Asymmetric Information and Middleman Margins: An Experiment with Indian Potato Farmers*

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Abstract

West Bengal potato farmers cannot directly access wholesale markets and do not know wholesale prices. Local middlemen earn large margins; pass-through from wholesale to farm-gate prices is negligible. When we informed farmers in randomly chosen villages about wholesale prices, average farm-gate sales and prices

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were unaffected, but pass-through to farm-gate prices increased. These results can be explained by a model where farmers bargain *ex post* with village middlemen, with the outside option of selling to middlemen outside the village. They are inconsistent with standard oligopolistic models of pass-through, search frictions or risk-sharing contracts. (JEL Codes: O120, L140)

1 Introduction

It is generally believed that middlemen in agricultural value chains in developing countries appropriate significant margins.[1] However there is little evidence on how large these margins are, and why they occur. Trading mechanisms between farmers and traders are also not well understood.[2] Do farmers and traders enter into *ex ante* risk-sharing contracts, or do they bargain only at the time of sale? What are farmers' outside options? Do farmers know less about price movements in downstream markets than traders do, and does this worsen their bargaining position? A better understanding of these issues may explain the observed low and unresponsive farmgate prices that arguably perpetuate poverty and limit agricultural growth. It could also explain why the gains from export growth do not "trickle down" to the ultimate producers, and whether and how increasing farmers' access to price information could affect these outcomes.

We examine these questions in the context of the supply chain for potatoes, a high-value cash crop in the Indian state of West Bengal (WB, hereafter). Farmers in our study area sell most of their potatoes to village middlemen, who aggregate purchases and then re-sell them at wholesale markets (*mandis*) to bulk buyers from distant cities or neighbouring states. Not only do farmers lack direct access to *mandis*, they are also unaware of the prices at which their potatoes are resold there. The gaps between these resale prices and farmgate prices are large: in the year of our study, farmgate prices were 44-46 percent of wholesale prices. Our calculations suggest that middlemen earned 50-71% of this gap. The pass-through from retail prices to farmgate prices was a statistically

[1] Morisset (1998) conjectures that trading companies may have caused large gaps between world commodity prices and consumer prices from the mid-1970s to the mid-1990s. Other research argues that middlemen in cash crop markets prevent the transmission of export price increases to producers (Fafchamps and Hill 2008, McMillan, Rodrik, and Welch 2002).

[2] Recent theoretical contributions include Antras and Costinot (2010), Antras and Costinot (2011), Bardhan, Mookherjee, and Tsumagari (2013) and Chau, Goto, and Kanbur (2009).

insignificant, negligible 2 percent, while pass-through to wholesale prices was a much larger 81 percent.[3]

The lack of direct access to wholesale markets is a distinctive feature of the WB potato supply chain. In some other Indian states farmers sell directly to wholesale buyers, and middlemen play no role (Goyal 2010, Fafchamps and Minten 2012, Jensen 2007). Increased access to price information in such environments improves spatial arbitrage across markets, reducing price dispersion (Jensen 2007) and increasing average prices (Goyal 2010).[4] In yet other contexts, farmers enter into advance contracts with middlemen but are also able to sell directly in a spot market; the resulting moral hazard problem limits the amount of risk-sharing (Blouin and Machiavello 2013, Machiavello and Morjaria 2015 and Saenger, Torero, and Qaim 2014). However WB potato markets resemble other vertical structures such as Ugandan coffee (Fafchamps and Hill 2008) and Mozambican cashews (McMillan, Rodrik, and Welch 2002).

A key goal of our paper is to understand the nature of trading relationships between middlemen and farmers. Do middlemen enter into *ex ante* risk-sharing relationships with farmers (as in Hart 1983, Ligon, Thomas, and Worrall 2002, Machiavello 2010)? Could these account for the low pass-through rates, and can middleman margins be understood as insurance premiums? Or do middlemen engage in oligopolistic competition, with or without search frictions, as in most models of pass-through in the trade and IO literature?[5] Our surveys indicate that many farmers engage in repeat transactions with the same traders. However they rarely report being bound by an advance contractual ar-

[3] We refer here to price transmission from wholesalers (downstream) to farmers (upstream). The "pass-through literature" examines transmission of price fluctuations from upstream producers to downstream consumers. Market structure limits price transmission in both contexts.

[4] Aker (2010), Nakasone (2013) and Hildebrandt et al. (2015) investigate the effect of mobile phones on prices in similar market contexts in Niger, Peru and Ghana, respectively.

[5] See, for example, Mortimer (2008) Antras and Costinot 2010, Bonnet and Dubois (2010), Antras and Costinot 2011, Chau, Goto, and Kanbur 2009, Atkin and Donaldson 2014, Gopinath and Itskhoki 2010, Weyl and Fabinger 2013 and Villas-Boas 2007.

rangement, either explicit or implicit. Instead, most farmers say that they receive daily price offers from village middlemen and then respond by either selling rightaway, holding out for a future sale, or transporting their potatoes to a neighboring small market (called a *haat*) to sell to a different middleman. This suggests that they engage in spot bargaining, and that village middlemen and middlemen in *haats* compete sequentially.

This paper develops a model of such a trading mechanism, and uses a field experiment to discriminate empirically between this model and other competing models. In our model, village middlemen collude, but compete with middlemen located in the *haats*. While bargaining with the village middleman, the farmer's outside option is to sell to this *haat* middleman. The price that the *haat* middleman offers is higher than the price that village middleman would offer under monopsony. It also varies with the actual wholesale price. In this way this outside option generates competitive pressure on the village middlemen. Price offers from the village middleman inform the farmer about the price offer they will receive if they hold out and approach the *haat* middleman instead. While this bargaining game has many equilibria, we focus on equilibria that generate the largest profits for the village middleman: these are fully non-revealing (or pooling), so that the village middleman's price offer does not vary at all with the wholesale price.[6] In this way the model explains the observed negligible pass-through from wholesale to farmgate prices.[7] The model also predicts that an intervention informing the farmer about prevailing wholesale prices would increase the pass-through of wholesale prices to farmgate prices. This intervention changes the farmer's information about his outside option, and so changes the price that the village middleman offers him. Whether the effect is

[6]Fully non-revealing equilibria maximize the village middleman's profits if self-consumption of potatoes is relatively unimportant, and if farmers are risk-averse with respect to the price they receive.

[7]Our model resembles models of relational contracts with private information where pooling can be more efficient than separating equilibria (Halac 2012, Malcomson 2016). However, in line with our empirical context, players in our trading environment bargain on the spot, instead of entering into implicit *ex ante* contracts.

positive or negative depends on the content of the information: when a treated farmer learns that his outside option is high, the middleman offers him higher prices. When instead he learns that it is low, the middleman offers him lower prices. On average, these heterogeneous effects on farmgate prices tend to cancel out.

