Mobile phones and agricultural market performance in Ethiopia

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Abstract:

Despite the widespread belief on the importance of increasing access to information technology - and especially mobile phones - on agricultural market performance in developing countries, there is relatively little solid empirical evidence. Exploiting unique data on wholesale prices and on the spatial and temporal roll-out of mobile phone towers in Ethiopia, we analyze the impact of mobile phone coverage on price dispersion between major cereal markets in the country. We find no signicant impact and link this lack of impact of IT (mobile phones) on agricultural market performance to availability of market information before mobile phones' take-o, to the need for visual inspection of produce because of lack of grades and standards, to and easy storability of cereals.

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Abstract

Despite the widespread belief on the importance of increasing access to information technology - and especially mobile phones - on agricultural market performance in developing countries, there is relatively little solid empirical evidence. Exploiting unique data on wholesale prices and on the spatial and temporal roll-out of mobile phone towers in Ethiopia, we analyze the impact of mobile phone coverage on price dispersion between major cereal markets in the country. We find no significant impact and link this lack of impact of increased access to mobile phones to availability of market information before mobile phones' take-off, to the need for visual inspection of produce because of lack of grades and standards, to and easy storability of cereals.

Keywords: price dispersion, mobile technology, agricultural market performance, information, Africa

JEL Classification: O1, O3, Q13

1 Introduction

The importance of information for the efficient functioning of markets has long been demonstrated (Stigler 1961). Theoretically, information makes market work and well-functioning markets improve welfare.[1] It is often assumed that markets and agents have sufficient information and that information is symmetric. However, information search is often costly, incomplete or asymmetric in reality, especially in developing countries and sub-Saharan Africa in particular as markets are dispersed and communication infrastructure is poor (Fafchamps 2004).

Specifically in agricultural markets, producers and traders often have limited information. Price information especially plays a crucial role in arbitrage - broadly defined as taking advantage of prices differences across market places, periods or buyers and sellers of different types - and market efficiency. If prices are not properly transmitted, local surpluses or scarcities can hurt both producers and consumers. Hence, the degree to which prices vary together across markets, i.e. the degree of market integration, provides a measure of how well markets function. Properly integrated agricultural markets should ensure proper trade between food surplus and food deficit regions. They are thus central not only to economic and agricultural growth (Dercon 1995) but also food security (Van Campenhout 2012).

In this context, a new technology that improves access to information can have important implications not only on the performance of agricultural markets but also on consumers and producers' welfare. By improving access to information, ICTs and mobile phones in particular may help reducing search costs and lead to lower price dispersion, thereby improving the functioning of these markets and increasing income and welfare.

Evidence from the literature on the effect of mobile phones in agricultural markets is mixed (Nakasone et al. 2014). One major strand has focused on the micro-level aspects, measuring the effects on farm prices and income. Some studies find positive welfare and price effects (Muto and Yamano 2009, Labonne and Chase 2009, Nakasone 2013), some find no effect (Fafchamps and Minten 2012, Mitra et al. 2013). The findings on the meso-/macro-level impact of mobile phones are also heterogeneous. Jensen (2007) shows a reduction in price dispersion across markets and a reduction in wastage in fish markets in India thanks to the introduction of mobile phone coverage. Similarly, Aker (2010) finds that the introduction of mobile phones led to a 10% reduction in the price dispersion of millet across markets. Aker and Fafchamps (2015) extend and nuance Aker (2010)'s results. They find that mobile phone coverage reduces spatial producer price dispersion for cowpea, a semi-perishable crop, but that it has no effect on producer price dispersion or on producer price levels of sorghum and millet, two staple grains that are less perishable. Interestingly, a stronger impact for perishable crops is also found by studies at the micro-level: by Muto and Yamano (2009) and by Nakasone (2013).

This paper builds on the growing empirical literature on the relationship between information technology - mobile phones - and agricultural market performance and development outcomes - agricultural price dispersion. Exploiting the spatial and temporal roll-out of mobile phone tower placement in Ethiopia, we provide evidence on the nature and magnitude of the effects of access to mobile phones on one measure of cereal market performance: wholesale price dispersion between markets. Analyzing market functioning in Ethiopia is pertinent since it is widely documented that poor integration of agricultural markets has had dramatic consequences leading to severe food insecurity and famines in some regions of the country while food stocks were available in other regions (Minten et al. 2014, von Braun et al. 1998, Gabre-Madhin 2001). In addition, the analysis of the cereal markets in the case of Ethiopia is particularly relevant since it is estimated that almost 75% of the planted area was allocated to cereals in 2010 (Central Statistical Agency of Ethiopia 2011). The country mostly relies on local cereal production to feed its population, very little is imported. We focus our analysis on the three major cereals: (white) wheat, (mixed) teff and maize.

In contrast with most previous studies (Aker 2010, Jensen 2007, Aker and Fafchamps 2015) and relying on nation-wide wholesale market price data for three major cereals in Ethiopia, we do not find any evidence that the increasing coverage of mobile phones has led to reduced price dispersion, a result that is robust

[1] As noted by Jensen (2007), two well-known results in economics, the First Fundamental Welfare Theorem (according to which competitive equilibria are Pareto Efficient) and the 'Law of One Price' (according to which the price of a good should not differ between two markets by more than the transaction cost between them) hinge on the assumption that economic agents have sufficient information on prices to optimally engage in arbitrage or trade.

across various specifications and control set-ups. We highlight the importance of the type of commodity and the initial conditions and propose three reasons to explain the lack of impact.

