	0.531(.500)	0.161(.139)
Wholesaler or semi-wholesaler (Yes=1)	0.305(.461)	0.320(.468)	-0.015(.069)
Member of traders' association (Yes=1)	0.353(.478)	0.286(.453)	0.067(.066)
<i>Panel B. Market-Level</i>			
Collection market (Yes=1)	0.122(.328)	0.422(.495)	-0.300(.180)
Retail market (Yes=1)	0.222(.416)	0.411(.493)	-0.188(.172)
Market located near border (Yes=1)	0.150(.357)	0.246(.432)	-0.096(.150)
Road quality (1=Paved road)	0.798(.401)	0.497(.501)	0.301(.183)
Small market: less than 53 traders (Yes=1)	0.090(.286)	0.291(.455)	-0.201(.136)
Medium market: between 53 and 81 traders (Yes=1)	0.209(.407)	0.165(.372)	0.043(.141)
Large market: between 81 and 128 traders (Yes=1)	0.209(.407)	0.320(.467)	-0.110(.194)
Number markets within 50 km	1.86(1.87)	1.08(1.18)	0.776(.669)
Number markets within 100 km	5.72(2.56)	4.75(2.92)	0.973(1.09)

Notes: Data collected from the Niger trader survey and from the mobile phone companies. . For the difference in means column, Huber-White standard errors clustered by market are in parentheses. *, **, *** implies statistical significance at the 1%, 5% and 10% levels, respectively.

Table 3. Effect of Mobile Phone Coverage on Number of Search Markets

Dependent variable: <i>Number of markets searched</i>	1	2	3	4	5	6	7	8
Mobile phone coverage	0.423 [.419]	-.009 [0.379]	-.058 [0.374]	-.057 [.086]				
Mobile phone coverage duration					0.205** [0.088]	.225* [0.118]	0.246*** [0.116]	.050* [0.029]
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Individual fixed effects	No	No	Yes	Yes	No	No	Yes	Yes
Negative binomial	No	No	No	Yes	No	No	No	Yes
Mean dependent variable for non-mobile phone markets	3.714	3.714	3.714	3.714	3.714	3.714	3.714	3.714
Number of observations	679	679	679	679	679	679	679	679
R-squared	0.003	0.207	0.211		0.014	0.213	0.213	
Wald chi-squared				218.25				302.07

Notes: The dependent variable is a positive count variable with some zero values. Mobile phone coverage equals 1 in year t if a market received coverage in that year, 0 otherwise. Mobile phone coverage duration represents duration (in years) that a market has had mobile phone coverage, 0 otherwise. Huber-White robust standard errors clustered at the market-level are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels. Similar effects are found using a Poisson regression.

Table 4. Effect of Mobile Phone Coverage on Number of Contacts

Dependent variable: Number of markets searched	1	2	3	4	5	6	7	8
Mobile phone coverage	0.286	-.134	-.206	-.057				
	[.425]	[.342]	[.296]	[.086]				
Mobile phone coverage duration					0.219**	.304*	0.28*	.062*
					[.140]	[.149]	[.149]	[.035]
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Individual fixed effects	No	No	Yes	Yes	No	No	Yes	Yes
Negative binomial	No	No	No	Yes	No	No	No	Yes
Mean dependent variable for non-mobile phone markets								
Number of observations	679	679	679		679	679	679	679
R-squared	0.0014	0.0301	0.0618		0.0109	0.0368	0.0671	
Wald chi-squared				198.9				201.69

Notes: Huber-White robust standard errors clustered at the market-level are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels. Similar effects are found using a Poisson regression.

Table 5. Nonlinear Effects of Mobile Phone Coverage Duration

	1	2
Dependent variable:	Follow	Consult
Incomplete Beta τ^1	1.271* [0.691]	1.117* [0.554]
Incomplete Beta τ^2	0.420*** [0.0965]	0.432*** [0.105]
Year	Yes	Yes
Market fixed effects	Yes	Yes
Trader fixed effects	Yes	Yes
Number of observations	696	696
R-squared	0.218	0.067

Notes: Huber-White robust standard errors are in brackets.
*, **, and *** denote significance at the 10%, 5%, and 1% levels.

Table 6. Heterogeneous Effects of the Duration of Mobile Phone Coverage

Dependent variable	1	2	3	4	5
Mobile phone coverage duration	.185** [.085]	.294 [.217]	.121 [.109]	.520*** [.224]	.616*** [.212]
Gender*mobile phone coverage duration	-.178 [.231]				
Age*mobile phone coverage duration		-.002 [.004]			
Trader type*mobile phone coverage duration (wholesaler/semi-wholesaler=1)			.480*** [.143]		
Road quality*mobile phone coverage duration (paved road=1)				-.398 [.270]	
Distance to paved road*mobile phone coverage duration					-.473* [.267]
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Market fixed effects	Yes	Yes	Yes	No	No
Trader fixed effects	No	No	No	Yes	Yes
Joint significance	No	Yes	Yes	No	Yes
Number of observations	679	679	679	679	679
R-squared	0.0652	0.0639	0.1819	0.1805	0.0109

Notes: Huber-White robust standard errors clustered at the market-level are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels. Similar effects are found using a Poisson regression.