To test these predictions, in 2008 we conducted a field experiment in 72 randomly chosen villages from two potato-growing districts of West Bengal. The villages were randomly assigned to either one of two treatment groups, or to a control group. In the treatment groups, we provided farmers with daily information about the prevailing potato prices in neighboring wholesale and retail markets. In one variant, called the private information treatment, four randomly selected farmers in each of 24 villages received the information through phonecalls from our team of telecallers. In the public information treatment, the information was posted publicly in 24 villages. In the control villages, no information was provided. Concurrently, we collected high-frequency data on potato cultivation, harvest, sales and related revenues and costs from a random sample of potato farmers in each village. Our analysis of the annual average quantity sold and price received by farmers validates our theoretical predictions: the intervention increased the pass-through from wholesale to farmgate prices, and that there was no average effect on farmgate prices and sales.

These results imply that *ex ante*, the information interventions did not change farmers' welfare, and reduced traders' welfare. *Ex post*, the welfare effects depend on the actual realizations of wholesale prices.[8]

Our experimental findings contrast sharply with the predictions of contracting or

[8]Welfare effects also depend on the effect of the intervention on farmers' storage decisions. These are analyzed in Section B in the online Appendix. Empirically, we find that information increased storage only for a small minority of treated farmers. The observed treatment effects for other farmers were therefore driven directly by price impacts rather than through induced effects on storage.

search friction models. Contracts where farmers and middlemen share risk predict that better information would *increase* trading volumes when the wholesale price is *low*, because improving farmers' price information reduces screening distortions in low price states. Also, contrary to models of risk-sharing contracts, WB potato middlemen did not make net losses *ex post* at any wholesale price realization. Finally, we do not observe a decrease in the dispersion of farmgate prices, as would be predicted by models of search frictions.[9]

Given our results, it is unlikely that policy interventions that improve farmers' information about resale prices would significantly reduce average middleman margins or enhance welfare. The deeper underlying problem is that middlemen wield considerable market power, because WB potato farmers lack direct access to wholesale markets. This lack of market access merits further investigation in future work.

2 The Context: Potato Production and Sales

Potatoes generate the highest value-added per acre of all cash crops produced in West Bengal (Bardhan and Mookherjee 2011, Maitra et al. 2017). The crop is planted between October and December, and harvested between January and March. The farmer might sell part of his output immediately, place some in home stores to be sold at any time in the next two or three months, and place the rest in cold stores, to be sold at any time until the cold stores are emptied in November.[10]

[9] The key analytical difference between our model and standard models of search frictions is that early price offers affect the farmer's beliefs about the distribution of offers that might follow if he continues to search. However, our model shares with standard search models the prediction that the gap between prices offered by traders within and outside the village would narrow. We do see this in the data.

[10] Due to cold store technical constraints and government regulations, potatoes cannot be carried over from one year to the next. Own-consumption accounts for less than 5% of the harvest.

2.1 Farmer-Trader Transactions and Market Structure

Farmers sell more than 90% of their marketed potatoes to traders operating within the same village (see Table 1).[11] The average village has about 10 such middlemen. They make price offers to local farmers on a daily basis. Farmers who choose not to sell to them, can instead sell to traders at local markets (*haats*) located an average of 5 km from the village. Traders check the quantity and quality of potatoes that they buy, transport them to wholesale markets (*mandis*) located 8 km away on average, where they negotiate sales to traders from city markets or neighboring states.[12] Most potatoes are sold ultimately to consumers in retail markets in Kolkata or neighboring states.

In a 2007 survey, farmers reported selling 72% of their potatoes to buyers whom they had been selling to for a year or more, and 32% to buyers whom they had been selling to for two years or more. However this high incidence of repeat transactions does not necessarily imply that they have prior contractual arrangements. In fact, our surveys indicate contracts are not common. In 2007, farmers sold only 21% of their potatoes to buyers from whom they had an outstanding loan. Farmers also told us that they were not bound to sell to the trader who had provided them inputs or credit, but were free to sell to someone else and to use the proceeds to repay the loan. In surveys we conducted in 2012, only 33% of the 144 randomly selected middlemen who purchased potatoes in our study villages reported a prior agreement to buy from their oldest supplier that year. A mere 6% reported an explicit arrangement about the quantity that they would buy, and 16% reported either an explicit or implicit understanding about the price they would pay.

[11] We restrict our analysis to the *jyoti* and *chandramukhi* varieties. Together these made up 90 percent of the potatoes grown by sample farmers.

[12] Village middlemen also trade in other seasonal produce and often sell agricultural inputs and provide credit; many of them have a shop in the village. Thus farmers and traders interact face-to-face at a high frequency, so that search costs are negligible.

Trader survey results are consistent with the hypothesis of collusion among village middlemen: 43 to 51% of traders admitted that they exchanged information about recent price offers with other traders before making offers to farmers, and about 40% said they checked recent sale prices with farmers. However they are less likely to collude with traders operating at the local *haat*, since they meet them less frequently and are unable to monitor their transactions.

The evidence also indicates that farmers lack access to wholesale buyers. Direct sales at the wholesale market are extremely rare: they account for less than 2% of sales (Table 1). In informal interviews, wholesale buyers told us that it was "not worth their while" to negotiate small trades and to monitor the quantity and quality of potatoes from many different farmers whom they did not know personally.

Ultimately, the market power of middlemen rests on barriers to entry into their line of business. In our 2012 survey, traders told us that capital was the important requirement to enter the potato trade. The median capital requirement reported was ₹50,000 (mean = ₹94472).[13] They also said it was important to have had a prior apprenticeship with a trader for an average of 3.5 years, and 3 years of experience cultivating potatoes. Prior contacts with at least 25 farmers, and large buyers in at least 3 distant markets were other important requirements. This suggests that entry requires financial investments as well as investments in relationships, which take time to build.

In addition, the regulatory environment in West Bengal restricts entry into the potato trading business. The West Bengal Agricultural Marketing Committee (APMC) Act requires any large firm seeking to buy directly from farmers to obtain a license from the state government. Cohen (2013) documents the fact that the West Bengal government

[13]The average agricultural loan for planting potatoes in these villages is about ₹8000 (data collected through informal interviews). Thus ₹50,000 is a forbiddingly large amount of capital for the average farmer in this village to raise.

rarely provides such licenses. No agri-retail firms were purchasing potatoes in our sample villages at the time we conducted our study. Thus the only competition that village traders face is from traders located in the neighbouring *haat*.