First, initial market conditions matter. As the cereals we study in this paper are widely traded in the country and traders had already wide access to cereal price information through landlines before the coverage by mobile phones, there might therefore have been less impact of improved access to information. This explanation is seemingly corroborated by evidence that these cereal markets were already well integrated before the spread of mobile phones (Getnet et al. 2005, Negassa and Myers 2007) although information was shown to be imperfect (Osborne 2004, 2005, Tadesse and Guttormsen 2011). Second, while prices can easily be transmitted over the phone, sharing information on quality is much more difficult. The lack of standardized quality in cereal markets and the resulting need for visual inspection to assess quality may limit the extent that mobile phones lead to better information and to increased efficiency of agricultural markets. Finally, most of the previous studies have looked at perishable crops. Because cereals are storable, price variability might be less and opportunities for spatial arbitrage - facilitated by mobile phones - might therefore be affected less by availability of better price information.

2 Background

2.1 Cereal Markets in Ethiopia

Ethiopia is fundamentally an agrarian country. While the manufacturing and service sectors are growing, the agricultural sector still accounts for nearly 46% of GDP, 73% of employment, and about 80% of foreign export earnings (Agriculture Transformation Agency 2014). Within the agricultural sector, cereal production and marketing dominate. Especially maize, wheat and teff are at the center of vibrant agricultural output markets and considered as priorities by the Agricultural Transformation Agenda (Benson et al. 2014, Agriculture Transformation Agency 2014). They are also the three most important cereals in the consumption basket, accounting for 40% of calories consumed at the national level and 27% of the food expenditures. In terms of production, output of teff, maize and wheat has increased significantly between 2003-2004 and 2010-2011. In seven years, production of teff and maize has almost doubled while production of wheat has increased by 70%. In terms of marketing, over 90% of sales by farmers are made at the local market.

The analysis of cereal markets in Ethiopia is particularly relevant because they are key to its agricultural and food economy. In 2011, cereals amounted to 68% of agricultural production and were grown on about 73% of the cultivated land (Taffesse et al. 2011). In terms of consumption, cereals represent more than 60% of total caloric intake of a representative household and more than 40% of its food expenditures (Rashid and Negassa 2011).

Due to different agro-ecologies over the country, a strong spatial specialization in terms of agricultural production as well as consumption patterns is observed (Chamberlin and Schmidt 2011). Production of wheat and maize is concentrated in the South and West of Ethiopia respectively. These areas are the major suppliers of cereals to the capital, Addis Ababa, and the North which is the cereal deficit region. Production of teff is more spread while demand is high in urban areas.[2] These regional differences combined with increasing production and urbanization have resulted in increasing marketing flows of agricultural products and cereals in particular over the last decade. Traders are key market actors and are the largest buyers of cereals (Minot and Sawyer 2013). As reported by Minten et al. (2014), the number of traders operating in cereal markets has also increased considerably in the same period.

In parallel, the connectivity between agricultural markets and trade of agricultural products has been facilitated by improved infrastructure. Between 1993 and 2008, all-weather surfaced roads increased by 133% thanks to a major road investment program by the Ethiopian government.[3]

[2] A geographical representation of the major production zones is shown in Appendix in a longer version of this paper.

[3] According to Minten et al. (2014), the improvements in roads and the improved competition in the transport sector have out-weighted the rise in fuel prices experienced during the decade and led to significantly lower transportation costs between markets in the country.

2.2 Expansion of Mobile Phone Coverage

In Ethiopia, coverage of both land lines and mobile phones is low compared to regional averages.[4] Mobile phone services were introduced in 1999 and their penetration also remains low, with less than 30% of Ethiopians owning a mobile phone subscription in 2013, compared to 65% in Sub-Saharan Africa. Controlling Ethio Telecom, the only mobile phone service provider in the country, the state currently has a monopoly on the telecommunications sector in Ethiopia. In 2006, Ethio Telecom announced a program to cover all countries in the coutnry and reduce the average distance the average rural inhabitant has to walk to the nearest mobile phone from 30 kilometres to 5 kilometers (Ethiopia Telecommunication Corporation 2007). After a slow initial increase, mobile phone ownership has started to rise significantly in the second half of the decade.

The growing availability of mobile phones has allowed farmers and traders to exchange information more easily. Analyzing coverage of main agricultural (cereal) markets, we see that the Addis Ababa market was the only one with access to mobile phones in 2000 but by 2005, most markets were covered (Figure 1). Turning to the use of phones by traders, we see that wheat, teff and maize traders had access to land lines either at home or at other locations. More specifically, while about 40% of teff and maize traders had access to a fixed phone at home before the introduction of mobile phones, only 8% of wheat traders had (Figure 2a). 80% of teff and maize traders had access to a phone on the market or at another location and this was the case for about 40% of wheat traders. Interestingly, this indicates that traders had a wide access to phones for business related purposes before the introduction of mobile technology. In addition, it seems that the communication void filled by mobile phones is larger for wheat than for teff or maize.

It is also interesting to observe the purpose for which mobile phones and fixed lines are and were used by traders (Table 1). More than 70% of traders report to use mobile phones to transmit prices. 43% of traders use mobile phones to request a show-up with sellers but only 23% of wheat traders and 29% of teff traders use mobile phones to agree on prices will sellers (in the case of maize, more than 50% of traders do). Given the lack of standards in Ethiopia, this is likely due to traders wanting to inspect the produce personally before making a deal.

