Tuning in the Market Signal: The Impact of Market Price Information on Agricultural Outcomes

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Abstract: This paper estimates the impact on agricultural market outcomes of providing small-scale farmers with access to market price information. We develop a simple general equilibrium model of the agricultural economy and use data from a natural experiment – the Market Information Service in Uganda – to assess the model's implications. Exploiting variation in access to market price information over time, across space, and between crops, we find that farmers that could access information were more likely to be involved in market exchange (the extensive margin); sold a higher share of output (the total margin); and benefitted from higher farm-gate prices. However, due to the endogenous response in market prices, farmers that were less likely to access information faced lower prices and were less likely to sell their surplus on the market. Together, our results indicate that the access to price information reduced market failures due to asymmetric information between farmers and traders, and lead to increased market activity and incomes for informed farmers, but also resulted in an increased dispersion in revenues between informed and uninformed farmers.

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"Buyers were offering 400 shs/kg for beans in our village, but when radio announced a price of 500 shs/kg we negotiated at that price"

"It's not easy to cheat farmers these days because they are getting information about market prices from the radio. Things are changing" [local trader in Uganda as reported in BBC Focus On Africa magazine, 2004]

1 Introduction

This paper investigates how access to information on market prices affects market activity and the allocations of goods in the economy. A cornerstone in economic theory is the role of information. One of the fundamental results in standard theory is that in perfectly competitive markets, where price taking producers and consumers are assumed to trade goods at publicly known prices, the allocations of goods in the economy is efficient.[1] In developing countries, however, these assumptions stand in sharp contrast to the reality faced by the main economic agents in the economy: the small-scale rural farmers (World Bank, 2007). While a majority of the population in developing countries live in rural areas and make their livelihood mainly from farming crops, access to updated information on prevailing prices in urban market centres is limited due to low levels of information and communication infrastructure (World Bank, 2007). Furthermore, when farmers choose to sell parts of their agricultural output, they typically do so by engaging in trade with local traders that buy their crops at the farm-gate, often with limited competition from other traders (Fafchamps and Minten, 2001; Ferris, 2004), and resell them in the urban market centers.[2] Importantly, while rural farmers have little access to updated price information, traders that constantly travel between rural areas and the market centers are naturally relatively well informed about the prevailing market prices.[3] The resulting economic exchange at the farm-gates could therefore be characterized as outcomes of a contracting process between traders and farmers, where traders have superior information relative to farmers. This type of asymmetric information, in turn, may lead to market frictions with sub-optimally low levels market exchange.

Furthermore. although sales of crops is the main source of cash income for many farmers in poor countries, farmers tend to sell only small shares of

[1] This is the famous First Fundamental Welfare Theorem.

[2] In Uganda, almost 80% of farmers sell their crops to private traders and only a few percent directly to a district market.

[3] See for instance Ferris (2004) and Banerjee and Meenakshi (2004).

their crop output. Figure 1 presents the percentage of total crop production that is sold by farmers in a set of low-income countries. As discussed further below, in Uganda, only around 25 percent of output is sold and less than one-third (and for some crops as few as one-tenth) of the farmers are active on the market. Thus, most of the agricultural production is consumed within the household. The low share of output sold is of course not necessarily due to market failures in agricultural markets, as the division of output between consumption and sales could be efficient if the markets are functioning well. However, given the lack of access to accurate price information in rural areas and the potentially important contractual frictions it may gise rise to, it is somewhat surprising that there are so few empirical studies estimating whether improvements in market information increases economic exchange and market participation by farmers. This paper aims to fill that gap.

We present a simple general equilibrium model with asymmetric information between farmers and traders, and assess the predictions of the model using data from a natural experiment – the Market Information Service in Uganda. Asymmetric information gives rise to contracting frictions between farmers and traders, as rent-seeking traders operating in rural areas with low availability of updated price information have incentives to claim that prices in urban markets are lower than prevailing ones. As a result, market exchange will be sub-optimally low, as the farmers' try to reduce the trader's incentives to report a low market price by cutting down the amount they sells when market prices are reported to be low.[4] Providing farmers with access to price information can reduce such market frictions, resulting in both increased market participation and higher farm gate prices. In partial equilibrium, this is the expected impact of the Market Information Service intervention: Farmers that get access to information are better off; while farmers that do not are unaffected. However, the increased participation (of informed farmers) in market exchange will induce changes in prices in urban market centers (i.e. market prices) and as a result, uninformed farmers will face lower prices and become less involved in market exchange.

Starting in 2000, the Market Information Service (MIS) in Uganda collected weekly data on market prices for some of the main agricultural commodities in 21 of Uganda's 56 districts, and disseminated the information through local FM radio stations in the participating districts. The presumption was that the provision of accurate, timely, and appropriate market information to farmers through radio transmissions would improve their ability to bargain with local traders. Using data from the Uganda National Household

[4]For an overview of bilateral contracting under asymmetric information, see Bolton and Dewatripont (2005).

Surveys of 2000 and 2005, as well as the data on market prices collected by MIS, we study the effects of giving farmers access to market price information on the likelihood of the farmers selling their crops, the share of the output sold, the prices received, and the effect on market prices. To identify the causal effects of access to the information, we exploit differences in exposure over time, across space, and between crops (within households).

The results show that access to market information increases the likelihood of selling the crop by 29% (from a baseline of 0.23), the share of output sold by 32% and the price by 0.41 standard deviations. As a result, crop income of farmers with access to market price information increased by an estimated 55%. Consistent with the model, we show that the effects are larger for crops that farmers are less able to predict the market price for (i.e., when the variance in the market price is high). This is consistent with larger *incentive effects* when the degree of asymmetric information increases. Finally, we show that the positive supply response from information leads to lower prices in urban market centers. Taken together our results indicate that the provision of market price information to small-scale farmers has both efficiency and distributional implications: Informed farmers benefit from higher farm revenues (due to reduced market frictions) while farm income falls for uninformed farmers (due to the change in market prices).

There is a small and recent literature on the effects of increased market information on market outcomes. Focusing on the ability to exploit arbitrage opportunities, Jensen (2007) evaluates the effects of the introduction of mobile phones on market outcomes in the fishing industry in Kerala, India. He finds that by improving fishermen's and traders' ability to communicate over large distances, the introduction of mobile phones improved arbitrage opportunities and resulted in reduced waste and decreased price dispersion across geographic markets. Studying traders' search behavior in Niger, Aker (2008) finds similar effects on price dispersions across grain markets when mobile phones were introduced. Both these studies focus on technology improvements that lower search costs in the decision on where to sell the output. Goyal (2010) exploits variation induced by the entry of a large private soybeans buyer (ITC) in Madhya Pradesh, India. She finds that providing farmers with information about wholesale prices of soybean in local markets and an outside option to sell directly at known prices to ITC, resulted in an increase in the average price of soybean in the local market. The finding is consistent with a model where information about current market prices and/or the introduction of a new outside option increased competition between the local traders. Our paper differs in important ways. First, as in Goyal (2010) we study the impact of increasing farmer access to price information, rather than trader access to information.[5] Second, since farmers in Uganda almost exclusively sell their crops to traders at the farm-gate and almost never travel to the market themselves, we do not primarily study the decision on where or to whom to sell the output. Instead, we investigate the impact on the economic exchange at the farm-gate when the farmer is better informed about the prevailing market price. The paper also highlights the importance of assessing the effects on market prices (i.e. general equilibrium effects), as uninformed farmers are not affected by the intervention in partial equilibrium, but faces lower prices when the response in market prices are taken into account. Finally, the functioning of agricultural markets in central to the development of low income countries and we study the question on why farmers in developing countries tend to sell only small fractions of their agricultural output. By addressing a particular source of market failure, the lack of updated market information leading to contractual frictions between farmers and traders, we assess to what extent market exchanges increase when the source of the market failure is removed. To the best of our knowledge, this is the first paper to estimate the impact of farmers' access to price information on farmers' likelihood of selling crops, the share of produce sold, the agreed upon farm-gate prices, and prices in urban market centers.

The remainder of this paper proceeds as follows: Section 2 and 3 discuss the institutional setup, including the Market Information Service project. Section 4 discusses the data and the empirical strategy. Section 5 presents the results. Section 6 conducts robustness checks and Section 7 concludes.

2 Uganda's Agricultural Sector

Uganda's economy is predominantly agrarian. The agricultural sector employs more than 80% of the labor force and is the main source of livelihood for more than 85% of the population. In addition, almost 94% of the agricultural production take place on smallholder plots, including virtually all food production (Ministry of Finance, 2008). Key agricultural products include cash crops (coffee, tea, cotton, tobacco, and cocoa) and food crops (plantains, maize, cassava, maize, beans, millet and sweet potatoes), and recently

[5]This is not to say that the information disseminated through radio did not contain any new information to traders. However, given that traders travels back and forth to the market places on a daily basis while farmers do not, it is clear that the relative information supplied to farmers was much larger. We also find no evidence of decreased price dispersion across districts after the radio disseminations started transmissions. Even if traders were benefitting, the empirical strategy identifies the farmer's access to price information.

a smaller set of horticultural produce. While there is significant variation across crops, the market is dominated by small-scale farmers. Detailed aggregate data for all crops is not available, but for maize, for example, it is estimated that 95% of the households engaged in maize production are small-scale farmers (with land holdings of 0.2-0.5ha), contributing over 75% of the marketable surplus of maize. Medium scale commercial farmers with 0.8-2.0ha of land under maize production contribute the remaining 25% (RATES Center, 2003).

Small-scale subsistence farmers sell off most of their surplus produce to rural traders immediately after the harvest due to limited infrastructure such as transport and storage facilities. For maize, rural traders, who operate in villages, constitute over 90% of the total number of maize traders and handle two-thirds of all traded maize. Typically, traders traverse villages on bicycles and pick-ups procuring produce at farm-gate prices on a cash basis. Moreover, almost no farmers engage in long-term contractual arrangements with a trader. In a survey on ten districts, Ferris et al. (2006) report that only 3% of the farmers were trading on the basis of long-term contractual arrangements. Instead, most farmers engage with the market through traders on an informal and opportunistic manner, resulting in spot contracts between farmers and traders.

Traders either work independently or as agents of larger urban traders. Since traders travel back-and-forth to the market, while farmers seldom sell their output on the main district markets, sellers generally have less or little information about current prices while buyers are often well-informed, at least about the price in the district market where they are active (RATES Center, 2003).

Prices on most cash- and food crops vary greatly in district markets in Uganda over time. To illustrate this, Figure 1 depicts the weekly market price for cassava in the Kasese district market center (the coefficient of variation over time is 0.28, close to the mean of 0.24). Given these price variations, it is not surprising that farmers in Uganda view getting market information as one of their highest priorities (Ferris, 2004).

Prices also vary greatly across locations. Figure 2 plots the market price of beans during week 20 in 2001 across the participating MIS-districts. The variation in prices across districts at a given point in time suggests that to the extent that farmers sell their output to traders located in their own district, the market price in that district, rather than the average price in the country, is the key statistic. Figure 2 also suggests that the lack of adequate transportation infrastructure makes it difficult to exploit arbitrage across markets, thus implying that prices can be systematically different across space at a given point in time.

2.1 The Market Information Service

In 2000, the Market Information Service project was initiated by two agricultural research organizations (IITA and ASARECA) in association with the Ministry of Trade, Tourism and Industry in Uganda. The starting point of the project was survey data indicating that most farmers had limited knowledge of the current market prices in the main district market centers, and scarce information on price movements and market trends. By providing accurate, timely and appropriate information, the assumption was that small-scale farmers would be able to make better decisions about what to produce and where to sell their output. Timely and accurate information would also improve farmers' bargaining position vis-à-vis local and regional traders.

In 2004, the Market Information Service was operating in 21 districts in Uganda.[6] Figure 1 shows a map of participating districts. The project collected data, on a weekly basis, on market prices for 19 agricultural commodities. In practice, however, the MIS regularly reported prices on the seven main food crops in Uganda (see details below): Beans, Cassava, Groundnuts, Maize, Millet and Sweet potatoes.