2.2 Farmers' Price Information

Transactions between the traders and buyers from distant markets are often bilateral. Therefore, information about the price that the trader receives is not in the public domain. In our 2007 baseline farmer surveys, 46% said their only source of wholesale price information was the trader they sold to. Only 13% reported asking friends and neighbours, and 6% received information through the media (See Appendix Table A2).[14] Although public telephone booths, landline phones and mobile phones were all available to varying extents, farmers told us that they had no contacts at *mandis* who would tell them the prevailing *mandi* price.

Responses to our farmer surveys suggest there is substantial information asymmetry between farmers and traders. Every fortnight from February to November 2008, we asked farmers to tell us the recent price in their neighboring market. Their reports (average ₹2.57 per kg) were very different from the village traders' resale prices that week (average ₹4.82 per kg). Instead, they were quite similar to the prices that *farmers* received if they sold at a *haat* in that week (average ₹2.55 per kg).[15] In other words, they (mis-)interpreted the term "market price" to mean the price they would receive if they took their potatoes to the *haat*, not the price at which middlemen resold their produce at the *mandi*. The mean absolute deviation between wholesale prices reported by farm-

[14]The media tends not to cover this layer in the supply chain: only three of the *mandis* in our sample exist in the official database on wholesale prices.

[15]The gross price at which a farmer sold at a market is computed by dividing the total revenue he received from selling at a market across all weeks in the year, by the quantity sold. ₹2.55 is the average of this number across all farmers who sold at *haats*.

ers and actual wholesale prices was 42.5% of the mean actual price. In Section 3.2 we present evidence that our information intervention significantly reduced this error.

2.3 Price Transmission Patterns

To what extent do fluctuations in retail prices pass through to traders and farmers? The first column in Table 2 presents the result of a regression of weekly *mandi* prices from 2007, 2008, 2011 and 2012 (only from weeks 13 and beyond for years other than 2008), on the weekly retail price in the relevant destination city market (Kolkata for *mandis* in Hugli districts, and Bhubaneswar for *mandis* in West Medinipur district). After controlling for *mandi*-specific annual potato yields, and year, *mandi* and week fixed effects, the pass-through from city prices to the *mandi* prices is considerable: a ₹1 increase in the city price is associated with a ₹0.81 increase in the *mandi* price. We confirm that the pass-through is large and significant even in 2008, the year of our study (column 2). However, as column 3 of the table shows, in 2008, when city prices increased by ₹1, the change in farmgate prices was a statistically non-significant ₹0.02. Column 4 shows that the pass-through from *mandi* prices to farmgate prices is also small (0.04) and non-significant.

This low price transmission is accompanied by large middleman margins, as we discuss below.

2.4 Margins Earned by Middlemen

Middlemen often hold potatoes after purchase, with a view to selling them later in the year when they expect the price to be high. However since they have the option of re-selling them immediately upon purchase, the difference between their selling and buying prices at the same point of time provides a lower bound to their expected gross margin.[16] Since we do not have data on traders' actual selling costs in 2008, we use as estimates the unit cost data for transport, handling and storage reported by farmers. Traders might exploit economies of scale and connections with store owners to reduce their unit costs below these numbers; if so, using farmer reports for unit costs gives us a lower bound to trader net margins.

Trader cost overheads vary by season, and we calculated average margins separately for each.[17] Using the distribution of quantities sold in the sample in different weeks as weights, we estimate average prices at which traders resold potatoes in the harvest and post-harvest seasons. We subtract the average price that farmers received when they sold to village traders, to arrive at the traders' gross margins.[18] Our calculations can be seen in Table A1 in the Appendix. After subtracting the relevant unit costs, the lower bounds on mean net trader margins in 2008 are ₹1.85 per kg at harvest time, and ₹1.36 per kg after harvest time. Middlemen therefore earned at least 28 to 38 percent of the *mandi* price, and 64 to 83 percent of the farmgate price, depending on the season when they bought and sold the crop.[19]

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[16]We do not adjust for traders' interest costs, since these are not relevant when potatoes are resold at the same time as they are purchased.

[17]Traders would not incur storage costs for transactions in the harvest period: they would buy potatoes from the field, have them cleaned and sorted and then transport them to the *mandi* and load them directly onto trucks sent by buyers. After June, traders buy potato bonds from farmers, pay storage charges to release the potatoes from the cold store, and have them dried, sorted, colored and loaded into the buyers' trucks. They do not incur transport costs at this stage because most cold storage facilities are located close to *mandis*.

[18]Cold stores charge a flat rate regardless of how long the potatoes are stored. We are careful to adjust traders' per-kg cost of transport according to the average distance that they transport potatoes.

[19]These numbers are similar to those found in previous work: In his 1998-99 study of 136 potato farmers in the Arambagh block of Hugli district, Basu (2008) found that middlemen margins net of transactions costs were 25 percent of retail price in the busy season, and 20 percent in the lean season. Farmgate prices were between 49 and 36 percent of the retail price.

3 The Experiment and the Data

Our experiment was conducted in a stratified random sample of 72 villages from the potato growing blocks of Hugli and West Medinipur districts. To reduce information spillovers, we ensured that sample villages were at least 10 kilometres apart from each other. In each block, sample villages were randomly assigned to three groups.[20] In two groups of 24 villages each, we conducted two different information treatments, while in the third group, we provided no information. In the two treatment groups, we delivered daily information about the price in the *mandis* that were relevant to the village. This was the price at which traders had re-sold potatoes to large buyers at these *mandis*, the previous day. In our analysis below we refer to this as the *mandi* price.[21] In addition, we also delivered information about the previous day's price at the nearest city market.

In the 24 private information villages, the price information was delivered individually to 4 households selected randomly from our survey households. Every morning for 11 months, the "tele-callers" based in our Kolkata information center relayed the *mandi* prices to each of these farmers via mobile phones that were given to them for the purpose of the project. The phones were merely a device by which to deliver the information. To ensure that they did not improve the farmers' connectivity more generally, we worked with the service provider to block outgoing calls from the phones, and changed the phone settings so that farmers could not view their own number. We did not inform the farmers of their mobile phone numbers, and all phone bills were delivered to us. This prevented the farmer from receiving any incoming calls except from us. We

[20]Each village was then mapped to the *mandi(s)* that were closest to it, which is where potatoes grown in that village tended to be re-sold by traders. Since blocks have one or two *mandis*, this effectively ensures that sample villages under a given *mandi* are randomly assigned to different information treatments.