3 Data

We use three main datasets from secondary and primary sources. The first is provided by the Ethiopian Grain Trading Enterprise (EGTE), a grain procurement arm of the government, and contains wholesale prices of cereals - prices that wholesalers obtain when selling in large bulks - on major wholesale markets on a weekly basis over a 12 year period (2000-2011). They are collected and based on actual observed transactions on major market days. In this paper, we use information on white wheat, mixed teff and maize prices. A simple monthly average is computed to obtain monthly prices. We use the national Consumer Price Index constructed by the Central Statistical Agency of Ethiopia to deflate prices.

Second, we obtained data on the time of the establishment of mobile phone towers from the branches of Ethio Telecom that were located in the area where the wholesale markets are located.[5]

The third dataset is the result of a focus group survey conducted on the major 31 cereal markets of the country in early 2012. The focus groups were composed of traders and brokers with significant experience in cereal trade in the markets. (Recall) questions going back to 2000 were asked on the extent of occurrence of shocks, changes in costs, travel time between wholesale markets, changes in access to and spread of mobile phones and the use of mobile phones in agricultural trade. The number of markets differs per crop as focus groups discussions and data collection was only carried out in markets where each crop was considered important (i.e. where the EGTE collects data on prices for the crop). This results in 13 markets for wheat, 20 markets for teff and 17 markets for maize.[6]

[4] While land lines have existed since long, only 0.8 lines were available per 100 people in 2013, compared to an average of 1.13 lines per 100 people in SSA.

[5] In a couple of cases when the information was not available at this level, it was obtained from relevant and informed local residents.

[6] A map with the exact location of the wholesale markets included in the analysis for each crop is included in Appendix in a longer version of this paper.

In this paper, we further narrow the sample to market pairs with actual cereal flows and for which information on transport costs is available. This is important because we want to exclude the market pairs that do not have any trade relationship and are hence not relevant for our analysis of market integration. We also want to make sure that we properly account for transport costs, a key variable supposedly related to price dispersion across markets. This results in a total of 42 market pairs for wheat, 68 market pairs for teff and 57 market pairs for maize.

4 Empirical Strategy

In order to evaluate the impact of the introduction of mobile phones on cereal price dispersion across Ethiopian markets, we use a difference-in-difference (DID) strategy comparing market pairs with and without mobile phone coverage over time, similar to Aker (2010) and Aker and Fafchamps (2015).[7] The DID strategy allows for unobserved heterogeneity that is time invariant, i.e. differences between treated and control market pairs that do not vary over time.

Since we do not observe outcomes for treated market pairs in the absence of treatment, we identify a relevant control group and estimate the average treatment effect by computing the difference in outcomes for the treated and control groups (Imbens 2004, Blattman and Annan 2010). To obtain a proper control group, we use as controls the market pairs that were treated the latest (i.e. in 2005 for teff and wheat markets and in 2007 for maize markets). This implies that we restrict the sample to data between 2000 and 2004 for the analysis of wheat and teff markets and to data between 2000 and 2006 for the analysis of maize markets. As a result, in the case of wheat 11 market pairs out of the total of 42 are used as controls. In the case of teff, 32 market pairs out of 68 are used as controls and in the case of maize, 12 market pairs out of a total of 57 are used as controls.

As measure of price dispersion and market integration we use the price difference between markets i and j at month t, defined as $y_{ij,t} = \mid log(p_{it}) - log(p_{jt}) \mid$. [8] We analyze the change in $y_{ij,t}$ before and after the introduction of mobile phones in each market pair. For each of the three cereals (wheat, teff and maize), we estimate the following model:

$$y_{ij,t} = \beta_0 + \beta_1 mobile_{ij,t} + \gamma X'_{ij,t} + \alpha_{ij} + \theta_t + \epsilon_{ij,t} \quad (1)$$

where $y_{ij,t}$ is our measure of price dispersion. $mobile_{ij,t}$ is a dummy variable equal to one in month t if both markets i and j have mobile phone coverage, and zero otherwise.[9] $X'_{ij,t}$ is a vector of time-varying control variables that affect spatial price dispersion, such as *transport costs* between the two markets, the occurrence of *weather shocks* in the market at time t and the presence of *cooperatives* in the market at time t. The α_{ij}'s are market pair fixed effects that allow us to control for time-invariant factors such as geographic location, urban status, and market size. The θ_t's are time fixed effects, either at the monthly or yearly level. $\epsilon_{ij,t}$ is an error term with zero conditional mean. β_1 is our main parameter of interest, a

[7] Several studies have analyzed agricultural market performance and market integration over time and space in Ethiopia. Most studies evaluate price behavior (the co-movement between prices) over time between individual market pairs using cointegration analysis (Dercon 1995, Gabre-Madhin 2001, Rashid and Negassa 2011), Parity Bounds Models (Negassa and Myers 2007) or Threshold Autoregressive Models (Tadesse and Guttormsen 2011, ?? Tam). However these models have intrinsic limitations, they are based on restrictive assumptions and only allow to perform the analysis at individual market pair levels (Van Campenhout 2007).

[8] Other measures of price dispersion used in the literature are the sample variance of prices across markets over time and the coefficient of variation across markets in a given time and region (see Jensen (2007) for example). We use the same measure as Aker and Fafchamps (2015).