The information was processed and disseminated through various radio stations in each MIS district. Each week, a 15-minute radio program was broadcast and each day, a 2-4 minute news bulletin was broadcast in altogether eight local languages. The main focus of the radio shows was to provide updates on district market prices. The radio stations used for dissemination were popular ones and in 2004, the MIS was estimated to reach seven of Uganda's twenty-four million people each week (Ferris, 2004).[7] The intervention, therefore, was on a large-scale.

Next, we present a simple model of price information and agricultural market exchange.

[6] The total number of districts in 2004 was 56. Not all districts could be included in the MIS project because for budget and administrative reasons.

[7] The MIS project initially bought air-time from the radio stations for the radio program. Interestingly, because of the popularity of the program among farmers, several commercial radio stations started to transmit the programs without public funds.

3 A simple model of price information and agricultural market exchange

We model an economy consisting of atomistic small-scale rural farmers, rural-urban traders, and consumers in an urban center. There is one good (crop) which is produced by the farmers, bought by traders at farmers' farm-gates, and resold to consumers in the urban market center. The model consists of two parts. In the first part, we model how farm-gate prices and quantity are set, conditional on farmers' access to information, and taking (urban) market prices as given. In the second part, we endogenize the market prices in the urban market center where all traders sell the crops bought from farmers. This then pins down the equilibrium quantities and prices both in the urban market center and at the farm-gates. The model will have two key features reflecting the conditions in many low-income countries, including Uganda as described above. First, since traders constantly travel back and forth between the urban market and the rural areas, the market price (and the demand shock) will be observable to traders. Rural farmers do not observe the market price, however. Second, competition between traders at the farm-gate is imperfect. This will then give rise to inefficiencies due to asymmetric information between traders and farmers. Finally, we present predictions on how prices and quantities will respond to an increase in the access to price information. The goal is to take these predictions to the data in the subsequent sections.

3.1 The Farm-Gate Equilibrium

Let each farmer produce one crop of quantity Q, of which he can sell $q \leq Q$ to a trader and consume the rest, $c = Q - q$. We are interested in how much a farmer sells of what he produces and the prices he receives for his crops (henceforth "farm-gate price"), conditional on what information he has of the current retail market price (henceforth "market price"). The farmer's payoff function is

$$U = R + u(Q - q) \ , \tag{1}$$

where R is the total amount paid to the farmer (for q) and $u(0) = 0, u'(c) > 0$, $u''(c) < 0$.

Competition between traders at each farm-gate is imperfect.[8] For sim-

[8] Reasons for this could be high fixed costs (buying a truck) for becoming a trader, or collusion between traders.

plicity, we assume that there is one trader at the farm-gate to whom the farmer can sell.[9] The trader's profit is

$$\Pi = mq - R \ , \tag{2}$$

where m is the current market price in the urban retail market.[10] We assume there to be three possible market prices $m_1 < m_2 < m_3$ that are realized with probability π_1, π_2 and π_3, respectively (and summing up to one). To ensure that m_1 can be a price in equilibrium, we assume that $u'(Q) < m_1$.[11]

The economy consists of a continuum of atomistic farmers, with measure one. The are two types of farmers: informed (knows the realized retail market price) and uninformed (cannot observe the realized retail market price). There are $r \in (0, 1]$ informed farmers in the economy.

To keep things simple and avoid signalling games, the trader reports a market price to the farmer, and the farmer offers a take-it-or-leave contract to the trader on quantity q_i (subscript denotes state of nature or market price) and per-unit price p_i (or, analogously, revenue $R_i = p_i q_i$). We are interested in the menu of contracts $\{(q_i, m_i;\ i = 1, 2, 3\}$ to which the farmer can commit to.[12]

3.1.1 The uninformed farmer

Assume that the farmer cannot observe the market price. The farmer only knows that the market price is m_i with probability π_i. This is essentially a standard bilateral contracting model, or monopolistic screening, under hidden information (In the appendix, we present the first-best solution maximizing total welfare).

The farmer will suggest a contract conditional on the market price that the trader reports. The uninformed farmer's problem is that the trader, who

[9] If, for example, one allows for two traders they could, **thro**ugh Bertrand competition, make the environment perfectly competitive. It is worth noting that this would be inconsistent with the anecdotal evidence presented above. Moreover, informing the farmer about the market price in such a case would also have no effect as Bertrand competition would drive the farm-gate price to the market price (short of transport costs).

[10] Transport costs t could easily be added, for example the linear cost tq, for the trader without changing the main results.

[11] Solving the farm-gate equilibrium with continuous prices does not change the main results. We choose discrete prices because they are much more tractable than continuous prices. In the Ugandan data, the market price distribution resembles a truncated normal distribution. When $\pi_2 > 0.5$ and $\pi_1 \approx \pi_3$, three discrete prices can be used to serve as an approximation for a truncated normal distribution.

[12] We solve for the first-best benchmark contract in the appendix.

knows the market price, has incentives to claim that the market price is lower than it actually is. However, since the trader is more eager to buy when the market price is high, the farmer can possibly reduce the trader's incentives to report a low market price by cutting down the amount he sells when the trader reports a low market price. By reducing the trader's incentives to report a low market price, the farmer can reduce the informational rent of the trader.

The problem for the uninformed farmer can, in its most general form, be stated as

$$\max_{\{(q_i^{UI}, R_i^{UI})\}} \sum_{i=1}^{3} \pi_i \left[R_i^{UI} + u(Q - q_i^{UI})\right] \qquad \text{subject to} \tag{3}$$

$$m_i q_i^{UI} - R_i^{UI} \geq 0 \quad \text{for all } i \tag{4}$$

$$m_i q_i^{UI} - R_i^{UI} \geq m_i q_j^{UI} - R_j^{UI} \quad \text{for all } i,j \tag{5}$$

Exploiting the fact that the Spence-Mirrless single-crossing condition holds, we can reduce the number of incentive constraints to a smaller set of local downward incentive constraints and a monotonicity condition (see the appendix).[13] The monotonicity condition holds if

$$\text{Assumption 1: } \frac{1}{\pi_1}(m_2 - m_1) \geq \frac{\pi_3}{\pi_2}(m_3 - m_2) \tag{6}$$

which we assume to be the case.

Rewriting the first-order conditions we have

$$q_1^{UI} = \begin{cases} Q - u_c^{-1}\left(m_1 - \frac{(\pi_2+\pi_3)}{\pi_1}(m_2 - m_1)\right) & \text{for } m_1 > \tilde{m}_1 \\ 0 & \text{for } m_1 \leq \tilde{m}_1 \end{cases} \tag{7}$$

$$q_2^{UI} = \begin{cases} Q - u_c^{-1}\left(m_2 - \frac{\pi_3}{\pi_2}(m_3 - m_2)\right) & \text{for } m_2 > \tilde{m}_2 \\ 0 & \text{for } m_2 \leq \tilde{m}_2 \end{cases} \tag{8}$$

$$q_3^{UI} = Q - u_c^{-1}(m_3) \tag{9}$$

[13]The Spence-Mirrless single-crossing condition is

$$\frac{\partial}{\partial m}\left[-\frac{\partial U/\partial q}{\partial U/\partial R}\right] = \frac{\partial}{\partial m}\left[-\frac{m}{-1}\right] > 0$$

For details on how to solve contract problems of this form, see Bolton and Dewatripont (2005).

where the threshold market prices $\tilde{m}_i$ are

$$\tilde{m}_2 \equiv \left(\frac{1}{1-\pi_1}\right)(\pi_2 u'(Q) + \pi_3 m_3) \tag{10}$$

$$\tilde{m}_1 \equiv \pi_1 u'(Q) + (1-\pi_1) m_2 \tag{11}$$

and $\tilde{m}_2 > \tilde{m}_1$ as long as assumption 1 holds. Note that if $m_1 > \tilde{m}_1$ and $m_2 > \tilde{m}_2$, an uninformed farmer always sells positive amounts of his output. Given that a large fraction of small scale farmers in developing countries (a majority of the farmers in Uganda) are subsistence farmers that consume all their crop output, the assumption that $m_1 > \tilde{m}_1$ and $m_2 > \tilde{m}_2$ are inconsistent with the data. In addition, since one of the goals of the model is to explain behavior on the extensive margin (i.e., the probability of selling any output), we instead make the natural assumption that the uninformed farmer is the least willing to sell at the lowest market price. That is, we assume that

Assumption 2: $m_1 < \tilde{m}_1$ and $m_2 > \tilde{m}_2$

holds, which implies that $q_1^{UI} = 0$. The probability that the uninformed farmer will engage in market exchange (i.e., the extensive margin) is then

$$\rho^{UI} \equiv P(q_i^{UI} > 0) = 1 - \pi_1. \tag{12}$$

From the IR-constraint and the IC-constraints (see appendix), we can determine the farm-gate prices for the uninformed farmer

$$p_1^{UI} = \{\text{no exchange}\} \tag{13}$$

$$p_2^{UI} = m_2 \tag{14}$$

$$p_3^{UI} = m_3 - \frac{q_2^{UI}}{q_3^{UI}}(m_3 - m_2) \tag{15}$$

Note that $p_i^{UI} \leq m_i$ for $i = 2, 3$. Using (14), (15), (64) and (65), the average farm-gate price and quantity are

$$E\left[p_i^{UI}\right] = \frac{1}{1-\pi_1}\left(\pi_2 m_2 + \pi_3 m_3 - \pi_3 \frac{q_2^{UI}}{q_3^{UI}}(m_3 - m_2)\right) \tag{16}$$

$$E\left[q_i^{UI}\right] = \pi_2\left[Q - u_c^{-1}\left(m_2 - \frac{\pi_3}{\pi_2}(m_3 - m_2)\right)\right] + \pi_3\left[Q - u_c^{-1}(m_3)\right] \tag{17}$$

Having presented the equilibrium outcomes for uninformed farmers, we now turn to the case of the informed farmer.

3.1.2 The informed farmer

Now instead assume that the farmer knows the current market price. The constrained maximization problem is then

$$\max_{\{(q_i^I, R_i^I)\}} \sum_{i=1}^{3} \pi_i \left[R_i^I + u(Q - q_i^I)\right] \quad \text{subject to} \tag{18}$$

$$m_i q_i^I - R_i^I \geq 0 \quad \text{for all } i, \tag{19}$$

where (19) is the trader's individual rationality constraints (IR).

Since the farmer has no incentives to relax the IR-constraints, we can solve for R_i^I from (19) and substitute into the maximand (18). This yields an identical problem as that in the first-best. Thus, the quantity sold under full information, q_i^I, is equal to the first-best quantities

$$q_i^I = Q - u_c^{-1}(m_i), \; i = 1, 2, 3 \tag{20}$$

From the IR-constraint we can solve for the farmer's revenue, R_i, and the unit price

$$p_i^I \equiv \frac{R_i^I}{q_i^I} = m_i. \tag{21}$$

We can now calculate the average farm-gate price and quantity

$$E\left[p_i^I\right] = \pi_1 m_1 + \pi_2 m_2 + \pi_3 m_3 \tag{22}$$

$$E\left[q_i^I\right] = \pi_1 \left(Q - u_c^{-1}(m_1)\right) + \pi_2 \left(Q - u_c^{-1}(m_2)\right) + \pi_3 \left(Q - u_c^{-1}(m_3)\right) \tag{23}$$

$$\rho^I \equiv P(q_i^I > 0) = 1, \tag{24}$$

where the last result implies that the informed farmer will always engage in market exchange since $u'(Q) < m_1$.