[21]The total volume of potatoes sold by our sample farmers in 2008 was less than 1 percent of the total volume traded in the large *mandis* in this area, so it is unlikely that our interventions changed *mandi* prices.

verified that our restrictions were effective. Our telecaller records indicate that 62% of all calls to private information recipients were received, and in 92% of the villages at least one cell phone recipient answered the call.

In the 24 public information villages, we delivered the *mandi* price information to a local shopkeeper or phone-booth owner (called the "vendor") in the village. For a nominal fee, he wrote the price information on charts and posted them in three public places in the village.[22] Through random checks we were able to verify that the price information was posted regularly.

The information interventions were piloted in the sample villages during June-November 2007. The actual experiment began in January 2008 and continued daily until November 2008. All villages and households were in the same treatment or control group in 2008 as they were in 2007. All empirical estimates of the interventions on farmer quantities and revenues will be presented for the 2008 data.

3.1 Data and Descriptive Statistics

We conducted surveys with a stratified random sample of 24 potato-growing households in each of the 72 villages in our study.[23] We restrict the analysis to the 1545 sample farmers who planted either of the two main varieties (*jyoti* and *chandramukhi*) of potatoes in 2008. A production survey was conducted in February, followed by a trade survey each fortnight between February and November. Table A2 in the Appendix shows a number of village and households characteristics by treatment groups, based on data collected before the pilot information interventions began in June 2007. Across all household

[22] If asked, telecallers and vendors were instructed to say that the information was being delivered for a research study, but they did not know its purpose, or how the information could be used.

[23] In 2006 we conducted a census in all sample villages to record which households had planted potatoes that year. We then stratified all potato-growing households by landholding category and drew a random sample from each stratum.

characteristics, the pre-intervention differences across treatment groups were jointly insignificant.

3.2 Effect of Information on Farmers' Price Information

In the fortnightly trade surveys, we asked farmers how frequently they tracked prices in wholesale and retail potato markets, and whom they collected the price information from. To analyse whether the interventions changed farmers' price tracking behavior, we run a regression according to the specification

$$\begin{aligned} y_{ivt} &= \beta_0 + \beta_1 \text{Private Information}_v + \beta_2 \text{Phone Recipient}_{iv} + \beta_3 \text{Public Information}_v \\ &\quad + \beta_4 X_{ivt} + \epsilon_{ivt} \end{aligned}$$

where y_{ivt} measures whether farmer i in village v tracked wholesale prices in fortnight t (Table 3, Panel A, Column 1), the number of days since he last tracked prices (Column 2), and his source of information (Column 3). Accordingly, we use a logit specification in Column 1, and a Poisson regression in Column 2.[24] Private information and Public information are dummy variables indicating the treatment group that the farmer's village is assigned to. In the villages that received the private information treatment, the four randomly chosen households who received information directly via mobile phone received a value of 1 for the Phone recipient dummy, as well as a value of 1 for the Private Information dummy. Hence the coefficient on Private information should be interpreted

[24]To avoid "demand effects" caused by survey questions that made our intervention salient, when we asked farmers to report their information source, we did not offer a choice indicating our intervention. The choices provided were, in order: friends, relatives, neighbours, caste members, traders, local government officials, NGO employees, cooperative members and other. If farmers chose the category "other" over all the previous categories, we interpret this as the information intervention. We re-code the variable to an indicator for whether the information was received through the intervention. Also, questions about price information were asked only to a randomly selected one-half of the sample. The results in Tables 6 and 7 continue to hold even if we analyze only the subset of households that were *not* asked questions about their price-tracking behaviour. See Appendix Table A4.

as the effect on farmers whose village received the private information treatment, but who did not personally receive phonecalls. Their outcomes would presumably be affected through the spread of information within the village. Control variables include the household's landholding, indicator variables for the potato variety, district, and the survey month. For convenience we report exponentiated coefficients in all three columns.

The results indicate that the intervention worked as planned. Farmers who received the interventions were significantly more likely to say that they track market prices and to have tracked them recently (columns 1 and 2). They were also more likely to report that they received the information through the intervention (column 3). The magnitude of the effects were larger in the public information treatment than in the private information treatment, and within the private information treatment, were larger for phone recipients.

Panel B in Table 3 shows that the intervention improved the precision with which farmers tracked prices. When we match the prices that farmers reported with the actual prices in the markets that they tracked, the average sum of squares of the normalized error in reported price is 0.18-0.19 for intervention households, which is significantly lower than the 0.22 for control households. This represents a decrease of 13.9 percent in the mean absolute deviation from the true price.[25]

4 Theory: Bargaining with Asymmetric Information

Consider a game with a single farmer F with an exogenous stock of potatoes Q, a single village trader VT,[26] and a set of market traders located in a *haat* outside the village.

[25]Recall from Section 2.2 that farmers appear to have interpreted the words "market price" as the price *they* could expect to receive if they sold at the *haat*, rather than the price at which traders resold their potatoes in the *mandi*. The information we delivered was about these resale prices. The reader may then wonder why the interventions reduced the error in their reports. It is likely that the information helped farmers infer the price they could get if they sold in the *haat*.

[26]This corresponds to the assumption that village traders collude perfectly with one another.

F cannot sell potatoes directly at the *mandi* located outside the village. He can sell either to the VT, or to a market trader. Every trader can resell the potatoes at the *mandi* at the prevailing price w, which they observe, and take as given. The farmer does not observe w, but he believes it follows a prior distribution G on support $[\underline{w}, \bar{w}]$ where $\infty > \bar{w} > \underline{w} \geq 0$.

Following a realization of w, the sequence of moves is as follows. At stage 1, VT meets F, and makes him a price offer p_1. F decides whether and how much (q_1) to sell at this price. At stage 2, the farmer decides whether to incur a transport cost of s to visit the *haat* with a quantity $q_2 \leq Q - q_1$ to sell to a market trader. He expects to receive at the *haat* a price $h(w)$, which is strictly increasing in w and satisfies $h(w) < w$ for all w. The price $h(w)$ is determined through oligopolistic competition between market traders.[27]

Let the total quantity the farmer sells be denoted by $q \equiv q_1 + q_2 \in [0, Q]$; the remainder $Q - q$ is consumed. His net sales revenue is $R \equiv p_1 q_1 + I[h(w)q_2 - s]$, where $I \in \{0, 1\}$ denotes the decision to visit the *haat*. His payoff is $W(R + \beta U(Q - q))$ where W is a strictly increasing, smooth concave function satisfying $W^{''} \leq 0$, and U is a strictly increasing, smooth and strictly concave function satisfying $U^{'}(0) = \infty$. The parameter $\beta \geq 0$ represents the importance of self-consumption in the farmer's payoff function. Our data show that farmers consume no more than 5% of their harvest, so we shall focus on the case where β is small. We assume throughout that $\underline{w} > \beta U'(Q)$, so there are always gains from trade. In the limiting case where $\beta = 0$, the farmer either sells his entire harvest or nothing at all, and the problem reduces to selling an indivisible good.