[9] Our definition of treatment is thus the presence of a mobile phone tower in each market of the market pair. This assumes that traders operating in one market start to use mobile phones as soon as they have access to the mobile phone technology. As a robustness test, we modify the treatment and lag the coefficient of mobile phone coverage by one year, to take into account that mobile phone use by traders may take some time (see Section 5.4). In addition, we have also checked two alternative specifications. First, we took into account that the duration of mobile phone coverage could affect price dispersion as the network grows and more traders become accustomed to the technology. We have modified the treatment to measure the number of months since both markets were covered by mobile phone. Second, we also used data on the use of mobile phones by traders instead of access and redefine the treatment in two ways: equalling to one when 75% of traders declare using mobile phones in both markets and when 100% of traders do. In each of the cases, results with such modified treatments do not change significantly. Results are not reported and are available upon request.

negative and significant value will indicate that mobile phone coverage reduced price dispersion between market pairs.

We first control for serial correlation, i.e. dependence over time within market pairs, clustering the standard errors at the market pair level. Then, following Aker (2010) and Aker and Fafchamps (2015), we allow for spatial correlation, i.e. dependence across market pairs within a time period, while allowing for some dependence between months by clustering the standard errors by quarter (Bertrand et al. 2004). Finally, since it is reasonable to assume that price dispersion in one market pair at time t could depend on price-dispersion in the same market pair at time $t-1$, we also estimate Equation (1) including a lagged dependent variable. We control for endogeneity by using the Arellano-Bond GMM estimator.[10]

The key identifying assumption to interpret β_1 as the effect of mobile phones on cereal market price dispersion is that the trends in outcomes are the same for both treated and untreated market pairs. While the DID strategy controls for time invariant heterogeneity, we must also assume that there are no time varying unobserved characteristics that are correlated with mobile phone coverage and price dispersion. This is discussed in Section 5.3.

5 Impact of Mobile Phones on Price Dispersion

We now turn to the empirical analysis of the effects of mobile phone coverage on cereal market price dispersion. In Section 5.1 we present the main estimation results. In Section 5.2 we extend the analysis to evaluate whether there are heterogeneous effects and in Section 5.3 we assess the identification assumptions. Robustness tests are discussed in Section 5.4.

5.1 Average Effects of Mobile Phone Coverage

Table 2 presents the results of Equation 1 for wheat (columns (1)-(3)), teff (columns (4)-(6)) and maize (columns (7)-(9)). We first discuss results for wheat markets. Using a standard fixed effects model (Panel I), we find that the coefficient of mobile phone coverage is negative but not significant when we control for market pairs and yearly and monthly fixed effects (column (1)), nor when we control for additional covariates such as transport costs between the two markets and weather-related shocks (column (2)). The coefficient on transport costs has the expected sign and is significant at the 5% level, a 10% decrease in transport costs decreases wheat price dispersion by 2.4%. As in Aker (2010), we also redefine the treatment and add a dummy variable equal to one when only one market in a pair has mobile phone coverage (column (3)). The effect of mobile phone coverage in both markets becomes significant. With this specification, the introduction of mobile phones is associated with a reduction in price dispersion in wheat markets of 3.8%.

In Panel II, we include market fixed effects and cluster the standard errors by quarter. The coefficient of mobile phone coverage is negative and significant in columns (1) and (3) and near to significant in column (2) and suggests a modest reduction in price dispersion of 3%. The magnitude of the coefficient of transport costs is substantially smaller but the coefficient is still positive and significant. In Panel III, we add a lagged dependent variable to the model using the Arellano-Bond estimator. The coefficient on the lagged dependent variable is positive and significant at the 1% level (columns (1)-(3)) while the coefficient on mobile phone coverage in both markets is only significant in column (3). Similarly to Panel I, in this case mobile phones decrease price dispersion by 4%. Overall, the sign, magnitude and significance of the estimated coefficients in Panels II and III are similar to the results in Panel I. Mobile phone coverage has none or little effect (about 3%) on the reduction in wheat price dispersion.

Columns (4)-(6) present the results from the same regressions for teff. The effect from mobile phone coverage in both markets on price dispersion is negative but not significant in the fixed effects model (Panel I) and becomes significant in Panels II and III. The magnitude of the effect is between 2% and

[10] The fixed effect transformation is not appropriate when the lagged dependent variable is added as explanatory variable because by construction, $y_{ij,t-1}$ is correlated with α_{ij}. The Arellano-Bond estimator relies on the idea that consistent estimators can be obtained by IV estimation of the parameters in first difference, using lags of the explanatory variables as instruments. For the estimator to be valid, the errors cannot be serially correlated after first differencing. We test for this crucial assumption and do not reject the null hypothesis of no auto-correlation of order 2.

3%. The effect of transport cost is positive and significant in Panel II where a 10% decrease in transport costs reduces price dispersion by 0.2% and in Panel III where the effect is much larger at 1.4%.

Columns (7)-(9) contain the results for maize. Perhaps surprisingly, the coefficient of mobile phone coverage is weakly significant at conventional levels and positive in Panels I and II and not significant in Panel III. Results suggest that the introduction of mobile phone coverage has had no effect on the reduction of price dispersion for maize. Mobile access may even have increased price dispersion by up to 3%, although the effect is not robust across specifications. The coefficients of transport costs have the expected positive sign and are significant in Panels II and III. In contrast to the other two crops, maize is procured by the Ethiopian Grain Trade Enterprise as well as the World Food Program for use in emergency aid and in the safety net program. There might therefore be sometimes unpredictability in market conditions because of these interventions, possibly explaining differential spatial arbitrage conditions than in the case of the two other cereals.