3.1.3 Informed versus uninformed farmers

Define the differences in average outcomes as $\beta_s \equiv E\left[q_i^I - q_i^{UI}\right]/Q$, $\beta_\rho \equiv \rho^I - \rho^{UI}$, and $\beta_p \equiv E\left[p_i^I - p_i^{UI}\right]$. Using (12), (16), (17), (24), (22) and (23), we can calculate the average difference in outcomes

Extensive margin:

$$\beta_\rho = \pi_1 > 0 \tag{25}$$

Share sold:

$$\beta_s = \frac{1}{Q}\left[\pi_1 q_1^I + \pi_2 (q_2^I - q_2^{UI})\right] > 0 \tag{26}$$

Farm-gate price:

$$\beta_p = \pi_1 (m_1 - \hat{m}) + \left(\frac{\pi_3}{\pi_2 + \pi_3} \right) \left(\frac{q_2^{UI}}{q_3^{UI}} (m_3 - m_2) \right) \lesseqgtr 0 \ . \qquad (27)$$

where $\hat{m} \equiv \frac{\pi_2 m_2 + \pi_3 m_3}{1-\pi_1}$. Even though the informed farmer gets a higher farm-gate price for each market price at which the uninformed farmer sells, we see that the *average* difference in farm-gate prices can be either positive or negative. This may seem counterintuitive, but it is driven by the fact that becoming informed has two effects on the farm-gate price: a direct *incentive* effect (positive) and an indirect *selection* effect (negative). First, the direct incentive effect is positive since, conditional on a market price, the informed farmer does not have to incentivize the trader in order to reduce informational rents. This increases the average farm-gate price for the informed farmer. Second, the indirect selection effect is negative since the informed farmer is willing to sell at the lowest market price, while the uninformed farmer is not. This decreases the average farm-gate price for the informed farmer. If $m_1 > \hat{m}$, the direct incentive effect dominates the indirect selection effect, and the effect of being informed is positive on the farm-gate price.[14] However, since it is not obvious a priori which effect that should dominate, this is an empirical question. We can now summarize the key results in the following proposition.

Proposition 1 *Taking the urban market price distribution as given, an informed farmer is more likely to be active on the mark*et than an informed farmer (t*he extensive margin);* $\beta_\rho > 0$, *and will on average sell a larger share of his output (the total margin);* $\beta_s > 0$. *The difference in average farm-gate price is in general indeterminate;* $\beta_p \lesseqgtr 0$. *If the incentive effect dominates the selection effect, the effect on the farm-gate price is positive,* $\beta_p > 0$.

Intuitively, since the trader is more eager to buy when the market price is high, the uninformed farmer can reduce the trader's incentives to report a low market price by cutting down the amount he sells when market prices are low. By sacrificing allocative efficiency, the farmer reduces the trader's incentives to misreport the market price and thus reduces the trader's informational rents. Such an incentive scheme may be too costly when the market price is very low, so for low prices the farmer will choose not to sell.

Proposition 2. *Provided that assumptions 1 and 2 hold, and for a given market price, an increase in* π_1 and π_3 *(which implies an increase in the*

[14] As long as the lowest market price, m_1, is higher than the expected market price under which uninformed farmers actively sell, $\hat{m} \equiv \frac{\pi_2 m_2 + \pi_3 m_3}{1-\pi_1} = E[m_i \mid q_i^{HI} > 0]$, the effect is positive.

variance of market prices) will increase the difference in the intensive and the extensive margin between the full information and the hidden information outcomes.[15]

Intuitively, stronger incentives are required to induce the trader not to report a lower price than the market price when the distribution of prices are more spread out.

3.2 The Urban Market Price

In the previous section, prices were taken as given. In this section, we endogenize the market prices. Each trader sells all the crops that he has purchased from farmers. Let the set of traders be large such that each trader is a price taker in the retail market at the urban center. The supply is then a function of the market price and the fraction of informed farmers,

$$S(m_i, r) = rq^I(m_i) + (1-r)q^{UI}(m_i) \quad , i = 1, 2, 3 \tag{28}$$

where $q^I(m)$ and $q^{UI}(m)$ are given by equations (63) - (65), and (20), respectively. We can consider the demand coming from consumers consisting of urban non-agricultural households. For simplicity, we assume a linear demand function

$$D(m_i, \varepsilon_i) = d - \delta m_i + \epsilon_i \quad , i = 1, 2, 3 \tag{29}$$

where ϵ_i is an aggregate demand shock. We assume there to be three possible demand shocks $\epsilon_1 < \epsilon_2 < \epsilon_3$, that are realized with probability π_1, π_2, π_3, respectively (and summing up to one). We can think of the demand shock emanating from shocks in urban wages due to import or export price shocks for non-agricultural commodities. Key is that the demand shocks give rise to market price shocks and they are unobservable to farmers but observable to traders. This gives rise to the asymmetric information frictions at the farm-gate when farmer and traders bargain over the contract.[16]

[15] An increase in π_1 and π_3 results in a fall in π_2. As a result, q_2^{HI} falls and ρ^{HI} increases. q_2^{FI} and ρ^{FI} remain unchanged. p_2^{HI} also falls but p_3^{HI} increases so the effect on $E[p_i]$ is unclear.

[16] The linear demand function is not necessary for the main results. It is sufficient with a downward sloping demand curve. Key is that farmers cannot observe the market prices and the demand shocks. Similar results could be produced with aggregate and idiosyncratic supply shocks affecting Q, as long as farmers cannot perfectly observe the two shock components.

The equilibrium (the urban market equilibrium and the farm-gate equilibrium) is pinned by three market clearing conditions

$$d - \delta m_1^* + \epsilon_1 = r q_1^I(m_1^*) \tag{30}$$

$$d - \delta m_2^* + \epsilon_2 = r q_2^I(m_2^*) + (1-r) q_2^{UI}(m_2^*, m_3^*) \tag{31}$$

$$d - \delta m_3^* + \epsilon_3 = q_3^I(m_3^*) \tag{32}$$

together with the farm-gate equilibrium quantities (63) - (65), and (20).

Taking the total derivative with respect to r, we can determine the effect of r, the share of informed farmers, on the retail market prices. The three derivatives are

$$\frac{\partial m_1^*}{\partial r} = -\frac{q_1^I(m_1^*)}{\delta + r\frac{\partial q_1^I(m_1^*)}{\partial m_1^*}} < 0 \tag{33}$$

$$\frac{\partial m_2^*}{\partial r} = \frac{q_2^{UI}(m_2^*, m_3^*) - q_1^I(m_1^*)}{\delta + r\frac{\partial q_1^I(m_2^*)}{\partial m_2^*} + (1-r)\frac{\partial q_2^{UI}(m_2^*, m_3^*)}{\partial m_2^*}} < 0 \tag{34}$$

$$\frac{\partial m_3^*}{\partial r} = 0. \tag{35}$$

The expected marginal effect of the share of informed farmers on the urban market price is thus

$$\beta_m \equiv \frac{\partial E\left[m^*\right]}{\partial r} = \pi_1 \frac{\partial m_1^*}{\partial r} + \pi_2 \frac{\partial m_2^*}{\partial r} < 0 \tag{36}$$

We can now state the third and final proposition:

Proposition 3. *The retail market price is decreasing in the share of informed farmers.*

The intuition behind this result is relatively straightforward, as informed farmers sell larger shares of their output (relative to uninformed farmers) given a market price. Increasing the share of informed farmers increases the total quantity sold by traders in the retail market, which shifts the supply curve outward. This then puts downward pressure on prices in the retail market.

Furthermore, Proposition 3 implies that Propositions 1 and 2 are now equilibrium statements with endogenized market prices. In other words, the differences between informed and uninformed farmers (β_ρ, β_s, β_p) are differences that are partly driven by how many farmers are informed, since uninformed farmers are affected by available price information through the supply behavior of informed farmers (and vice versa).

3.3 Predictions

Using Propositions 1-3, we can summarize the main predictions:

Prediction 1 (Extensive Margin): *Informed farmers are more likely to engage in market exchange ($\beta_\rho > 0$).*

Prediction 2 (Total Margin): *Informed farmers sell larger shares of their output ($\beta_s > 0$).*

Prediction 3 (Farm Gate Price): *The effect on the farm-gate price is in general indeterminate ($\beta_p \lesseqgtr 0$). If the direct incentive effect dominates the indirect selection effect, the effect is positive.*

Prediction 4 (Price Uncertainty Effects): *The effect on supply behavior (Extensive and Total Margin) is increasing when there is more underlying uncertainty in the market price (i.e., when the market price distribution is wider).*

Prediction 5 (Retail Market Price): *When the share of informed farmers increases, the retail market price decreases ($\beta_m < 0$).*

Next, we present how we take these predictions to the data.[17]

4 Data

To test the predictions of the model, we want to measure whether a farmer is informed about the market price, whether he engages in market exchange (ρ_i), the share of output sold (s_i), the farm-gate price for sold crops (p_i), and market prices (m_i). We are then interested in whether the Uganda Market Information Service that informed farmers about prevailing market prices through local radio stations affected the outcome variables as predicted by the model.

We use three data sets: The Uganda National Household Survey 1999/2000 and 2004/2005 (hereafter UNHS 1999 and UNHS 2005) and data from the

[17] Note that the effects should be interpreted with consideration to the general equilibrium effects associated with the price information broadcasts. As predicted by the model and shown by the empirical results, the urban market price will decrease due to increased supply when many farmers are informed. This will also affect the uninformed farmers and the farm-gate estimates should therefore be interpreted according to β_ρ, β_s, β_p under endogenized prices.

Market Information Service, provided by Foodnet. The two household surveys include a full crop module, enabling us to calculate farm-gate prices for crops sold, p_i in the model, as well as measures of market participation on both the extensive (ρ) and intensive (s) margins. The farmer data is measured at the plot level. Summary statistics of the UNHS 1999 and 2005 are reported in table 1. The data from the Market Information Service contains weekly data on collected urban market prices (from 2000 to 2005, with some missing data). There is one urban market per district. The broadcasts were phased in, starting in 2000 for the earliest district (Kampala) and completed by 2004.[18] Using the UNHS 1999 dataset, we are able to use data from before the broadcast started. By using the UNHS 2005 dataset, we can use data for when the MIS was fully operational. In addition, for a subset of eight districts, we have been able to collect information on the exact month in which broadcasts started.

4.1 Measuring the outcome variables (ρ, s, p, m)

In our sample of the UNHS 1999 and 2005 datasets, there are 7960 and 5733 farmers, respectively. Each farmer in the dataset produces one crop or more. We use crop level data which contains information on what type of crop that is produced, the quantity produced, the quantity sold, and the price for the quantity sold. We also have access to a subset of the MIS radio scripts that were used for the broadcasts. They show that there were some minor crops for which price information was collected but very seldom broadcast. We use the main MIS crops, defined as those that were reported in radio scripts on average at least once per month in 2004 and for which we have at least 1,000 data points (farmer plots) in the 2005 UNHS survey.[19] The main MIS crops constitue 76% of the reported MIS crop observations in the crop surveys.

We take a conservative approach with respect to outliers, all of which clearly seem to be a result of misreporting. Thus, we drop all price observations with a reported unit price (the survey contains information on the quantity produced of each crop, the quantity sold, and the total value of the sale) higher than the highest reported weekly market price across all MIS district market centers and we drop all price observations with a unit price below

[18] We drop the capital Kampala from our sample since there are no rural farmers in Kampala.

[19] 1,000 plots correspond to roughly 1% of the reported MIS crops. We also exclude Bananas/Matooke since the MIS only reported one type of Banana/Matooke price while the crop modules list three types of plantain banana crops (Matooke) and we were unable to separate for which one there were broadcasts.

roughly 0.01US$ (which corresponds to dropping all observations below the 1th percentile of the distribution for each crop). We also drop observations with a higher quantity sold than harvested.

We use a similar rule to define control crops (non-MIS crops). Specifically the control crops are those crops for which the MIS did not collect data for and that constitute at least one percent of the reported non-MIS crops in the 2005 UNHS survey. We drop coffee since the Uganda Coffee Development Authority (UCDA) runs a similar radio program for coffee in the main coffee producing areas of Uganda.