[27] A specific example is one with k equidistant market traders on a concentric circle of unit length, as in Salop (1979). With linear transport cost t per unit distance traversed by farmers, simultaneous price competition between the market traders yields price $h(w)$ which solves the equation $w - h = [\frac{q'(h)}{q(h)} + \frac{k}{t}]^{-1}$. Here $\frac{k}{t}$ is a parameter representing the extent of competition in the *haat*.

We now introduce a number of assumptions. Let $q(p)$ denote the farmer's supply function, which maximizes $pq + \beta U(Q - q)$, and define $\Pi(p) \equiv pq(p) + \beta U(Q - q(p))$. Clearly $q(p)$ is strictly positive at any price p satisfying $p > \beta U'(Q)$, strictly increasing and approaches Q as p becomes arbitrarily large. Our first assumption is that the supply function is weakly concave ($q''(.) \leq 0$).[28]

The second assumption is that $W(\Pi(p))$ is concave. That is, an increase in farmgate price risk makes F worse off. In the limiting case where β is zero, this requires W to be weakly concave, and includes the case where the farmer is risk-neutral. Hence we assume at least a mild level of risk-aversion, with the required lower bound vanishing as β approaches zero.[29]

Our final assumption pertains to the nature of competitive pressure imposed by the market traders on VT. If there were no competition from other traders, VT would behave monopsonistically, and select monopsony price $m(w) = \arg\max(w - m)q(m)$ which solves $w = m + \frac{q(m)}{q'(m)}$. We assume that if F were to know the realization of w, VT would have to offer him more than the monopsony price, to prevent F from exercising his option to visit the *haat*. Specifically, for all $w \in [\underline{w}, \bar{w}]$

$$M(w) > m(w) \tag{1}$$

where F's reservation price $M(w)$ is defined by

$$\Pi(M(w)) = \Pi(h(w)) - s \tag{2}$$

[28]This allows the constant elasticity consumption utility function $U(c) = \frac{c^{1-\sigma}}{1-\sigma}$ when $\sigma > 0$ and different from 1, where supply function is $q(p) = Q - p^{-\frac{1}{\sigma}}$. If $\sigma = 1$ the utility function is logarithmic and $q(p) = 0$.

[29]If $W(y) = \frac{y^{1-\mu}}{1-\mu}$ and $U(c) = \frac{c^{1-\sigma}}{1-\sigma}$ with $\mu, \sigma \geq 0, \neq 1$, we need $\mu > \frac{1}{\sigma}\left(\frac{\beta}{\underline{p}}\right)^{\frac{1}{\sigma}}[Q + \frac{\sigma}{1-\sigma}\left(\frac{\beta}{\underline{p}}\right)^{\frac{1}{\sigma}}][Q - \left(\frac{\beta}{\underline{p}}\right)^{\frac{1}{\sigma}}]^{-2}$, where $\underline{p}$ denotes a lower bound to the price that VT could offer. Such a natural lower bound does turn out to exist: the farmer's reservation price in state $\underline{w}$.

We also assume that $\Pi(h(\underline{w})) > s$, to ensure that $M(.)$ is well-defined and positive-valued.

We use Weak Perfect Bayesian Equilibrium (WPBE) as the equilibrium concept. Suppose $V \equiv W(\Pi(.))$. Then, formally, the equilibrium is a price-offer by VT and an acceptance strategy for F $p(w), a(p)$, with supporting posterior beliefs $G(.|p)$ that obey Bayes rule on the equilibrium path, where:

1. $p(w)$ maximizes $a(p)[w-p]q(p)$
2. $a(p)$ maximizes $aV(p) + (1-a)E_{G(.|p)}[V(M(w))]$ over $[0,1]$

The outcome of any WPBE is a pattern of state-dependent trades, where in state w, F sells:

$$F \text{ sells} \begin{cases} q(p(w)) \text{ to } VT \text{ with probability } \alpha(w) \equiv a(p(w)) \\ q(h(w)) \text{ to } F \text{ otherwise} \end{cases}$$

4.1 Classes of Equilibria

We first describe different classes of equilibria, which vary in terms of how much information VT's price offers convey to F about the realization of w. We first describe equilibria that reveal w entirely, then those that convey no information at all, and finally hybrid forms that convey some information. We then present the main results and explain the intuition behind them. Formal proofs can be found in the online Appendix.

4.2 Fully Revealing Equilibrium

An equilibrium is said to be *fully revealing* or separating if the associated price offer function $p(.)$ is strictly increasing in w.

Proposition 1 *When (1) holds, there exists a fully revealing or separating equilibrium, where VT offers $p(w) = M(w)$ in state w, and the offer is accepted by F with probability $\alpha(w) \in [0, 1]$ which is a strictly increasing function satisfying the differential equation*

$$\frac{\alpha'(w)}{\alpha(w)} = \frac{M'(w)}{w - M(w)}[1 - \frac{(w - M(w))q'(M(w))}{q(M(w))}] \tag{3}$$

with endpoint constraint $\alpha(\bar{w}) \leq 1$.[30]

Along the equilibrium path, F can infer the exact realization of w from the observed price offer. The price offer equals F's reservation price corresponding to state w, so that F is indifferent between accepting and rejecting it. F accepts with probability $\alpha(w)$, which by construction creates an incentive for VT to offer the price $M(w)$ when the state is w. Since $M(w) > m(w)$ and VT's payoff function is concave in the price, he is tempted to offer a price lower than $M(w)$. However the price offer reveals w to F, and, and given F's outside option of selling at $M(w)$, a lower price offer is less likely to be accepted. This offsets the larger profit that VT obtains if it is accepted. The possibility that trade does not occur is a deadweight loss arising from VT's incentive compatibility constraint: VT is worse off when the price offer is not accepted, while F is indifferent.