Table 7. Treatment Effect Bounding for Endogeneous "Sorting" into Mobile Phone Markets

	(1)	(2)	(3)
Dependent variable:	Untrimmed	"Best case"	"Worst Case"
	ATE	Bound	Bound
# of markets followed	0.190**	0.200**	0.184**
	[0.0842]	[0.0820]	[0.0842]
# of people consulted for market information	0.205**	0.223**	0.228**
	[0.0973]	[0.0933]	[0.0933]

Notes: Data from the Niger trader survey and secondary sources. The untrimmed ATE is the difference in the means of traders in mobile phone and non-mobile phone markets, based upon the duration of coverage. It is analogous to the duration regressions in column 5 of Tables 3 and 4, but with clustered standard errors. The best and worst-case bounds are calculated as the difference in means of traders in mobile phone and non-mobile phone markets after 'trimming' the top or the bottom of the distribution of the outcome variable in the treatment group that has moved less frequently. Huber-White robust standard errors clustered at the market-level are in parentheses. * is significant at the 10% level, ** the 5% level, *** the 1% level.

Figure 1. Graphical Representation of Incomplete Beta Function for Different Parameter Values

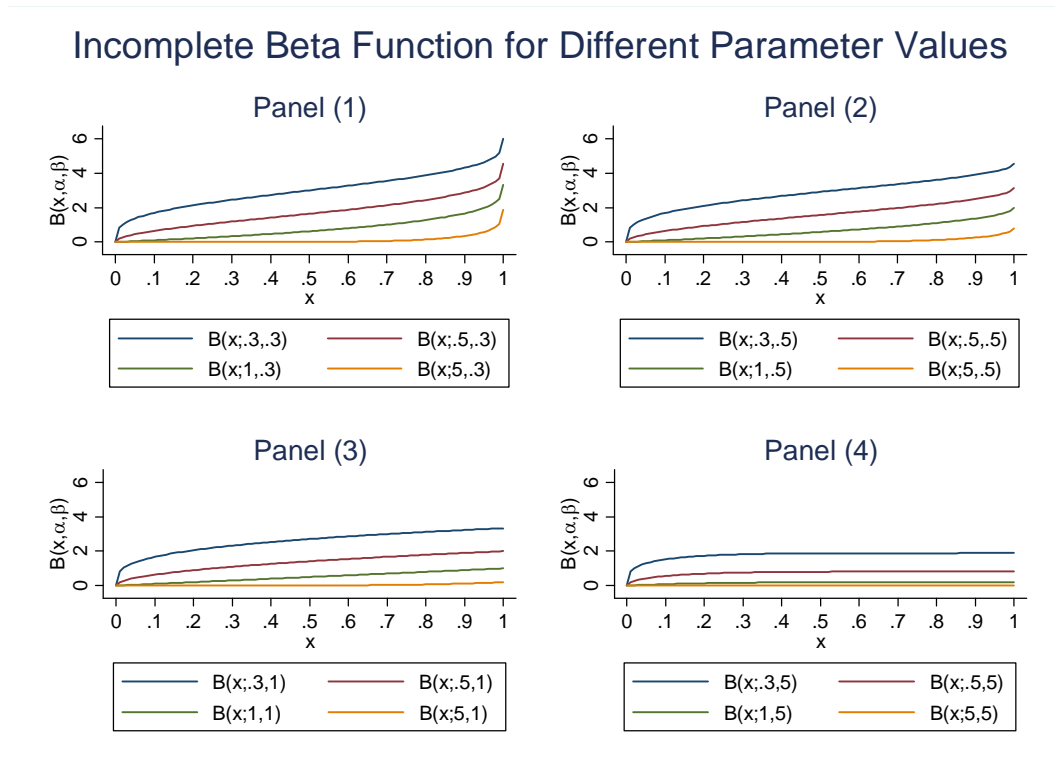


Figure 2a. Nonlinear Effects of Mobile Phone Coverage Duration on the Number of Markets Followed