For each crop, we construct an indicator variable equal to one if any of the output was sold, and zero otherwise, as well as the share of the output that was sold.[20] For farm-gate prices, we then calculate the per kilogram price by dividing the total price by the quantity sold (in kilograms).[21] We can then calculate the standardized farm-gate price.[22]

The UNHS 1999 and 2005 datasets also have information on whether the farmer owns a radio, whether the farmer sold directly to the district market center and a quiz testing the farmer's knowledge of agricultural technology. The latter variable consists of seven multiple answer questions.[23] We construct a variable measuring the fraction of correct answers by the farmer.

For urban market prices, we use the MIS data provided by Foodnet. By exploiting the data for the subset of eight districts where we know the month in which the broadcasts started, we can divide the ten districts into early and late MIS districts. The early districts received broadcasts starting in February 2001 and the late districts received broadcasts starting in September 2002.[24]

[20] In Uganda, there are two growing seasons per year. For each UNHS dataset, the crop data contains information for each season.

[21] The datasets also contain information on type of buyer. In 2005, 70% of the output were sold to a private trader in the household's village, 16% directly to another consumer or neighbor/relative, 9% at the district's market center, and 5% to "other type of buyers". For simplicity, although the output is not always literally sold to a private trader at the farm-gate, we label the price of all transaction types as the "farm-gate price".

[22] That is, $p_{ij} = (\tilde{p}_{ij} - \bar{p}_j)/\sigma_j$, where $\tilde{p}_{ij}$ is the farm-gate price/kilogram in Uganda Shillings received for the sold quantity of crop j by household i; $\bar{p}_j$ is the mean farm-gate price in the sample, and σ_j is the corresponding standard deviation.

[23] Such as: Which of the following cassava planting methods provides better yields? 1. Vertically planted sticks; 2. Horizontally planted sticks; 3. Both; 4. Don't know.

[24] The early districts are Jinja, Kabale, Masindi, Mbarara, and Soroti. The late districts are Gulu, Mbale, and Tororo.

5 Empirical Strategy

This section outlines how we estimate the predictions of the model. We first present the coefficient of interest and the empirical challenges of estimating it. We then present our empirical strategy and specifications for how we estimate the effects.

5.1 Farm-Gate Outcomes: Predictions 1-3

We are interested in the effects of being informed about the district market price and estimating

$$y_i = \alpha + \beta info_i + \varepsilon_i. \tag{37}$$

where α is the average outcome y_i for an uninformed farmer, the effect of being informed, β, is given by (25) for the extensive margin, (26) for share sold, and (27) for the farm-gate price. The error term ε_i captures all other determinants of y_i and is orthogonal to $info_i$. We face two empirical challenges in identifying β. First, regarding measurement, ideally we want to measure whether the farmer is informed or uninformed. That is, we want to measure whether each farmer always knows the market price in the district market center. However, the UNHS 1999 and 2005 datasets do naturally not contain this information. Instead, we will use various measures of *access* to price information, as we will exploit variation in access to price information through radio broadcasts via the Market Information Service. That is, we will estimate the reduced form effects of having *access* to the Market Information Service on farmers' market outcomes. It is worth noting that as long as the effect of having access to the price information of the Market Information Service affects the outcome variables only through informing farmers about market prices, this will give us a lower bound of β.[25]

Second, regarding identification, estimation of β requires that *access* to the Market Information Service is uncorrelated with the other determinants of the outcome variables. The Market Information Service broadcasts information through local radio stations, and the UNHS datasets contain information on radio ownership of farmers. However, only using radio ownership

[25] In principle, access to information could be used as an instrument for being informed (if we had the data) in an IV-framework. The reduced form coefficient will give us a lower bound of β (under homogeneous effects). This is because the reduced form population coefficient $\beta^{rf} = \beta * \beta^{first} \leq \beta$, where $\beta^{first} \in (0, 1]$ is the first-stage population coefficient of access on being informed. It is also worth pointing out that from a policy perspective, β^{rf} is an interesting coefficient in its own right.

as a measure of access to price information is unlikely to capture causal effects, since radio ownership is likely to be correlated with other determinants of market outcomes (e.g., living close to the urban centers, farmer wealth, agricultural productivity, etc). To identify the causal effects of access to the information, instead, we instead employ two differences-in-differences (DD) and triple-differences (DDD) estimations in various dimensions. Specifically, we study farming households with and without radio across space (MIS districts versus non-MIS districts) and between crops (MIS crops versus non-MIS crops). The main differences-in-differences specifications are

$$y_{idc} = \alpha + \delta radio_{idc} + \beta radio_{idc} \times infodistrict_d + \mu_{dc} + \varepsilon_{idc} \ , \qquad (38)$$

where y_{idc} is the outcome of farmer i in district d producing crop c.[26] The variable $radio_{idc}$ is a dummy variable equal to one if the farmer owns a radio, $infodistrict_d$ is a dummy equal to one if district d is an MIS district (i.e., collecting and broadcasting price information through radio). We use district-by-crop fixed effects μ_{dc}. Our key outcome variables are p_{idc}, the standardized farm-gate price per kilogram received for crop c by farmer i; s_{idc}, the share of output that is sold; and ρ, an indicator variable taking the value of 0 if $q_{ij} = 0$ and 1 otherwise (the extensive margin). We cluster the standard errors at the district level (there are 56 districts in the full sample). We use the 2005 UNHS dataset and by predictions 1-3 we expect: $\beta_p > 0$; $\beta_\rho > 0; \beta_s > 0$. To consistently estimate β, the following assumption is needed:[27]

Identifying assumption (equation 38): Farmer selection into radio ownership is homogeneous in districts with and without price information broadcasts.

If, for some reason, selection into radio ownership is not homogeneous in districts with and without the MIS, the identifying assumption required for estimating equation (38) is violated and the estimates will be biased. To address this possibility, we use both the 1999 and 2005 UNHS datasets and estimate the following equation from the sample of MIS districts only (i.e., $infodistrict_d = 1$)

$$y_{idct} = \alpha + \delta radio_{idct} + \theta year05_t + \beta radio_{idct} \times year05_t + \mu_{dc} + \varepsilon_{idc} \ , \quad (39)$$

[26] Please notice the slight abuse of notation as the equation now refers to β as the reduced form effect of access to price information, rather than the effect of being informed in equation (37).

[27] We must also assume no information spill-overs. However, in the case of spill-overs where farmers without radio get the price information from talking to neighboring farmers with radio, we will understimate the true effects.

where y_{idc} is the outcome of farmer i in district d, producing crop c in year t; $year05_t$ is a dummy variable indicating the observation is from 2005, and zero if it is from 1999, and μ_{dc} is district-by-crop fixed effects. By predictions 1-3, we expect: $\beta_\rho > 0$; $\beta_s > 0$; $\beta_p \lesseqgtr 0$. To consistently estimate β, the identifying assumption is:[28]

Identifying assumption (equation 39): Farmer selection into radio ownership is time-invariant.

Although both the above assumptions may seem plausible, we might worry about selection of radio ownership being time-variant and different across districts with and without price information broadcasts. This might, for example, be the case if farmers with higher quality crops have a higher demand for price information, and some of the marginal farmers will have bought a radio in response to the introduction of MIS. More generally, farmers with radio in MIS broadcasting districts, as compared to farmers with radio in districts with no MIS broadcasts, might therefore have different unobserved characteristics in 2005. This would then violate the identifying assumptions and bias the results. To address this concern, we exploit variation across crops in triple-differences estimations. Since the MIS did only collect and broadcast information on some, but not all, crops, farmers with radio only received regular price information through radio for some crops. Therefore, we define two groups of crops: MIS crops and non-MIS crops. MIS crops are crops for which district prices were regularly reported on the MIS radio programs and include Maize, Beans, Groundnuts, Cassava, Millet and Sweet potatoes.[29] Non-MIS crops are crops on which the Market Information Service did not disseminate price information.[30] Importantly, since many farmers produce more than one

[28] In the exogeneity check section below, we assess this assumption by running placebo estimations using only district that never received MIS broadcasts.

[29] We coded all radio scripts in 2004 and coded all reports of crop prices. We then calculated the share of reports (out of all reports of crop prices) for each crop during 2004. The main food crops (see Uganda Bureau of Statistics, 2000) maize, beans, groundnuts, cassava, millet, and sweet potatoes were mentioned in the radio scripts 5% of the times, with prices for maize and beans being reported most often. The MIS project also regularly reported prices for Matooke [plantains or food bananas], but the agricultural module in the household survey data does not code plantains but several types of Matooke (Matooke food, Matooke beer, Matooke sweet), so we cannot link the two data sets for this crop. Note that the popular name for the plantain (food banana) is Matooke, which is also the name for the popular prepared dished of the plantain. Several crops were only reported a handful of times in some districts (less than 1%) during the year.

[30] We drop minor non-MIS crops defined as those crops that constitute less than 1 of the reported non-MIS crops in the 2004/2005 crop survey. The following crops are included: Avocado, Cowpeas, Cotton, Field peas, Onions Pawpaw, Peas, Pigeon peas, Pineapple,

crop, this strategy allows us to also use *farmer fixed effects*. That is, this controls for *any* unobserved farmer characteristic that homogeneously affects farmers' market activity. The main triple-difference specification is therefore similar to equation 21, with the added variation across crops and the use of farmer fixed effects,

$$y_{idc} = \alpha + \delta r \times ic_{idc} + \lambda id \times ic_{idc} + \beta r \times id \times ic_{idc} + \eta_c + \gamma_i + \varepsilon_{idc}, \quad (40)$$

where y_{idc} is the outcome of farmer i in district d, producing crop c. The variable r_{idc} is a dummy variable equal to one if the farmer owns a radio; id_{idc} is a indicator variable equal to one if district d is a MIS district (and zero otherwise); ic_{idc} is a indicator variable equal to one if the crop produced by farmer i is an MIS crop (and zero otherwise); η_c are crop fixed effects; and γ_i are farmer fixed effects. To test the predictions of the model, we will use the UNHS 2005 data. By predictions 1-3, we expect: $\beta_\rho > 0$; $\beta_s > 0$; $\beta_p \lesseqgtr 0$.

Identifying assumption (equation 40): Differential farmer selection into radio ownership across districts with and without price information broadcasts is only determined by farmer characteristics that are homogenous across crops.

5.2 Farm-Gate Outcomes: Prediction 4

To further investigate the predicted mechanisms further, we test the auxiliary prediction that the effects of price information on the likelihood of selling and the share of the output sold are larger when there is more uncertainty about the market price. That is, when there is more variation in the market price it is more difficult for the farmer to predict the market price, which creates more information frictions between traders and farmers. We use the weekly data from the Market Information Service on district market prices for the MIS crops and calculate the coefficient of variation (CV) in market prices for each crop during the year 2004.[31] We then test the auxiliary prediction of the model by the following specification

$$y_{idc} = \alpha + \delta radio_{id} + \beta radio_{id} \times cvhigh_c + \mu_{dc} + \varepsilon_{idc} \ , \quad (41)$$

Plantation trees, Sugarcane, Tobacco, Tomatoes, Vanilla, and Yams. Prices on coffee were reported through UCDA radio broadcast and were consequently not included.

[31] The average coefficient of variation in crop market prices is 0.15 and the standard deviation is 0.085.

where y_{idc} is the outcome of farmer i in district d, producing crop c. The variable r_{idc} is a dummy variable equal to one if the farmer owns a radio; $cvhigh_d$ is a dummy variable equal to one if crop c is a high price variation crop (above the median in the distribution of coefficients of variation across MIS crops); and μ_{dc} are district-by-crop fixed effects. By prediction 4, we expect $\beta_\rho > 0$; $\beta_s > 0$; $\beta_p \lesseqgtr 0$. The specification allows for the selection of radio ownership to differ across farmers with different characteristics, as well as the selection of high and low price uncertainty crops to differ across farmers. The identifying assumption is

Identifying assumption (equation 41): The *joint* selection of radio ownership and crop with high price uncertainty is uncorrelated with the other determinants of farmers' supply outcomes.