4.3 Fully Non-Revealing Equilibrium

At the other extreme, if VT offers the same price $\bar{p}$ irrespective of the realization of w and F accepts the offer with some positive probability $\bar{\alpha}$, then the equilibrium reveals no information to F. When such a fully non-revealing equilibrium (FNRE) exists, and $\bar{\alpha} \in (0, 1)$, F must be indifferent between accepting and rejecting. Any such equilibrium is Pareto dominated by an equilibrium where the pooled price $\bar{p}$ is identical, but F instead

[30] The equilibrium is supported by off-equilibrium path beliefs wherein any price offer below $p(\underline{w})$ leads F to believe $w = \underline{w}$ with probability one, and any price offer above $p(\bar{w})$ leads him to believe $w = \bar{w}$ with probability one.

accepts with probability one. For this reason we focus on FNRE with $\bar{\alpha} = 1$.[31]

Proposition 2 *The following conditions are sufficient and (almost) necessary for the existence of a fully non-revealing equilibrium, where VT offers the same price $\bar{p}$ irrespective of the realization of w, and this price offer is accepted by F with probability one:*[32]

(FP1) $\underline{w} \geq \bar{p}$*, where* $\bar{p}$ *satisfies* $W(\Pi(\bar{p})) = E_w[W(\Pi(M(w)))]$.

(FP2) If the state is $\bar{w}$, VT does not deviate from price offer $\bar{p}$ to price offer $M(\bar{w})$, where $M(\bar{w})$ is also accepted with probability one.

Note that while the the fully revealing equilibrium always exists, the fully non-revealing equilibria can fail to exist if the support of the distribution of w is sufficiently wide.[33] However, when this happens, partially revealing equilibria generally exist. We describe these next.

4.4 Partially Revealing Equilibrium

In a step-function partially revealing equilibrium (SPRE) the price offer is a step function. The support of w is partitioned into a set of consecutive intervals $I_i \equiv$

[31] There may also exist FNRE involving a pooled price above $\bar{p}$ where F is strictly better off accepting than rejecting, and where the price offer is accepted with probability one. Such an FNRE cannot be compared in the Pareto sense with the one we focus on below, because it makes F better off but makes VT worse off. In what follows we ignore such FNRE by assuming that the equilibrium that maximizes VT's payoff is selected.

[32] It is supported by the following off-equilibrium-path beliefs: if the price offer is $p \leq \bar{p}$, then F does not update his beliefs. If $p \geq \bar{p}$, F believes $w = \bar{w}$.

[33] One example is when $\underline{w}$ is 0 or sufficiently close to 0: the fixed price in a pooling equilibrium has to be positive, and so has to be larger than $\underline{w}$; this cannot happen when $\underline{w} = 0$. When w is sufficiently low, VT is unwilling to pay F more than w. Alternately, if the upper bound $\bar{w}$ of the support of the wholesale price is sufficiently large but the pooling price is bounded, then condition (FP2) is violated: the fixed price is too far below $M(\bar{w})$, and VT offers a price above $\bar{p}$.

$[w_i, w_{i+1}], i = 1, \ldots, n$ with $w_1 = \underline{w}$ and $w_{n+1} = \bar{w}$. VT offers a constant price $\bar{p}_i$ when w is in $[w_i, w_{i+1})$, with $\bar{p}_i > \bar{p}_{i-1}$. On the equilibrium path, F accepts offer $\bar{p}_i$ with probability α_i. The fixed price $\bar{p}_i$ satisfies $W(\Pi(\bar{p}_i)) = E_{w|w \in I_i]}[W(\Pi(M(w)))]$, and F is indifferent between accepting and rejecting $\bar{p}_i$ after learning that $w \in [w_i, w_{i+1}]$.

Proposition 3 *The following conditions are sufficient and (almost) necessary for a step-function partially revealing equilibrium to exist.*[34] *For each i:*

(PP1) $w_i \geq \bar{p}_i$.

(PP2) If the state is w_{i+1}, VT is indifferent between offering $\bar{p}_i$ and $\bar{p}_{i-1}$.

(PP3) If the state is $\bar{w}$, VT does not deviate from price offer $\bar{p}_n$ to price offer $M(\bar{w})$, where $M(\bar{w})$ is accepted with probability one.

A partially revealing equilibrium is intermediate between a fully non-revealing and fully revealing equilibrium. VT's price offer varies in a coarse way with w: rising when w moves from one interval to the next, but constant within any interval. As in a separating equilibrium, all price offers except the highest have to be rejected with some probability, and acceptance probabilities must rise with the price offer. In any interval $I_i = [w_i, w_{i+1}]$, when w is close to w_i, VT is tempted to lower the price offer from $\bar{p}_i$ to $\bar{p}_{i-1}$, since $\bar{p}_i > M(w_i) > m(w_i)$. However the penalty for lowering the price is that the lower price will be rejected with a higher probability. Within any given interval I_i, the price offer is constant, and trade takes place with some probability. The ratio of the probabilities that F accepts $\bar{p}_i$ and $\bar{p}_{i-1}$ is selected to ensure that condition (PP2) holds. This is analogous to (3) in a fully revealing equilibrium.

[34] When he receives an offer in the interval $I_i = (\bar{p}_{i-1}, \bar{p}_i]$, F updates the support of his beliefs to I_i. Offers below $\bar{p}_1$ induce the same beliefs as $\bar{p}_1$, while any offer above $\bar{p}_n$ induces F to believe that $w = \bar{w}$. F rejects any offer in the interval $(\bar{p}_{i-1}, \bar{p}_i)$.

There can also be equilibria which are partially revealing in other ways: price offer functions that are mixtures of step-functions and strictly increasing segments. Clearly there is a plethora of possible equilibria, varying in the extent of information that is revealed to F.

Since F is always indifferent between accepting and rejecting the price offers in each equilibrium, it is evident that the separating, fully non-revealing and partially revealing equilibria all generate the same *ex ante* welfare for F. However VT's *ex ante* welfare could vary. We turn to this issue next.

4.5 Comparing Profitability of Alternative Equilibria

We start by comparing the *ex ante* profits earned by VT in the selected FRE and FNRE, assuming the FNRE exists.

Proposition 4 *If β is sufficiently small, VT earns a larger ex ante profit in the FNRE than in any FRE.*

The key force driving the result is that trade may not occur at all in the FRE, whereas the FNRE always results in trade. Besides, the sale price in the FRE varies with the state, resulting in risk that benefits neither VT nor F. Since F has the same expected utility in both equilibria, the constant price in the FNRE is lower than the average price in the FRE. This lower average price in the FNRE also benefits VT, since the farmer's reservation price is higher than the monopsony price. From VT's point of view, the FRE outperforms the FNRE only in one dimension: the quantity he purchases co-moves with the wholesale price, so that he purchases larger (resp. smaller) quantities when the wholesale price is high (resp. low). This benefit is small when F places a low value on personal consumption. At the same time the deadweight loss associated with failure to trade in most states remains bounded away from zero, so the FNRE results in a larger expected profit for VT when β is small enough.