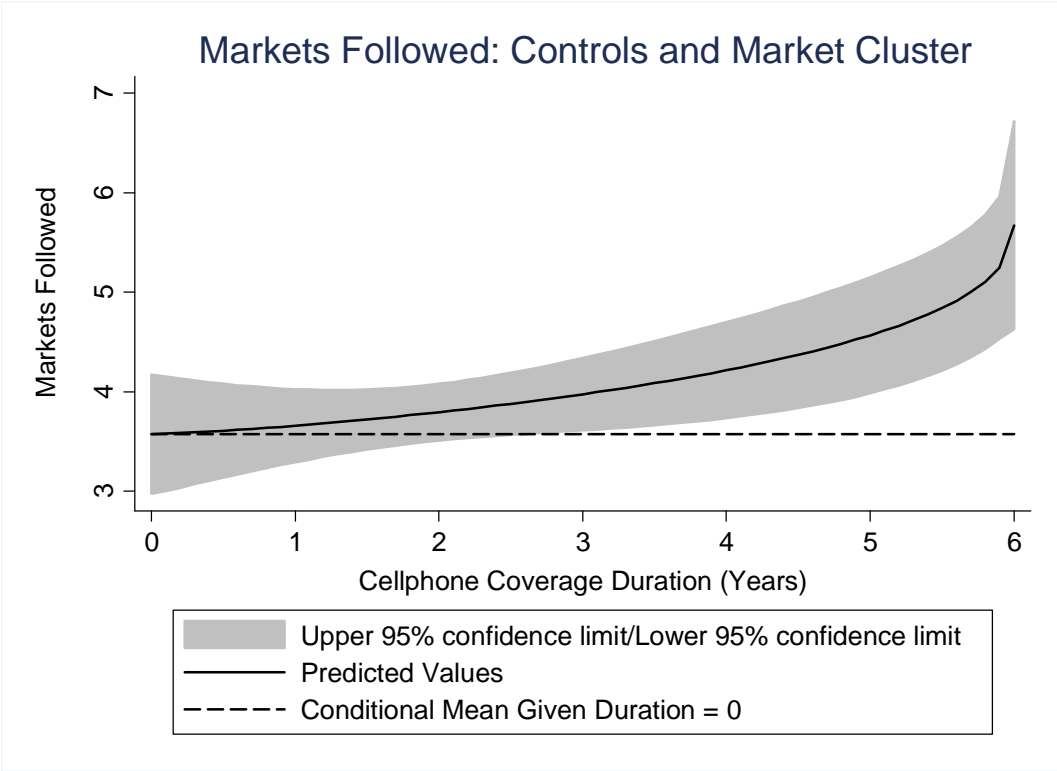


Figure 2b. Nonlinear Effects of Mobile Phone Coverage Duration on the Number of People Consulted