Under this assumption, we can consistently estimate β. Naturally, examples where this assumption would be violated can be found. For example, risk aversion could be heterogeneous among farmers and may affect the contracting with traders. If risk averse farmers also select into crops with low price uncertainty, and are more likely to own a radio because of higher demand for information, then the assumption would be violated. To partially assess this assumption, we run separate regressions on the 1999 placebo sample (before the MIS started broadcasting) and the 2005 sample.[32] If the identifying assumption is correct, we expect $\beta = 0$ in the 1999 sample.

5.3 Prediction 5: Retail Market Price

Prediction 5 implies that when the share of informed farmers increases, the prices in the urban retail market should decrease due to increased supply. To test prediction 5, we use the market price data from the urban retail markets and estimate the following two specifications[33]

$$m_{cdt} = \alpha + \beta idist_d \times started_{dt} + \gamma_t + \mu_{cd} + \lambda_d \times t_t + \varepsilon_{cdt} \ , \tag{42}$$

$$m_{cdt} = \alpha + \delta r_{cd} + \beta r_{cd} \times started_{dt} + \gamma_t + \mu_{cd} + \lambda_d \times t_t + \varepsilon_{cdt} \tag{43}$$

[32] Note that since we do not have any data on market prices for the crops that were not part of the Market Information Service, we cannot exploit variation across MIS and non-MIS crops.

[33] The urban market price data contains data both on off-lorry prices and retail prices. We use the off-lorry prices as these are what is paid to the traders. The two prices are naturally very similar: the correlation is 0.96.

where m_{cdt} is the standardized price of crop t in the market center of district d, in week t. The variable $idist_d$ is a dummy variable indicating if the MIS district received broadcasts starting in February 2002, and zero if the MIS district did not receive broadcasts until after the sample period (the sample runs from August 2001 to August 2002); $started_{dt}$ is a dummy variable indicating post-January 2002, and zero otherwise; r is the percentage of farmers in district d and growing crop c that owns a radio in 1999; γ_t are time fixed effects (weeks); μ_{dc} are district-by-crop fixed effects; $\lambda_d \times t_t$ is a district linear time trend. By prediction 5, we expect $\beta < 0$ in both specifications.

Identifying assumptions : When estimating equation (42), the assumption is that in the absence of price information broadcasts, early and late MIS districts would have parallel trends in crop prices. Similarly, for equation (43), in the absence of broadcasts, the crop price in districts with a large fraction of farmers with radio would have a parallel trend to districts with a small fraction of farmers with radio.

5.4 Exogeneity Checks

To assess the identifying assumptions in equations (38), (39), and (40), we run a set of placebo tests before running the main regressions.

First, if the identifying assumption for (38) is correct, then there should be no effect before the price information broadcasts started. Therefore, we estimate equation (38) using the 1999 UNHS dataset. Second, if the identifying assumption for (39) is correct, there should be no effect over time in districts that never received the price information broadcasts. Table 2 shows the placebo tests of equations (38) and (39). Columns (1) and (2) report the estimates for farm-gate prices, columns (3) and (4) reports them for the share of output sold, and the estimates for the probability of selling are found in columns (5) and (6). They show that the differences-in-differences estimates in columns (1) - (6) are small and insignificant.

Third, by a similar logic, we estimate (40) using the 1999 UNHS dataset. If the identifying assumption is correct, there should be no differential effect across crops before the MIS broadcasts started. Columns (1) - (6) in Table 2 report the estimates. We see that the triple-differences estimates are small and insignificant.

Finally, in order to assess the parallel trend assumption in equation (42), Figure 4 shows weekly average standardized market prices for early districts ($idist_d = 1$) and average standardized market prices for late districts ($idist_d = 0$), before (Phase 0) and after (Phase 1) the broadcast started in the early districts. We see that before the broadcast started, the market prices follow each other closely as there is no apparent difference in prices. Importantly, there is no evidence of a differential decreasing trend for early districts, relative to late districts. Consistent with prediction 5, we also see that after the broadcast started (Phase 1) in late districts, early districts have visibly lower prices than late districts. Figure 4 shows weekly prices up to and including August. In September, one of the late districts (Gulu) started broadcasting. To further assess the identifying assumption, Figure 5 also shows market prices for early districts over time, but instead of all late districts it only shows the average price for Gulu. We see that when Gulu receives broadcasts in September, the average price immediately converges to the average price of the early districts. This strongly suggests that the price differences were driven by the introduction of the broadcasts.

We also run placebo tests to assess the identifying assumptions of equations (41) and (43). We show the results of these estimations in the same tables as the treatment estimations (Tables 9 and 10).

Together, the exogeneity checks are consistent with the identifying assumptions, which lends some credibility to the empirical strategy.

6 Results

In this section, we present the regression results. We first show the results for the farm-gate outcomes and then we present the results for the urban market prices. Finally, we show the results for the auxiliary prediction on the heterogenous effects of market price uncertainty.

6.1 Predictions 1-3: Farm-Gate Outcomes

Predictions 1-3 imply that access to price information will decrease the asymmetric information between farmers and traders and lead to an increased likelihood of selling the crops and larger shares of the output sold. If the incentive effect dominates the selection effect, the effect on the farm-gate price is positive (and it is negative if the opposite holds).

Table 4 reports the results for the estimations of equations (38) and (39). Columns (1) and (2) show the results for farm-gate prices. In both specifications, the interaction coefficients are positive (0.132 and 0.138) and statistically significant (5% and 10%, respectively). Columns (3) and (4) depict the results for the share of output sold. Also here are the interaction coefficients in both specifications positive (0.167 and 0.174) and statistically significant (both at 5%). Columns (5) and (6) depict the results for the extensive margin. The interaction coefficients in both specifications are positive (0.042 and 0.047) and statistically significant (5% and 1%, respectively). Together, the results are consistent with the predictions of the model: informed farmers are more likely to sell their crops (Prediction 1), they sell larger shares of their output (Prediction 2) and they obtain higher prices (Prediction 3). The fact that the farm-gate price increases is consistent with the incentive effect dominating the selection effect.

The validity on the estimates in Table 4 hinges on the identifying assumption necessary for estimating (38) and (39). If they are violated, for example because farmers with unobserved farmer characteristics differentially select into radio in districts with price information broadcasts, the estimates will be biased (and, perhaps, most likely upward). Next, we present the triple-difference estimates that exploit variation across crops. In the most restrictive specification, we use farmer fixed effects that allow for any unobserved farmer characteristic.

Table 5 shows the results for the triple-differences estimates on the likelihood of selling any output (the extensive margin). Using crop and district fixed effects, column (1) shows that the estimate **is** positive (0.086) and significant at the 1% level. Column (2) shows the **results,** adding district-by-crop fixed effects, and the triple-differences estimate is positive (0.079) and significant at the 1% level. Finally, the results using the most restrictive specification by adding farmer fixed effects show that the estimate is positive (0.066) and significant at the 10% level.

Table 6 shows the results for the triple-differences estimates on the share of output sold (the total margin). Using crop and district fixed effects, column (1) shows that the estimate is positive (0.357) and significant at the 5% level. Column (2) shows the results adding district-by-crop fixed effects, and the triple-differences estimate is positive (0.342) and significant at the 5% level. Finally, the results using farmer fixed effects show that the estimate is positive (0.276) and significant at the 10% level.

Table 7 shows the results for the triple-differences estimates on farm-gate prices. Using crop and district fixed effects, column (1) shows that the estimate is positive (0.343) and significant at the 1% level. Column (2) shows the results adding district-by-crop fixed effects, and the triple-differences estimate is positive (0.216) and significant at the 10% level. Finally, the results using farmer fixed effects show that the estimate is positive (0.407) and significant at the 10% level.

We can compare the triple-differences estimates using farmer fixed effects in Tables 5, 6, and 7, with the differences-in-differences estimates in Table 4. If the latter estimates were upward biased by unobserved farmer characteristics, we should see that using farmer fixed effects should decrease the estimate. Instead, we see that the estimates using farmer fixed effects are consistently somewhat higher: for the extensive margin (0.066, versus 0.042 and 0.047); for the total margin (0.276, versus 0.167 and 0.174) and for the farm-gate price (0.407, versus 0.132 and 0.138).

Taking the point estimates using the farmer fixed effects literally, access to price information increases the probability of selling by 6.6 percentage points. This is a quantitatively substantial effect, since the probability of selling is 22.6 percent in the baseline group (Using farmers in MIS districts producing crops for which price information was broadcast, i.e., InfoDistrict=1, Infocrop=1, Radio=0). In other words, this corresponds to a 29.2% increase in the probability of selling. Furthermore, the point estimate in Table 6 implies that the share of the output sold increases by 31.8% (0.276 log points), using the same baseline (converted to levels, this implies going from 0.121 to 0.159). Finally, the effect on the farm-gate price is quantitatively important, since access to price information increases the farm-gate price by 0.41 standard deviations.

6.2 Prediction 4: Uncertainty about the Market Price

To further test the predictions, Table 8 presents results for the prediction that the effect of price information on the likelihood of selling and the share of the output sold is larger when there is more uncertainty about the market price (i.e., when the distribution is more spread out). That is, when there is more variation in the market price, it is more difficult for the farmer to predict the market price, which creates more information frictions between the trader and the farmer.

Columns (1), (3), and (5) first present placebo regressions using the 1999 UNHS dataset. If the identifying assumption underlying equation (41) is correct, there should be no differential effect of radio ownership for crops with a high market price variation before the price information broadcasts. Indeed, the interaction term is close to zero and insignificant in all three regressions. As predicted by the model, however, there is a differential effect after the broadcasts have started. Columns (2) and (4) show the point estimates for the extensive margin and the total margin, respectively. In both columns, the interaction term is positive and significant at the 10% level. Column (6) shows the result for the farm-gate price and the coefficient is positive but insignificant. That the coefficient is insignificant is no surprise given that the prediction of the farm-gate price is indeterminate. However, when the incentive effect dominates the selection effect, the effect on farm-gate prices is positive. The size and sign of the point estimate are at least suggestive of this being the case (as shown in Table 7).

6.3 Prediction 5: The Urban Market Price

Consistent with predictions 1-4, we have shown that price information increases the supply of crops. By prediction 5, this should shift the supply curve outward in the urban market, and lower the retail price. Table 9 presents the results for the urban market price. Columns (1) and (2) presents the results for equation (42). In both specifications, the interaction term coefficient is negative and significant at the 5% level. Using the full set of fixed effects in column (2), the point estimate implies that the market price decreases with 0.94 standard deviations. This is a substantial effect.

Furthermore, if the effects were truly driven by a supply effect from informed farmers listening to radio broadcasts, we should see that the effect of broadcasts is larger when there are more farmers with radio. Columns (3) and (4) present the results for equation (43). In both specifications, the interaction term coefficient is negative and significant at the 5% level. Using the full set of fixed effects in column (4), the point estimate (-0.024) implies that the market price decreases by 0.24 standard deviations when there is a 10 percent increase in farmers with radio.[34]

Finally, to assess whether, for other reasons, there is a time trend in crops with a relatively large share of farmers with radio, we run a placebo test. Specifically, in columns (5) and (6) we estimate equation (43) over the *same* period but for districts that received price information broadcasts after the sample period (in September 2002). The interaction term is insignificant and positive in the placebo regressions. This suggests that the results in columns (3) and (4) were indeed driven by access to price information through the radio broadcasts.

[34]The results show that the average market price decreases within the district. We find no evidence of a shift in the dispersion of market prices (results not shown). Due to incentive and selection effects, the model gives no clear predictions on other moments than the mean.

6.4 Quantifying the Effects on Farmer Revenue

Consistent with the predictions of the model, we have shown that farmers with access to price information are more likely to sell their crops, sell larger shares of the output, and receive higher farm-gate prices. To quantify the total effect on crop revenue, we estimate equations (38), (39), and (40) with crop revenue (i.e., the quantity sold in kg times the price per kg) as the outcome variable. Columns (1) and (2) show that the interaction coefficient is positive (0.439 and 0.467, respectively) and significant (5% and 1%, respectively). The triple-differences estimates of equation (40) are presented in columns (3) - (5). They show that the point estimates are large (0.886, 0.782, and 0.699) and significant in all but the specification with farmer fixed effects (it is borderline insignificant as the p-value is 0.107).