Our final result below considers the limiting case where $\beta = 0$, and shows that the FNRE is the most profitable equilibrium across *all* equilibria. If the FNRE does not exist, a similar result obtains for the comparison of step-function partially revealing equilibria with more or less information revealed to the farmer (in the sense of Blackwell). Hence profit-maximizing equilibria involve maximal pooling.

Proposition 5 *Suppose $\beta = 0$, and an FNRE exists. Then the FNRE where a constant price offer $\bar{p}$ is accepted with probability one, generates the largest ex ante profit of all WPBE equilibria.*

4.6 Effects of Information Provision

Now consider how these equilibria are affected by an information intervention, which changes F's prior beliefs. There will be no effect at all if the equilibrium is fully revealing. Non-revealing equilibria will be affected. Given the results in the previous section, we assume that the fully non-revealing equilibrium exists and is the prevailing equilibrium selected by traders both before and after the intervention.[35]

It is easiest to consider the case where the information provided by the intervention is represented by a partition of the set of possible wholesale prices, i.e., farmers receive a price signal $\sigma(w)$ which takes the form of a step function, taking the value σ_j when $w \in I_j \equiv [w_j, w_{j+1}]$, with $j = 1, \ldots, m$, $\sigma_{j+1} > \sigma_j$ and $w_1 = \underline{w}, w_m = \bar{w}$. The signal

[35]The results are qualitatively similar when the fully non-revealing equilibrium fails to exist, so that the pre-intervention "maximal pooling equilibrium" is partially revealing. In such an equilibrium VT's price offer $\bar{p}_i$ informs F that w belongs to interval I_i. As long as the intervention generates a different information partition than I_i, it affects the equilibrium allocation. The price offers in the new equilibrium then co-move more with the wholesale price.

alters F's beliefs: signal realization σ_j informs F that $w \in I_j$. A fully non-revealing equilibrium conditional on this new set of beliefs now involves a different pooled price $\bar{p}_j$ satisfying $[W(\Pi(\bar{p}_j)) = E_{w|w \in I_j}][W(\Pi(M(w)))]$. If j is low (resp. high), F learns that the wholesale price is low (resp. high), so that the pooled price is lower (resp. higher) than if F did not receive the signal. The price that F receives now co-moves more with the wholesale price. *We therefore expect to see a significant drop in price and traded quantity when the wholesale price is low, and a significant rise in price and traded quantity when the wholesale price is high.* The effects on the average price and quantity may thus be negligible.[36]

Similar predictions obtain when the price signal does not alter the support of the farmer's beliefs, if it satisfies a monotone likelihood property such that low values of w are correlated with low values of the signal. Given a signal σ which induces the farmer's beliefs over w to be updated to $G(.|\sigma)$, the intervention results in a pooled price $\bar{p}(\sigma)$ satisfying $W(\Pi(\bar{p}(\sigma))) = E_{\{G(w|\sigma)\}}[W(\Pi(M(w)))]$. If σ and w are positively correlated, high (resp. low) realizations of w and σ tend to occur together with high probability, causing $\bar{p}$ to co-move with w. Compared to before the intervention, the farmgate price and sold quantity now co-move more with the wholesale price, and are lower (resp. higher) when the wholesale price is lower (resp. higher) than average.

These predictions are summarized in the first row of Table 4, and turn out to be different from predictions of other competing models of the trading mechanism that we describe in Section 6.

However the model predicts that information provision leaves the farmer's *ex ante* welfare unaffected. Conditional on signal σ_j, the farmer's welfare is

[36]However, because $W(\Pi(.))$ is concave, the effects are not necessarily zero. If $W(\Pi(.))$ were strictly concave, the effect on the average price is positive.

$E_{w|w\in I_j}][W(\Pi(M(w)))]$, so the unconditional *ex ante* welfare is $E[W(\Pi(M(w)))]$. This is a general property of all equilibria, both before and after the provision of information. The arguments above indicate that the effect on village trader's welfare is negative if β is sufficiently small. Hence information provision results in an *ex ante* Pareto inferior outcome!

5 Experimental Results

We now turn to empirical tests of the theoretical predictions above. We abstract from dynamic considerations associated with effects on storage and timing of sales by farmers. Accordingly, we simplify the empirical analysis by aggregating the data to the annual level. The empirical results are not substantially modified when we extend the model to incorporate dynamic aspects (see Section B in the Appendix).

5.1 Average Treatment Effects

We start by estimating the effect of the interventions on the farmers' sales and revenues. Our data include information about the quantity of potatoes of each variety and self-reported quality grade that a given farmer sold in each transaction in 2008, and the gross revenue and the net (of transport, handling and storage costs) revenue and price per kilogram he received. We aggregate the sales of each variety-quality combination by farmer across the year, to compute the annual quantity sold and the annual average of farmgate price.

Table 5 shows the average treatment impacts. The regression specification follows equation (1), where y_{ikqv} is the dependent variable: annual quantity of variety k and quality q sold by farmer i in village v, and net farmgate price, which is the ratio of the annual net revenue received to the quantity sold.[37] Besides controlling for the farmer's landholding size, all regressions include dummies for the potato variety and quality.

In alternative columns, we include *mandi* fixed effects to control for fixed differences at the *mandi* level.[38] In column (1) the sign of the coefficient for all three intervention dummies is positive, but none of them are significantly different from zero. Including *mandi* fixed effects in column (2) reverses the sign of the private information and the public information coefficients, and they all remain insignificant, consistent with our theoretical predictions.[39] Columns (3) and (4) show that there is also no significant average impact of the intervention on farmgate prices. In Figure 1 we plot average weekly farmgate prices in the treatment and the control villages, and the corresponding *mandi* prices. In line with our regression results, there is no discernible difference between the different farmgate price series.

5.2 Heterogeneous Treatment Effects

The main prediction of the *ex post* bargaining model in Section 4 is that informing farmers about the *mandi* price would increase the quantity they sold and price they received if the *mandi* price was high, and lower it if the *mandi* price was low. To verify this prediction rigorously we use the regression specification:

$$\begin{aligned} y_{ikqv} &= \beta_0 + \beta_1 \nu_{ikm} + \beta_2 \text{Private information}_v + \beta_3 \text{Phone recipient}_{iv} + \beta_4 \text{Public information}_v \\ &\quad + \beta_5 (\text{Private information}_v \times \nu_{ikm}) + \beta_6 (\text{Phone recipient}_{iv} \times \nu_{ikm}) \\ &\quad + \beta_7 (\text{Public information}_v \times \nu_{ikm}) + \beta_8 X_{ikqv} + \epsilon_{ikqv} \end{aligned}$$

[37] We discount the revenue for delays between the time of sale and the date when payment is received.