5.2 Heterogenous Effects

In this Section, we investigate whether the fact that we fail to find significant effects in the previous section may be explained by the presence of heterogeneous treatment effects across market pairs. We explore whether mobile phone coverage has different effects (i) in markets that are further apart, (ii) in different periods of the year, (iii) dependent on the number of markets that are connected and (iv) for thinner markets. Results are presented in Table 3. Regression specifications are similar to those in Table 2 - Panel I except that we add an interaction term and the dummy for the sub-group of interest.

A first interesting finding is that results are heterogeneous across types of cereals. Second, we find evidence of significant heterogeneous effects in less than half of the models tested. Turning to the effect of distance, we expect dispersion between markets to be larger when markets are more distant. This is indeed what we find in the case of teff. Investigating the effect of the period of the year, consistently with Aker and Fafchamps (2015), we find that mobile phones reduce price dispersion less during the harvest period, both in the case of teff (column (5)) and maize (column (8)). An explanation for this could be that traders' mis-coordination is higher outside of the harvest period, when markets are thin, and hence the room for further integration between markets is higher. Interestingly, the joint effect of mobile phone coverage and network coverage in other wheat markets is positive, suggesting that the mobile phone coverage reduces price coverage less when the number of connected markets increases (column (3)). Finally, it could be argued that information is especially useful for markets where the products are thinly traded. While we do not find evidence of this in wheat and teff markets, we find that that mobile phone coverage reduces price dispersion more in markets where maize is thinly traded (column (12)). [11]

5.3 Assessing the Identification Assumptions

Because mobile phone coverage was most probably not randomly assigned, a concern is that unobserved characteristics may be correlated both with mobile phone access and cereal price dispersion. The key identifying assumption behind Equation (1) to identify β_1 as the effect of mobile phones on price dispersion is that the trends across mobile phones and non-mobile phones markets must be parallel, i.e. that they would follow the same trend over the period of investigation in the absence of treatment or equivalently that unobserved characteristics affecting program participation do not vary over time with treatment. If the assumption was not satisfied, the coefficients estimated would be biased.

The difference-in-difference strategy controls for time invariant unobserved characteristics but we must also assume that there are no time varying unobservable characteristics that are correlated with mobile phone access and agricultural market performance. While we cannot formally test this since we do not observe outcomes for treated market pairs in the absence of treatment and outcomes for controls in the case of treatment, we propose several ways to address the issue. We first look at the evolution of price dispersion for treated and control groups over time graphically (Not shown in this shorter version of the paper). This visual examination provides support to the fact that both groups followed similar trends

[11] This finding is perhaps surprising but is consistent with the finding of Aker (2008) according to which there are diminishing marginal returns to mobile phones on price dispersion.

over time. In terms of magnitude, the price dispersion in wheat markets is on average 40 ETB/quintal which is roughly equivalent to 25 US$ per ton.[12]

We then analyze differences in price dispersion and market level variables before the treatment (in 2000) with descriptive statistics. Results (not shown in this version of the paper) suggest that there price dispersion was not statistically different in the pre-treatment period for teff and maize markets. In the case of wheat, it seems that the average price dispersion between treated markets was already smaller than between control markets, as were transport costs.

We extend our investigation of the descriptive statistics and also perform a falsification test. We estimate Equation (1) using data before the introduction of mobile phones in each of the market pairs. If markets that received mobile phones earlier were following different time trends, the difference should have already been present before mobile phones were introduced. Results are available in a longer version of this paper. We find that pre-treatment trends for teff and maize price dispersion are not significantly different from zero for market pairs that received mobile phone coverage compared to those who did not. However, confirming the descriptive statistics, the trend for wheat price dispersion seems to differ. We have also split the sample into two periods (January-June 2000 and July-December 2000) to evaluate whether the difference was present in the two periods. This appears to be the case in wheat markets. This raises concerns about the parallel trend assumption for wheat price dispersion and suggests that the findings regarding wheat cereal markets should be interpreted with more caution.

Finally, we combine the DID method with a weighting technique to match treated and control market pairs on pre-treatment characteristics to better control for pre-treatment conditions that may affect mobile phone coverage (Imbens 2004, Hirano et al. 2003). [13] The weights function is given by:

$$\omega_{ij} = \frac{Treated_{ij}}{\hat{p}(X_{ij,0})} + \frac{1 - Treated_{ij}}{1 - \hat{p}(X_{ij,0})} \tag{2}$$

Estimates (not shown in this shortened version of the paper) are consistent with the unweighted results presented in Table 2. Mobile phone coverage has no significant and robust effect on price dispersion in wheat and teff markets. Somewhat surprisingly, estimated coefficients of mobile phone coverage for maize markets are positive and now significant at the 5% level suggesting an increase in price dispersion of 3%.

5.4 Robustness Tests

In this Section, we propose three robustness tests to evaluate whether our findings are robust across specifications. Results are briefly discussed for the sake of concision in this version of the paper. First, as take-off of mobile phone use by traders may take some time, we replace the treatment previously defined as the presence of mobile phone towers in both markets as the lagged effect of mobile phone coverage by one year. Redefining the treatment in such a way does not alter the results qualitatively.[15]

Second, in our main specification we control for market and market pair fixed effects. This can capture variables such as the liquidity and the size of the markets, provided they grow at the same pace - an assumption that is admittedly quite restrictive. As a robustness test, we add as additional control *the number of traders in the smaller market*.The rationale for doing this is to reflect increasing competition in the markets as documented by Minten et al. (2014). In addition, it can be considered as a rough proxy for the thinness of the markets.