Using the most conservative point estimate in column (1), this implies that farmers with access to price information have 55.1% (0.439 log points) higher crop revenues than farmers without access to price information. The results therefore indicate that access to price information has substantial effects on farmer crop incomes.

6.5 Investigating Alternative Mechanisms

In this section, we investigate other potential explanations for the results. First, we consider that the broadcast did not only affect outcome by providing price information. Instead, it may be that the radio programs also provided farmers with information that had direct effect on agricultural productivity, by teaching farmers about farming techniques. This could affect quantity sold, quantity produced, as well as the quality of the crops (which could increase the farm-gate price). We use the UNHS 2005 survey quiz on agricultural technology knowledge to test for the hypothesis that the broadcast informed farmers about farming technique. Column (1) presents the results using the fraction of correct answers on the quiz. We find no evidence on technology learning.

Second, we consider the alternative that the price information changed where the farmer sold their output. In principle, if risk averse farmers become informed about the market price, they may be more likelihood to travel directly to the district market to sell their crops. Columns (2) - (4) present the results. We find no evidence of a change in where the goods are sold.[35]

[35] We run the same regressions using a dummy indicating if the farmer sold the crops to a private trader in the village. We find no evidence of changed behavior.

Finally, we investigate whether the price information made farmers produce more of the crops for which there was price information. If changing the composition of crops produced is costless for the farmer (by increasing the plot area for crops with price information and decreasing it for crops without price information), we would expect output to increase which, in turn, could affect the farm-gate outcomes. However, unless higher production is also associated with higher *share* of output sold, such a production effect would tend to work against finding an effect on s. Columns (5) - (7) show the results. We find no evidence of production behavior on average.[36]

7 Conclusion

This paper finds that price information plays an important role in facilitating market exchange. It also sheds some new light on some important policy questions.

First, how to boost agriculture production in developing countries has been an ongoing policy question. The question is of particular importance for countries in sub-Saharan Africa where the growth in agricultural yield has been stagnant. While the academic literature on the subject is extensive, existing research has primarily focused on two broad sets of explanations: the low technology adoption rate (of technologies such as HYV crops, irrigation and fertilizers) and the functioning of agricultural markets.

The issue of functioning markets was a prime concern behind the reforms of the agricultural markets in many sub-Saharan Africa countries in the late 1980s and 1990s. However, the supply response from liberalizing agricultural markets has been weaker than expected. One explanation that has been put forward for this low supply response is that the pre-liberalization period where the government essentially fixed a price for key food and cash crop commodities (often a price well below the market price) has been replaced by a situation where better informed (at least about local market conditions) local traders are able to force down prices to farmers with little idea of price movements and market trends. Our results are at least qualitatively consistent with this claim.

The effects of information on outcomes are interesting from an economic theory perspective. However, the effects are also relevant for the discussion

[36] This could be explained either by significant adjustment costs or by beliefs that the price information broadcasts would terminate. Also, we cannot rule out changes in output within the group MIS crops.

about the role of information and communication technologies (ICTs) for economic development (cf. Jensen, 2007). Living standards for most of the world's poorest are largely determined on how much they get paid for their output, mainly crops. Thus, the functioning of output markets is central to the income for farmers engaged in agriculture in low-income countries. In most developing countries, markets are dispersed and the infrastructure is poor. Small-scale producers typically lack information on market prices, so that the potential for inefficiency in the allocation of goods across markets and the allocation between consumption and trading is large.

Moreover, asymmetric information between sellers (i.e. poor small-scale farmers) and buyers adds important distributional concerns. By improving the access to information, ICTs may help poorly functioning markets work better, improve farmers' bargaining positions, and thereby increase the incomes of the poor. In addition, our results suggest that urban consumers, through lower prices, indirectly benefit from the better functioning. However, access to price information seldom reaches everyone, and it is still an open question to what extent farmers with little access to information are affected when a large part of the rural population gets access to good information. Our results show that price information can have substantial general equilibrium effects, pushing prices downward. Whether poor farmers without access to information decrease their integration with markets and become even poorer as a consequence of lower prices is a potentially important question for future research.

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Appendix: Sketch of the solution

The first-best is defined from the following maximization problem

$$\max_{q_i} \sum_{i=1}^{3} \pi_i \left[U_i + \Pi_i\right] \;\Rightarrow\; \max_{q_i} \left[u(Q - q_i) + m_i q_i\right]. \tag{44}$$

The first-order conditions, which implicitly define the first-best quantity sold function, q_i^{FB},

$$-u'(Q - q_i^{FB}) + m_i \leq 0 \quad \text{for all } m_i \tag{45}$$

equates the marginal utility of consumption with the market price. We assume that $u'(Q) < m_1$, implying that the first-order condition (45) is always binding and thus

$$q_i^{FB} = Q - u_c^{-1}(m_i) \ . \tag{46}$$

The uninformed farmer case: We can rewrite the problem from its most general form.[37] Note that only one of the IR constraints (4) is binding since

$$m_3 q_3 - R_3 \geq m_3 q_2 - R_2 \geq m_2 q_2 - R_2 \geq m_2 q_1 - R_1 \geq m_1 q_1 - R_1 \geq 0. \tag{47}$$

Exploiting the fact that the Spence-Mirrless single-crossing condition holds, we can reduce the number of incentive constraints to a smaller set of local downward incentive constraints and a monotonicity condition. The farmer's problem can thus be stated as

$$\max_{\{(q_i,R_i)\}} \sum_{i=1}^{3} \pi_i \left[R_i + u(Q - q_i)\right] \qquad \text{subject to} \tag{48}$$

$$m_1 q_1 - R_1 = 0 \tag{49}$$

$$m_i q_i - R_i = m_i q_{i-1} - R_{i-1} \quad \text{for all } i > 1 \tag{50}$$

$$q_i \geq q_j \text{ if } m_i \geq m_j. \tag{51}$$

To solve the constrained problem, we set up the Lagrangian, assuming that the monotonicity condition (51) holds. That is

$$\begin{aligned} L &= \max \sum_{i=1}^{3} \left\{\pi_i \left[R_i + u(Q - q_i)\right] + \lambda_i \left[m_i q_i - m_i q_{i-1} - R_i + R_{i-1}\right]\right\} \\ &\quad + \mu \left[m_1 q_1 - R_1\right], \end{aligned} \tag{52}$$

[37] We suppress the superscripts for ease of exposure.

where λ_i is the Lagrange multiplier associated with the IC-constraint at price m_i, and μ is the multiplier associated with the IR-constraint (49). The first-order conditions for (q_1, R_1) are

$$\frac{dL}{dq_1} = -\pi_1 u'(Q - q_1) + \lambda_1 m_1 - \lambda_2 m_2 + \mu m_1 = 0 \tag{53}$$

and

$$\frac{dL}{dR_1} = \pi_1 - \lambda_1 + \lambda_2 - \mu = 0. \tag{54}$$

The first-order conditions for (q_2, R_2) are

$$\frac{dL}{dq_2} = -\pi_2 u'(Q - q_2) + \lambda_2 m_2 - \lambda_3 m_3 = 0 \tag{55}$$

and

$$\frac{dL}{dR_2} = \pi_2 - \lambda_2 + \lambda_3 = 0. \tag{56}$$

The first-order conditions for (q_3, R_3) are

$$\frac{dL}{dq_3} = -\pi_3 u'(Q - q_3) + \lambda_3 m_3 = 0 \tag{57}$$

and

$$\frac{dL}{dR_3} = \pi_3 - \lambda_3 = 0. \tag{58}$$

Rewriting yields the following conditions for q_i (where superscript UI stands for uninformed farmer)

$$-u'(Q - q_3^{UI}) + m_3 = 0 \tag{59}$$

$$-u'(Q - q_2^{UI}) + m_2 - \frac{\pi_3}{\pi_2}(m_3 - m_2) \leq 0 \tag{60}$$

$$-u'(Q - q_1^{UI}) + m_1 - \frac{(\pi_2 + \pi_3)}{\pi_1}(m_2 - m_1) \leq 0. \tag{61}$$

The monotonicity condition (51) holds if

$$\text{Assumption 1: } \frac{1}{\pi_1}(m_2 - m_1) \geq \frac{\pi_3}{\pi_2}(m_3 - m_2), \tag{62}$$

which we assume to be the case. Thus

$$q_1^{UI} = \begin{cases} Q - u_c^{-1}\left(m_1 - \frac{(\pi_2+\pi_3)}{\pi_1}(m_2 - m_1)\right) & \text{for } m_1 > \tilde{m}_1 \\ 0 & \text{for } m_1 \leq \tilde{m}_1 \end{cases} \tag{63}$$

$$q_2^{UI} = \begin{cases} Q - u_c^{-1}\left(m_2 - \frac{\pi_3}{\pi_2}(m_3 - m_2)\right) & \text{for } m_2 > \tilde{m}_2 \\ 0 & \text{for } m_2 \leq \tilde{m}_2 \end{cases} \tag{64}$$

$$q_3^{UI} = Q - u_c^{-1}(m_3) \tag{65}$$

where the threshold market prices $\tilde{m}_i$ are

$$\tilde{m}_2 \equiv \left(\frac{1}{1-\pi_1}\right)(\pi_2 u'(Q) + \pi_3 m_3) \tag{66}$$

$$\tilde{m}_1 \equiv \pi_1 u'(Q) + (1-\pi_1)m_2 \tag{67}$$

and $\tilde{m}_2 > \tilde{m}_1$ as long as assumption 1 holds.

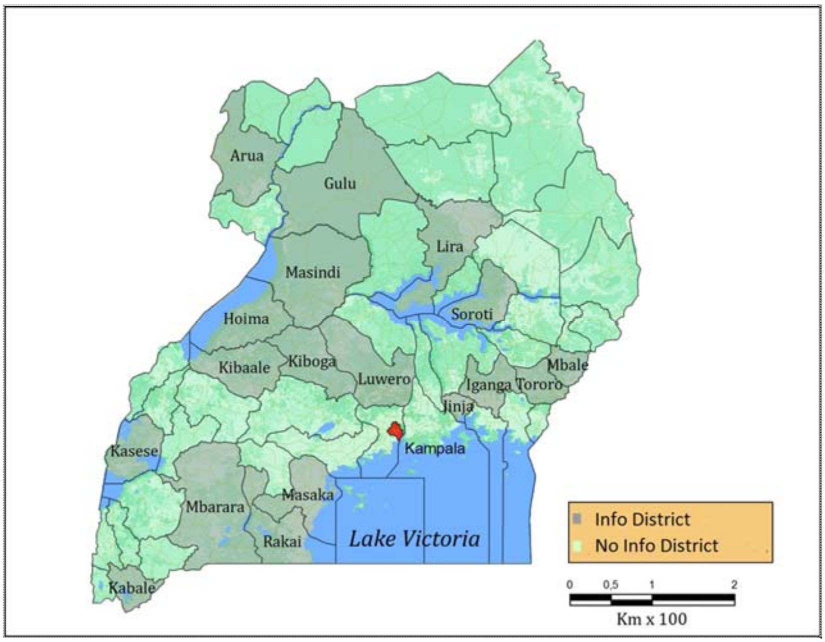

Figure 1. Districts with the Market Information Service

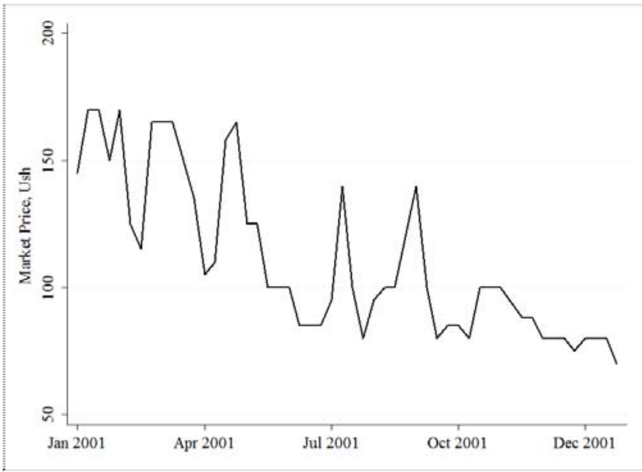

Figure 2. Cassava Market Price, Mbale 2001.