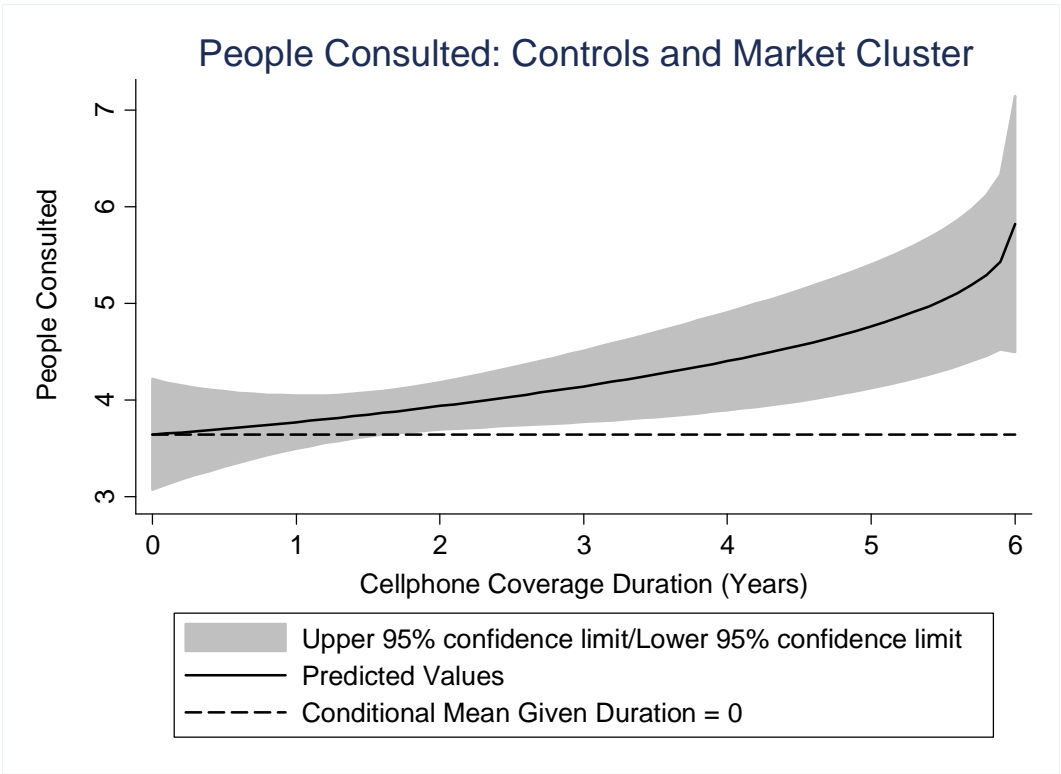
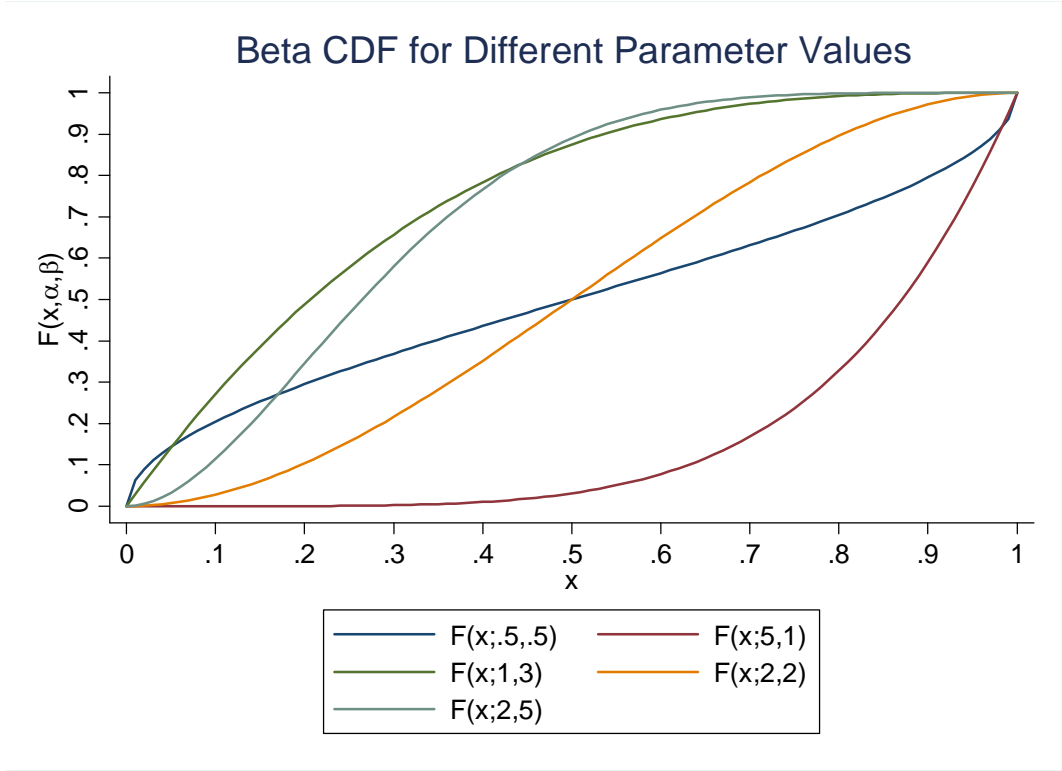


Figure A1. Beta Cumulative Distribution Function for Different Parameter Values



References

- [1] Aker, Jenny C. 2008. "Does Digital Divide or Provide? The Impact of Mobile Phones on Grain Markets in Niger." *BREAD Working Paper No. 177*.
- [2] Aker, Jenny C. and Isaac Mbiti. 2010. "Mobile Phones and Economic Development in Africa." Summer 2010. *Journal of Economic Perspectives*.
- [3] Baye, Michael, J. Morgan and P. Scholten. 2007. "Information, Search and Price Dispersion." *Handbook on Economics and Information Systems*. Elsevier, T. Hendershott, ed.
- [4] Institut National de la Statistique. 2005. *Profil de Pauvreté*. Niamey, Niger.
- [5] International Telecommunications Union (2008). *World Telecommunication Indicators Database*. Geneva: International Telecommunications Union.
- [6] Lee, D. 2005. "Training, Wages, and Sample Selection: Estimating Sharp Bounds on Treatment Effects". *NBER Working Paper #11721*. Cambridge: National Bureau of Economic Research.
- [7] Manski, C., 1990. "Nonparametric Bounds on Treatment Effects." *American Economic Review Papers and Proceedings*, 80, 319-323.
- [8] Reinganum, J.F. 1979. "A Simple Model of Equilibrium Price Dispersion." *Journal of Political Economy*, 87, 851-858.
- [9] Stahl, D.O. 1989. "Oligopolistic Pricing with Sequential Consumer Search." *American Economic Review*, 79, 700-712.
- [10] Stigler, G. 1961 "The Economics of Information." *Journal of Political Economy*, 69 (3), 213-225.
- [11] United Nations Development Program. 2009. *Human Development Report 2008/2009*. New York, NY: UNDP.