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[12] As an indication, we can roughly compare this figure with the average price dispersion between millet markets found by Aker (2010) in Niger. The average price dispersion for millet in Niger was 35 US$ per ton, notably similar to the magnitude we find in this paper.

[13] For each cereal, we first estimate the probability of receiving mobile phone coverage, $\hat{p}(X_{ij,0})$, with a probit model on pre-treatment market pair level covariates.[14] As shown by Rosenbaum and Rubin (1985), a weighted least squares estimation with weights computed using the estimated propensity scores will lead to unbiased estimates of the Average Treatment Effect.

[15] Only in the case of maize, the coefficient of mobile phone coverage which was positive and weakly significant in our main specification (Table 2 - Panel I) is now insignificant.

We would hence expect a negative relationship between number of traders and price dispersion. This is however not what we observe. In the case of both wheat and maize, a higher number of traders is associated with a higher price dispersion.[16]

Finally, we assess the consistency of the standard errors in two ways.[17] First, we allow for arbitrary within-market pair correlation and within-month correlation, implementing 2-way clustering of the standard errors at the market pair and month levels. Second, we apply the method of Driscoll and Kraay (1998) to explicitly take into account cross-sectional and temporal dependence in panel data. This marginally modifies the significance level of some coefficients but does not alter the results qualitatively.

These robustness tests confirm the validity of our findings and the lack of robust effects of mobile phone coverage on price dispersion across cereal markets.

6 Discussion and Conclusion

This paper provides evidence of the effects of mobile phone coverage on agricultural market performance in Ethiopia. After a thorough analysis where we take into account transport costs and analyze seasonal, distance, network and thin market effects, we find no robust significant effect of the expansion of mobile phone coverage on the reduction of spatial wholesale price dispersion in cereal (wheat, teff and maize) markets. Our results are precisely estimated and are robust across several specifications.

To the best of our knowledge, this paper is the first to stress the limitations of mobile phone access to improved market performance for major cereal staple crops in developing countries. Our findings suggest that the impact of improved access to information on market performance is context specific. One implication from our result is that access to information for improved marketing efficiency might not be as important as is often assumed and does not necessarily lead to better performing and more efficient markets. Comparing our findings with previous studies (Jensen 2007, Aker and Fafchamps 2015) where mobile phone coverage was found to lead to lower margins, we argue that the impact of technology on agricultural markets can differ substantially by the type of commodity and by the initial conditions.

More specifically, we stress three potential explanations for our result. A first explanation for our lack of significant effect can be the fact that as mentioned in the background section, traders' access to fixed phone lines was already important before the introduction of mobile phones. When price information is available through other channels, we do not expect that the introduction of mobile phones in rural areas will necessarily have an impact on market performance and aggregate welfare generated in agricultural markets (Jensen 2010).

A second reason why we encounter no strong significant impact is possibly the lack of standardized quality in the cereal markets we study (Minten et al. 2014, Rashid and Negassa 2011). While information on prices can easily be communicated over the phone, information on quality is much more difficult to transmit and quality is often assessed by visual inspection or by touching or tasting the products (Minten et al. 2013, Bekele and Ayeye 2006). Because this type of quality information is harder to transmit over the phone, it may limit the extent that mobile phones lead to better information on these market goods and to increased efficiency.

Finally, the type of commodity under study, cereals in our case, matters. Previous studies found a stronger impact of accessing mobile phones on price dispersion of more perishable crops such as fish , banana or cowpea, compared to cereals such as millet or sorghum or maize which are storable for longer time periods (Jensen 2007, Muto and Yamano 2009, Aker and Fafchamps 2015). One explanation put forward by these authors is that while better access to information is likely to improve arbitrage and reduce price dispersion in agricultural markets, the effect should be stronger the more perishable the commodity, when inter-temporal arbitrage is not possible and when the freshness at time of exchange affects prices significantly. For less perishable crops such as cereals, the possibility of inter-temporal

[16] However, it should be kept in mind that there could be an endogeneity issue with this variable if traders enter into the markets in response to larger margins. Results from this robustness test should be interpreted with caution.

[17] This is an important issue in our case since our data is likely to exhibit dependence between various market pairs. For example, unobservables from the market pair Addis-Ababa - Mekelle will likely be correlated with unobservables from the market pair Addis-Ababa - Bahir Dar. By adding time fixed effects, we address simple cross-sectional dependence: an unobserved effect that is shared by all observations at time t and invariant across cross-sections.

storage (even if limited) may act as a buffer on local market price fluctuations, hence undermining the effect mobile phone access can have. Further investigation is needed to assess whether cereal traders in Ethiopia engage in inter-temporal trade and storage but preliminary evidence suggests that cereal storage behaviour and capacity is limited (Rashid and Negassa 2011) and that this factor may not be a primary explanation for our findings.