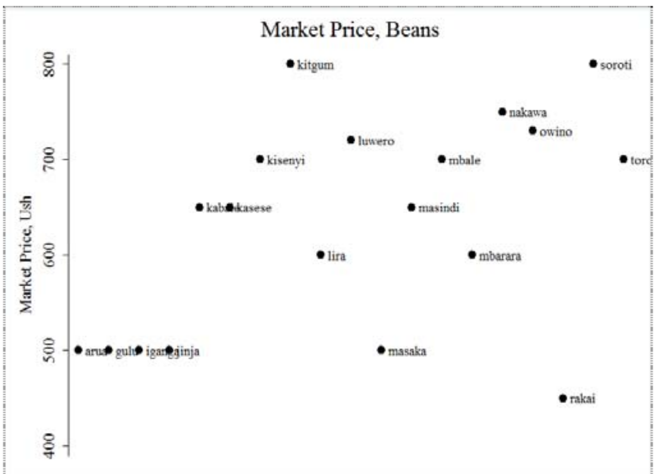

Figure 3. Beans Market Price, Week 20, 2001.

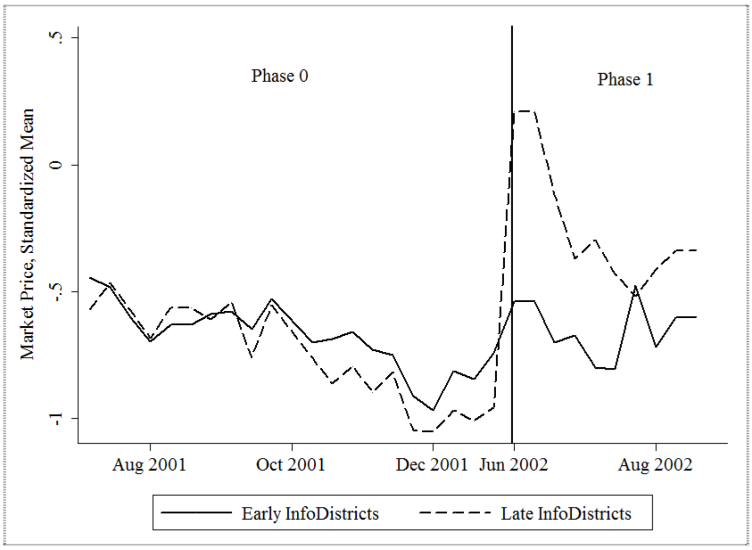

Figure 4. The figure shows weekly mean standardized market price for the main MIS crops in early districts (Phase 1 broadcasts starting in Feb 2002) and late districts (after Aug 2002). There is missing data for Jan-May 2001.

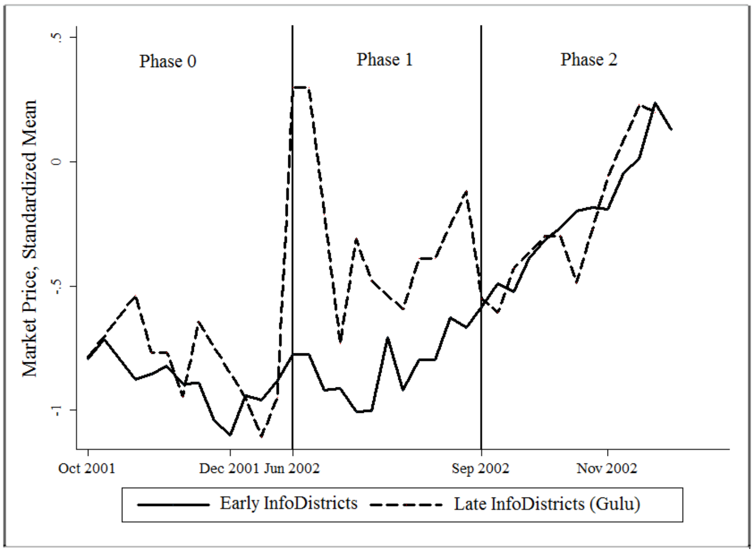

Figure 5. The figure shows weekly mean standardized market price for the main MIS crops in early districts (Phase 1 broadcasts starting in Feb 2002) and Gulu district. Gulu received broadcasts starting in Sep 2002. There is missing data for Jan-May 2001.

Table 1. Summary Statistics

Variable	Panel A: UNHS Crop Survey, 2005 Obs	Mean	S.D.	Min	Max	Panel B: UNHS Crop Survey, 1999 Obs	Mean	S.D.	Min	Max
Selling any Output, Dummy	33049	0.28	0.45	0	1	22747	0.34	0.47	0	1
Share of Output Sold, Log	33049	0.17	0.31	0	1	22747	0.18	0.29	0	1
Farm Gate Price, Standardized	9109	0.07	1.03	-2.35	9.29	7352	-0.42	0.93	-2.35	7.46
Radio	33049	0.70	0.46	0	1	22747	0.59	0.49	0	1
InfoDistrict	33049	0.43	0.50	0	1	22747	0.47	0.50	0	1
InfoCrop	33049	0.92	0.26	0	1	22747	0.96	0.20	0	1
Output, kg	33049	251.7	458.8	0.04	4992.0	22747	254.1	429.9	.0015	4980.0
Revenue, Ush	32990	19787	80422	0	2500000	22672	13576	53354	0	2653500
Agricultural Tech. Knowledge,	32954	0.51	0.23	0	1	0				
Sold to District Market	9355	0.09	0.29	0	1	0				
	Panel C: Urban Market									
Urban Market Price, Standardized	1495	0.00	0.98	-3.43	3.63					
InfoDistrict	1495	0.62	0.49	0	1					
Broadcasting Started	1495	0.42	0.49	0	1					
% Farmers with Radio	1241	56.43	16.61	22.86	100					

Table 2. Farm Gate Outcomes, DD Placebo

Dependent Variable	Farm Gate Price		Share of Output Sold, Log		Selling any Output, Dummy	
	(1)	(2)	(3)	(4)	(5)	(6)
Radio	0.038	0.062**	0.049	0.026	0.010	0.004
	(0.030)	(0.029)	(0.051)	(0.044)	(0.012)	(0.011)
Radio x InfoDistrict	-0.008		0.080		0.019	
	(0.042)		(0.073)		(0.018)	
Year 2005		0.473***		-0.205***		-0.063***
		(0.078)		(0.077)		(0.020)
Radio x Year 2005		-0.038		0.087		0.024
		(0.048)		(0.057)		(0.015)
Observations	6665	7717	21771	28790	21771	28790
R-squared	0.335	0.201	0.182	0.114	0.174	0.108
Sample Districts	All	No Info	All	No Info	All	No Info
Sample Year	1999	1999/2005	1999	1999/2005	1999	1999/2005
Sample Crops	InfoCrops	InfoCrops	InfoCrops	InfoCrops	InfoCrops	InfoCrops
District-by-Crop FE	Yes	Yes	Yes	Yes	Yes	Yes

Radio is a dummy variable indicating if the household owns a radio. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. *Year 2005* is a dummy variable equal to one if the household is from the UNHS 2005 (i.e., after the MIS started) dataset, and equal to zero if it is from the UNHS 1999 (i.e., before the MIS started) dataset. Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrops* indicates that the crops in the sample are crops which the MIS broadcasts market price information for. *Farm Gate Price* is the standardized price per kilogram for which the household sold the crop. *Selling any Output* is a dummy variable indicating if the household sold any of the crop output, and zero otherwise. *Share of Output Sold* is the amount sold in kilogram divided by the total output in kilogram. The data for the dependent variables comes from UNHS. Robust standard errors in parentheses, clustered at the district level (40 clusters) in columns 1,3,5 and at the district-crop level (197 clusters) in columns 2, 4, 6. *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Farm Gate Outcomes, DDD Pre-MIS Placebo

Dependent Variable	Farm Gate Price, Standardized		Share of Output Sold, Log		Selling any Output, Dummy	
	(1)	(2)	(3)	(4)	(5)	(6)
Radio	0.027		0.040		0.013	
	(0.077)		(0.134)		(0.031)	
Radio x InfoDistrict	-0.119		0.068		0.008	
	(0.092)		(0.157)		(0.037)	
Radio x InfoCrop	0.026	-0.079	0.012	0.097	-0.002	0.017
	(0.070)	(0.121)	(0.142)	(0.139)	(0.034)	(0.031)
InfoDistrict x InfoCrop	0.084	0.160	0.004	0.133	0.009	0.052
	(0.150)	(0.198)	(0.197)	(0.273)	(0.054)	(0.072)
Radio x InfoDistrict x InfoCrop	0.104	0.138	-0.009	-0.137	0.005	-0.036
	(0.091)	(0.183)	(0.167)	(0.271)	(0.041)	(0.064)
Observations	7352	7352	22747	22747	22747	22747
R-squared	0.248	0.694	0.181	0.544	0.152	0.519
Sample Year	1999	1999	1999	1999	1999	1999
Sample Districts	All	All	All	All	All	All
Sample Crops	All	All	All	All	All	All
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Farmer FE	No	Yes	No	Yes	No	Yes

Radio is a dummy variable indicating if the household owns a radio. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. The sample year is 1999 (i.e., before the MIS started). Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrop* indicates that the crop is a crop which MIS broadcast market price information for, and zero if the crop is one for which the MIS did not. *Farm Gate Price* is the standardized price per kilogram for which the household sold the crop. *Selling any Output* is a dummy variable indicating if the household sold any of the crop output, and zero otherwise. *Share of Output Sold* is the amount sold in kilogram divided by the total output in kilogram. The data for the dependent variables comes from UNHS. Robust standard errors in parentheses, clustered at the district level (40 clusters).
*** p<0.01, ** p<0.05, * p<0.1.

Table 4. Farm Gate Outcomes, DD

Dependent Variable	Farm Gate Price		Share of Output Sold, Log		Selling any Output, Dummy	
	(1)	(2)	(3)	(4)	(5)	(6)
Radio	0.045**	0.036	0.094**	0.099**	0.021**	0.020
	(0.022)	(0.036)	(0.037)	(0.049)	(0.009)	(0.013)
Radio x InfoDistrict	0.132**		0.167**		0.042**	
	(0.053)		(0.067)		(0.017)	
Year 2005		0.502***		-0.392***		-0.116***
		(0.112)		(0.091)		(0.023)
Radio x Year 2005		0.138*		0.174***		0.047***
		(0.077)		(0.050)		(0.013)
Observations	7706	6654	30513	23494	30513	23494
R-squared	0.157	0.253	0.088	0.105	0.083	0.101
Sample Districts	All	InfoDistricts	All	InfoDistricts	All	InfoDistricts
Sample Year	2005	1999/2005	2005	1999/2005	2005	1999/2005
Sample Crops	InfoCrops	InfoCrops	InfoCrops	InfoCrops	InfoCrops	InfoCrops
District-by-Crop FE	Yes	Yes	Yes	Yes	Yes	Yes

Radio is a dummy variable indicating if the household owns a radio. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. *Year 2005* is a dummy variable equal to one if the household is from the UNHS 2005 (i.e., after the MIS started) dataset, and equal to zero if it is from the UNHS 1999 (i.e., before the MIS started) dataset. Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrops* indicates that the crops in the sample are crops which the MIS broadcasts market price information for. *Farm Gate Price* is the standardized price per kilogram for which the household sold the crop. *Selling any Output* is a dummy variable indicating if the household sold any of the crop output, and zero otherwise. *Share of Output Sold* is the amount sold in kilogram divided by the total output in kilogram. The data for the dependent variables comes from UNHS. . Robust standard errors in parentheses, clustered at the district level (56 clusters) in columns 1,3,5 and at the district-crop level (100 clusters) in columns 2, 4, 6.
*** p<0.01, ** p<0.05, * p<0.1.