Our analysis provides an important contribution to the growing debate about the effect of information technology on economic development. However, several limitations remain. First, the time frame under study covers the initial years of mobile phone expansion in Ethiopia. Second, although mobile phone expansion is managed by the government and widespread spatial coverage is a clear policy objective, mobile phone expansion is unlikely to be totally random and further investigation could shed light and better control for some of the factors explaining mobile phone roll-out over the country. One potential situation which would lead to an underestimation of the effects would be one where more remote markets where the potential for market integration would be the largest would be treated the latest. Third, our analysis focuses on wholesale cereal price dispersion and traders' behavior related to mobile phones. We are not able to address welfare issues and general equilibrium effects. Although there is evidence that mobile phones are not an important channel to access price information for farmers and are used by very few Ethiopian farmers (Tadesse and Bahiigwa 2015), further investigation is needed to evaluate the distributional effect of mobile phones on agricultural markets.

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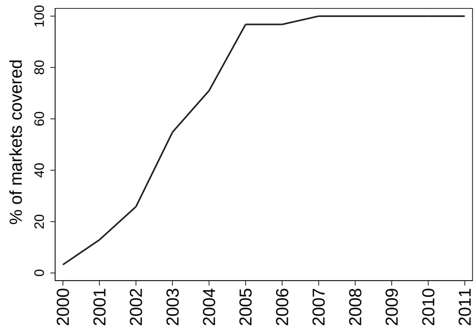
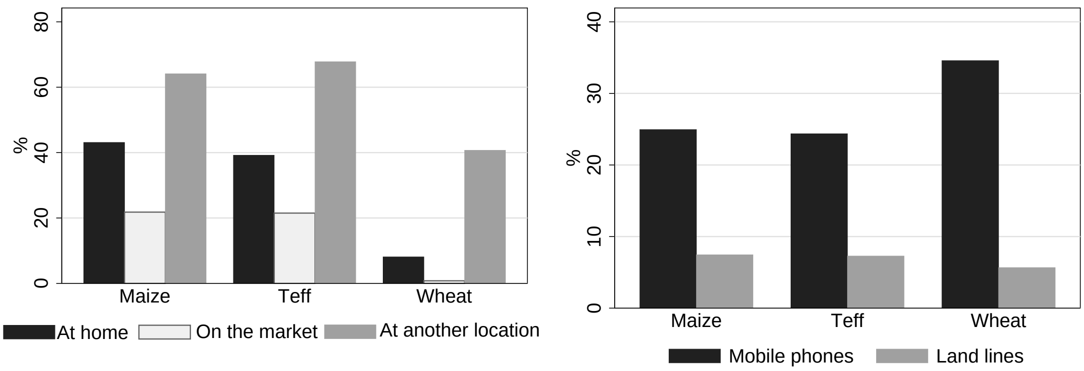
Appendix: Figures and Tables

Figure 1: Mobile phone coverage of cereal markets and use by traders (2000-2011) (%)



Source: Minten et al. (2014)

Figure 2: Access and frequency of use of land lines and mobile phones by traders



(a) Access to a fixed phone before the introduction of mobile phones (% of traders)

(b) Average # of trade-related phone calls per day per trader in peak season (2011)

Source: Based on Minten et al. (2014)

Table 1: Purpose of use of land lines and mobile phones by traders (% of respondents)

	Wheat		Teff		Maize	
	"Are mobile phones used to..."	"Were land lines used to..."	"Are mobile phones used to..."	"Were land lines used to..."	"Are mobile phones used to..."	"Were land lines used to..."
Inform/transmit prices	73	24	83	43	89	48
Agree on prices with sellers	23	1	29	6	53	15
Request a show-up with sellers	43	7	40	14	43	15
Agree deals with transporters	48	10	40	4	41	10
Agree on prices with buyers	25	3	46	14	56	21
Request a show-up with buyers	35	6	41	23	40	17
Follow-up payments with buyers	35	9	75	34	88	32

Source: Based on Minten et al. (2014)

Table 2: Access to mobile phone coverage and wholesale price dispersion

Dependent variable: : $y_{ij,t} = \mid log(p_{it}) - log(p_{jt}) \mid$

Panel I - Fixed Effects									
		Wheat			Teff			Maize	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mobile coverage	-0.022	-0.017	-0.038*	-0.0091	-0.011	-0.013	0.031*	0.029*	0.020
both markets	(0.015)	(0.014)	(0.021)	(0.0094)	(0.0094)	(0.014)	(0.016)	(0.015)	(0.017)
Transport costs		0.21**	0.24**		-0.045	-0.046		0.089	0.092
		(0.094)	(0.098)		(0.033)	(0.033)		(0.066)	(0.067)
Weather shock		-0.011	-0.012		0.025	0.026		-0.028**	-0.028**
one market		(0.020)	(0.022)		(0.027)	(0.027)		(0.013)	(0.013)
Cooperatives		-0.019	-0.018		-0.015	-0.015		0.015	0.016
one market		(0.028)	(0.028)		(0.023)	(0.023)		(0.015)	(0.015)
Mobile coverage			-0.039			-0.0041			-0.017
one market			(0.024)			(0.015)			(0.013)
N	2520	2520	2520	4080	4080	4080	4788	4788	4788
R^2	0.278	0.286	0.291	0.219	0.221	0.221	0.166	0.173	0.174