Table 5. Extensive Margin, DDD

Dependent Variable	Selling any Output, Dummy		
	(1)	(2)	(3)
Radio	0.027	0.014	
	(0.022)	(0.029)	
Radio x InfoDistrict	-0.044	-0.038	
	(0.035)	(0.041)	
Radio x InfoCrop	-0.009	0.009	-0.003
	(0.024)	(0.027)	(0.029)
InfoDistrict x InfoCrop	-0.062*		-0.035
	(0.031)		(0.037)
Radio x InfoDistrict x InfoCrop	0.086***	0.079**	0.066*
	(0.032)	(0.036)	(0.038)
Observations	33049	33049	33049
R-squared	0.117	0.160	0.357
Sample Year	2005	2005	2005
Sample Districts	All	All	All
Sample Crops	All	All	All
Crop FE	Yes	Yes	Yes
District FE	Yes	Yes	Yes
District-by-Crop FE	No	Yes	No
Farmer FE	No	No	Yes

Radio is a dummy variable indicating if the household owns a radio. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. The sample year is 1999 (i.e., before the MIS started). Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrop* indicates that the crop is a crop which MIS broadcast market price information for, and zero if the crop is one for which the MIS did not. *Selling any Output* is a dummy variable indicating if the household sold any of the crop output, and zero otherwise. Robust standard errors in parentheses, clustered at the district level (56 districts).
*** p<0.01, ** p<0.05, * p<0.1.

Table 6. Share of Output Sold, DDD

Dependent Variable	Share of Output Sold, Log		
	(1)	(2)	(3)
Radio	0.118	0.056	
	(0.094)	(0.123)	
Radio x InfoDistrict	-0.187	-0.179	
	(0.153)	(0.182)	
Radio x InfoCrop	-0.038	0.040	-0.022
	(0.097)	(0.115)	(0.118)
InfoDistrict x InfoCrop	-0.260*		-0.147
	(0.130)		(0.151)
Radio x InfoDistrict x InfoCrop	0.357**	0.342**	0.276*
	(0.138)	(0.161)	(0.161)
Observations	33049	33049	33049
R-squared	0.143	0.188	0.377
Sample Year	2005	2005	2005
Sample Districts	All	All	All
Sample Crops	All	All	All
Crop FE	Yes	Yes	Yes
District FE	Yes	Yes	Yes
District-by-Crop FE	No	Yes	No
Farmer FE	No	No	Yes

Radio is a dummy variable indicating if the household owns a radio. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. The sample year is 1999 (i.e., before the MIS started). Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrop* indicates that the crop is a crop which MIS broadcast market price information for, and zero if the crop is one for which the MIS did not. *Share of Output Sold* is the amount sold in kilogram divided by the total output in kilogram, clustered at the district level (56 districts). *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Farm Gate Price, DDD

Dependent Variable	Farm Gate Price, Standardized		
	(1)	(2)	(3)
Radio	0.170**	0.093	
	(0.075)	(0.082)	
Radio x InfoDistrict	-0.211*	-0.084	
	(0.112)	(0.109)	
Radio x InfoCrop	-0.117	-0.048	-0.144
	(0.085)	(0.091)	(0.113)
InfoDistrict x InfoCrop	-0.057		-0.136
	(0.178)		(0.276)
Radio x InfoDistrict x InfoCrop	0.343***	0.216*	0.407*
	(0.119)	(0.112)	(0.243)
Observations	9109	9109	9109
R-squared	0.053	0.165	0.481
Sample Year	2005	2005	2005
Sample Districts	All	All	All
Sample Crops	All	All	All
Crop FE	Yes	Yes	Yes
District FE	Yes	Yes	Yes
District-by-Crop FE	No	Yes	No
Farmer FE	No	No	Yes

Radio is a dummy variable indicating if the household owns a radio. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. The sample year is 1999 (i.e., before the MIS started). Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrop* indicates that the crop is a crop which MIS broadcast market price information for, and zero if the crop is one for which the MIS did not. *Farm Gate Price* is the standardized price per kilogram for which the household sold the crop. Robust standard errors in parentheses, clustered at the district level (56 districts). *** p<0.01, ** p<0.05, * p<0.1.

Table 8. Heterogeneous Effects: Market Price Uncertainty

Dependent Variable	Selling any Output, Dummy		Share of Output Sold, Log		Farm Gate Price, Standardized	
	(1)	(2)	(3)	(4)	(5)	(6)
Radio	0.034**	0.050***	0.149***	0.199***	0.006	0.115*
	(0.013)	(0.014)	(0.051)	(0.056)	(0.041)	(0.060)
Radio x Price Uncertainty High	-0.019	0.031*	-0.072	0.143*	0.067	0.150
	(0.027)	(0.019)	(0.104)	(0.074)	(0.079)	(0.103)
Observations	9974	12876	9974	12876	3234	3284
R-squared	0.166	0.072	0.176	0.077	0.321	0.175
Sample Year	1999	2005	1999	2005	1999	2005
Sample Districts	InfoDistricts	InfoDistricts	InfoDistricts	InfoDistricts	InfoDistricts	InfoDistricts
Sample Crops	InfoCrops	InfoCrops	InfoCrops	InfoCrops	InfoCrops	InfoCrops
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
District-by-Crop FE	Yes	Yes	Yes	Yes	Yes	Yes

Radio is a dummy variable indicating if the household owns a radio, from the UNHS datasets. *Price Uncertainty High* is a dummy variable indicating if the coefficient of variation for the market price of the crop in the district for which the household lives in is above the average, and zero if it's below. The coefficient of variation in district market prices is calculated using data from Foodnet for the period of the UNHS 2005 sample. *Farm Gate Price* is the standardized price per kilogram for which the household sold the crop. *Selling any Output* is a dummy variable indicating if the household sold any of the crop output, and zero otherwise. *Share of Output Sold* is the amount sold in kilogram divided by the total output in kilogram. The data for the dependent variables comes from UNHS. Robust standard errors in parentheses, clustered at the district-crop level.
*** p<0.01, ** p<0.05, * p<0.1.

Table 9. Urban Market Prices

Dependent Variable	Market Price, Standardized					
	(1)	(2)	(3)	(4)	(5)	(6)
InfoDistrict	0.254*					
	(0.128)					
InfoDistrict x Broadcasting Started	-0.657**	-0.940**				
	(0.304)	(0.376)				
% Farmers with Radio			0.010**		-0.011	
			(0.004)		(0.021)	
% Farmers with Radio x Broadcasting Started			-0.023**	-0.024**	0.020	0.020
			(0.009)	(0.011)	(0.030)	(0.030)
Observations	1495	1495	854	854	387	387
R-squared	0.120	0.133	0.151	0.153	0.259	0.259
Sample Districts	All	All	Info	Info	No Info	No Info
No of District-Crop Markets	48	48	27	27	12	12
Week FE	Yes	Yes	Yes	Yes	Yes	Yes
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes
District Market FE	No	Yes	Yes	Yes	Yes	Yes
District-Crop Market FE	No	Yes	No	Yes	No	Yes
District Market Trend	No	Yes	Yes	Yes	Yes	Yes

The sample contains data at the district-crop-week level from the Market Information Service for the period August 2001 to August 2002, with missing data for the period January to May 2002. Each district has one urban market center. *InfoDistrict* is a dummy variable indicating if the district for which the MIS started broadcasting information for in February 2002, and zero if it is a district for which the MIS started broadcasting in September 2002. *Broadcasting Started* is a dummy indicating if the week is after February 2002, and zero if it is before February 2002. *% Farmers with Radio* is the percentage of farmers in the district and growing the crop that own a radio in 1999. Data sources: Foodnet and UNHS 1999. Robust standard errors in parentheses, clustered at the district-crop market level in columns (1) – (4). Due to a low number of clusters, columns (6) and (7) use Newey-West standard errors with two period (weeks) lags. *** p<0.01, ** p<0.05, * p<0.1.

Table 10. Crop Revenue

Dependent Variable	Crop Revenue, Log				
	(1)	(2)	(3)	(4)	(5)
Radio	0.342***	0.348***	0.596**	0.368	
	(0.095)	(0.122)	(0.241)	(0.315)	
Year 2005		-0.995***			
		(0.228)			
Radio x InfoDistrict	0.439**		-0.430	-0.343	
	(0.168)		(0.392)	(0.455)	
Radio x Year 2005		0.467***			
		(0.130)			
Radio x InfoCrop			-0.303	-0.025	-0.264
			(0.261)	(0.294)	(0.320)
InfoDistrict x InfoCrop			-0.701**		-0.403
			(0.339)		(0.390)
Radio x InfoDistrict x InfoCrop			0.886**	0.782*	0.699
			(0.366)	(0.413)	(0.426)
Observations	30513	23494	32990	32990	32990
R-squared	0.087	0.105	0.130	0.174	0.370
Sample Districts	All	Info	All	All	All
Sample Year	2005	1999/2005	2005	2005	2005
Sample Crops	InfoCrops	InfoCrops	All	All	All
Crop FE	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	No
District-by-Crop FE	Yes	Yes	No	Yes	No
Farmer FE	No	No	No	No	Yes

Radio is a dummy variable indicating if the household owns a radio. *Year 2005* is a dummy variable equal to one if the household is from the UNHS 2005 (i.e., after the MIS started) dataset, and equal to zero if it is from the UNHS 1999 (i.e., before the MIS started) dataset. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. The sample year is 1999 (i.e., before the MIS started). Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrop* indicates that the crop is a crop which MIS broadcast market price information for, and zero if the crop is one for which the MIS did not. Robust standard errors in parentheses, clustered at the district level (56 clusters) in all columns except column (2), where there are only 17 districts. Column (2) uses clustering at the district-crop level (100 clusters). *** p<0.01, ** p<0.05, * p<0.1.

Table 11. Alternative Mechanisms

Dependent Variable:	Agricultural Technology Knowledge	Sold Directly to the District Market			Output, Log		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Radio	0.029**	0.022***	-0.001		0.387***	0.326***	
	(0.012)	(0.007)	(0.039)		(0.028)	(0.084)	
Radio x InfoDistrict	0.007	0.004	0.026		-0.009	-0.024	
	(0.015)	(0.014)	(0.062)		(0.057)	(0.131)	
Radio x InfoCrop			0.023	-0.006		0.061	-0.104
			(0.040)	(0.046)		(0.085)	(0.092)
InfoDistrict x InfoCrop				0.003			-0.048
				(0.069)			(0.181)
Radio x InfoDistrict x InfoCrop			-0.022	-0.006		0.015	0.085
			(0.064)	(0.066)		(0.132)	(0.128)
Observations	30474	7920	9355	9355	30563	33049	33049
R-squared	0.212	0.092	0.126	0.603	0.280	0.292	0.500
Sample Districts	All	All	All	All	All	All	All
Sample Year	2005	2005	2005	2005	2005	2005	2005
Sample Crops	InfoCrops	All	All	All	InfoCrops	All	All
Crop FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-by-Crop FE	Yes	Yes	Yes	No	Yes	Yes	No
Farmer FE	No	No	No	Yes	No	No	Yes

Radio is a dummy variable indicating if the household owns a radio. *InfoDistrict* is a dummy variable indicating if the household lives in a Market Information Service (MIS) district broadcasting market prices in 2005, and zero otherwise. The sample year is 1999 (i.e., before the MIS started). Sample districts equal to *All* includes both districts with the MIS in 2005 (InfoDistricts) as well as districts without the MIS in 2005 (No Info). *InfoCrop* indicates that the crop is a crop which MIS broadcast market price information for, and zero if the crop is one for which the MIS did not. *Agricultural Technology Knowledge* is the fraction of correct answers from the UNHS 2005 survey on agricultural technology knowledge. Selling to a Trader is a dummy variable equal to one if the farmer sold the crop to a private trader in the farmer's village, and zero otherwise. Robust standard errors in parentheses, clustered at the district level (56 clusters). *** p<0.01, ** p<0.05, * p<0.1.