Panel II - Markets FE, quarter clustering									
		Wheat			Teff			Maize	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mobile coverage	-0.033*	-0.025	-0.043**	-0.020*	-0.018*	-0.017*	0.028*	0.030*	0.022
both markets	(0.016)	(0.016)	(0.020)	(0.0098)	(0.0095)	(0.0088)	(0.014)	(0.015)	(0.015)
Transport costs		0.050***	0.052***		0.020***	0.020***		0.025***	0.025***
		(0.010)	(0.010)		(0.002)	(0.002)		(0.007)	(0.0066)
Weather shock in		-0.016*	-0.016*		0.010	0.010		-0.028	-0.028
one market		(0.009)	(0.009)		(0.019)	(0.019)		(0.027)	(0.027)
Cooperatives in		-0.005	-0.005		-0.012**	-0.012**		0.018*	0.019**
one market		(0.009)	(0.009)		(0.006)	(0.005)		(0.009)	(0.009)
Mobile coverage			-0.031***			0.0016			-0.015***
one market			(0.011)			(0.0098)			(0.0052)
Market FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2520	2520	2520	4080	4080	4080	4788	4788	4788
R^2	0.514	0.526	0.528	0.395	0.406	0.406	0.420	0.427	0.428

Panel III - Dynamic model									
		Wheat			Teff			Maize	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mobile coverage	0.017	0.017	-0.041**	-0.033**	-0.033**	-0.10***	0.0047	0.0044	-0.011
both markets	(0.013)	(0.013)	(0.020)	(0.014)	(0.014)	(0.038)	(0.020)	(0.020)	(0.027)
Transport costs		0.060	0.071		0.14***	0.14***		0.17**	0.16**
		(0.11)	(0.10)		(0.047)	(0.046)		(0.081)	(0.081)
Weather shock in		-0.010	-0.010		-0.004	-0.007		0.017	0.017
one market		(0.016)	(0.016)		(0.020)	(0.020)		(0.013)	(0.013)
Cooperatives in		-0.013	-0.012		0.025	0.026		0.020	0.020
one market		(0.024)	(0.024)		(0.021)	(0.021)		(0.020)	(0.021)
Mobile coverage			-0.10***			-0.093**			-0.027
one market			(0.034)			(0.041)			(0.025)
Lagged $y_{ij,t}$	0.43***	0.43***	0.40***	0.49***	0.49***	0.49***	0.59***	0.59***	0.59***
	(0.061)	(0.061)	(0.060)	(0.041)	(0.042)	(0.042)	(0.030)	(0.030)	(0.030)
N	2436	2436	2436	3944	3944	3944	4674	4674	4674
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*p<0.10, **p<0.05, ***p<0.01. In Panel I, standard errors are clustered at the market pair level. In Panel II they are clustered at the quarter level. In Panel III, robust standard errors are reported. *Mobile coverage both markets* = 1 in period t when both markets have mobile phone coverage, 0 otherwise. *Transport costs* are measured in *log* of ETB/quintals.

Table 3: Heterogeneous effects of mobile phone coverage on price dispersion

Dependent variable: $y_{ij,t} = \mid log(p_{it}) - log(p_{jt}) \mid$												
	Fixed effects											
	Wheat				Teff				Maize			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mobile coverage	0.0056	-0.011	-0.13***	0.0057	0.012	-0.020**	-0.057*	-0.024*	0.034**	0.015	0.014	0.058***
both markets	(0.011)	(0.013)	(0.028)	(0.014)	(0.012)	(0.0090)	(0.031)	(0.014)	(0.017)	(0.014)	(0.032)	(0.019)
Mobile phone	-0.045				-0.035**				-0.012			
* Distance dummy	(0.029)				(0.014)				(0.018)			
Mobile phone		-0.011				0.019***				0.027***		
* Harvest season		(0.0089)				(0.0058)				(0.0065)		
Mobile phone			0.17***				0.098*				0.034	
* Network			(0.044)				(0.058)				(0.045)	
Mobile phone				-0.027				0.023				-0.043***
* Thin market				(0.019)				(0.016)				(0.014)
Transport cost	0.16*	0.21**	0.24**	0.20**	-0.053*	-0.045	-0.040	-0.044	0.084	0.089	0.086	0.078
	(0.091)	(0.094)	(0.094)	(0.093)	(0.031)	(0.033)	(0.034)	(0.033)	(0.068)	(0.066)	(0.065)	(0.069)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2520	2520	2520	2520	4080	4080	4080	4080	4788	4788	4788	4788
R^2	0.296	0.286	0.293	0.287	0.225	0.223	0.243	0.223	0.174	0.176	0.177	0.179
Joint significance	0.213	0.343	0.0002	0.323	0.034	0.001	0.174	0.221	0.123	0.0004	0.08	0.004

*p<0.10, **p<0.05, ***p<0.01 Standard Errors are clustered at the market pair level. *Mobile coverage both markets* $= 1$ in period t when both markets have mobile phone coverage, 0 otherwise. *Transport costs* are measured in *log* of ETB/quintals. Additional covariates include the occurrence of a weather-related shock in one of the markets at time t and the presence of cooperatives in one of the markets at time t. *Distance* $= 1$ if markets are located more than 340km apart in the case of wheat, more than 332km apart for teff and more than 440km apart for maize. *Harvest* $= 1$ for the period between September and February which corresponds the the Meher season, the main crop season. *Network* measures the % of markets with mobile phone coverage at time t. *Thin* $= 1$ for for the markets or market pairs where the cereals are thinly traded, defined as markets where the average quantity of cereals passing through the market per week is lower than the median. Joint significance: The numbers presented correspond to the p-values of the test of joint significance of the coefficients of *mobile coverage* and the respective interaction terms.