[38] Sample villages were mapped to the *mandi* whose catchment area they lay in. In the information interventions, farmers/village vendors received the price information from that *mandi*.

[39] Since the estimated effects on quantity and farmgate prices with *mandi* fixed effects are negative for the private information treatment farmers who don't receive phonecalls, we think it unlikely that the true effects are positive but simply not detected due to lack of statistical power.

where ν_{ikm} is the realized average price (or price shock) in *mandi* m. As before, standard errors are clustered at the village level.

For these heterogeneous effects to be identified, it must be the case that the *mandi* price is uncorrelated with the error term in the regression. In particular, it is important that variation in *mandi* prices not be correlated with variation in unobserved characteristics that might also affect the pass-through of prices. Note first that our experiment involved only a small fraction of the villages supplying to each market, so wholesale *mandi* prices were unlikely to be affected by our treatments.[40] As Table A3 in the Appendix shows, within any district, *mandis* with average annual prices above and below the median were not significantly different in distance from the retail market, access to metalled roads, agricultural wage rates, or presence of industry/manufacturing. There is some evidence (only in Hugli district) that the average yield was slightly higher in villages under *mandis* with the above-median annual average price, and that the residents of these villages were less likely to have landline phones. However, the *mandi* fixed effects in our regressions control for these differences.[41] Below we also discuss a robustness check where we instrument for the *mandi* price with the city price.

The results in Tables 6 and 7 correspond to quantity sold and price per kilogram, respectively. The different columns in Table 6 use different specifications of the *mandi* price, different samples and different dependent variables. Focus first on Columns 1 through 4, where all 1545 farmers are included in the sample, and the total quantity of potatoes sold (in kilograms) is regressed on the intervention dummies and their interactions with the price regressor. In column 1 the price regressor is the *mandi* price for each farmer-variety combination in the sample, averaged over the weeks when the farmer sold

[40] Recall that the block-stratified assignment of villages to treatment category ensures that under a given *mandi* there are villages randomly assigned to different information treatments.

[41] Results are qualitatively similar when *mandi* fixed effects are not included.

the variety. Thus it represents the average resale price the trader could have received for potatoes he purchased from this farmer, and we estimate how farmer outcomes vary with this price.

We see a positive coefficient on the *mandi* price average, although it is not significant.[42] The intercept effects on both the private and public information treatments are negative, and the interactions of the treatment with the average *mandi* price are positive. In other words, the information interventions caused farmers facing a low *mandi* price to sell a smaller quantity than they would have sold otherwise. However, at higher *mandi* prices, this negative effect was attenuated. The results indicate that in a village facing the 10th percentile of *mandi* price, the private information intervention caused a (phone non-recipient) farmer to reduce sales by 1090 kg (or 28 percent of the control mean, significant at 10%), and the public information intervention caused the farmer to reduce sales by 1189 kg (or 31 percent, significant at 5%). In a village facing the 90th percentile of *mandi* price, the private and public information caused farmers to sell an additional 1158 kg (or 30 percent) and 723 kg (or 19 percent) respectively, although these two positive effects are not statistically significant. From column 1 in Table 7 we calculate that in a village facing the 10th percentile of *mandi* price, the private information intervention lowered the farmgate price received by a phone non-recipient farmer by 18 paise (or 9%), whereas in a village facing the 90th percentile of the *mandi* price, it increased his farmgate price by 24 paise (or 12%).

The weights used to compute the farmer-specific *mandi* price average in Column 1 are endogenous to a farmer's decision to sell: if he chooses to sell only when the actual *mandi* price is high, then this average is an overestimate of the true average *mandi* price

[42] Note, if the baseline equilibrium is FNRE then we expect there to be no relationship between the *mandi* price and the quantity sold or price received. However if the FNRE does not exist, then the baseline equilibrium is partially pooling, in which case a higher *mandi* price causes the village trader to offer the farmer a higher price and the farmer responds by selling more. This can explain this positive coefficient.

the farmer was facing. This concern is addressed in Column 2 by instead using an average where the weekly *mandi* prices are weighted by the volume of potatoes sold in that week by sample farmers in control villages in that district. This average is exogenous to the farmer's decision to sell, but may be less relevant to the farmgate price. We continue to see a large and statistically significant negative intercept effect and positive slope effect of the private information interventions. The signs are similar for the public information treatment, although the slope coefficient is not precisely estimated.

Note that in the bargaining model, the information intervention changes the equilibrium because it informs the farmer that the *mandi* price is either higher or lower than the expected price. So in column 3, instead of using the actual *mandi* price as the regressor we use the deviation of the 2008 *mandi* price from the predicted price, using weekly *mandi* prices from other years for which we have data (2007, 2011 and 2012) to generate the prediction. Under standard rational expectation assumptions, this *mandi* price "shock" ought to be orthogonal to farmers' *ex ante* price information and other relevant characteristics.[43] Note the intercept effect of the interventions now measures the effect of the treatment for farmers selling in states where the expected *mandi* price equalled the actual price, unlike previous specifications where the intercept effects pertained to a hypothetical *mandi* price of zero. The model predicts that if the intervention does not change the farmer's belief about the prevailing price, it cannot change the equilibrium. The interaction term of the treatment with the slope coefficient continues to have the same interpretation: it estimates the effect of the intervention when the actual price is above the expected price.

As expected, we see in column 3 that the intercept terms are non-significant. The effects of the information treatments on the slope coefficient are positive, and the one

[43] Since the explanatory variable is itself derived from estimates from other regressions, we report cluster-bootstrap standard errors, where the *mandis* are defined as the clusters.

on the private intervention is statistically significant.[44] In column 4 we instrument the *mandi* price with the interaction of the city price and the distance between the *mandi* and the city. This addresses the concern that *mandi* price changes may be endogenous to the intervention. If the city price is unaffected by the price in any given *mandi*, the exclusion restriction is satisfied. As we know from Table 2, there is considerable pass-through from the city price to the *mandi* price; hence it is unsurprising that the instruments are not weak.[45] Our results for the private information treatment are quantitatively and qualitatively similar when we use the instrumented *mandi* price instead of the actual.

6 Testing Alternative Models

We now discuss whether the experimental results are consistent with alternative models of the farmer-trader trading mechanism.

6.1 Risk-Sharing Contracts with Full Commitment

An *ex ante* contract would specify the quantity that the farmer sells and the price the middleman pays, for each realization of w (reported by the trader). This would allow the middleman and farmer to share price risk. In a direct analogy to implicit wage-employment contracts where firms insure workers against product price shocks that they observe privately (Hart 1983), a risk-neutral middleman would pay the farmer a constant

[44]The effect of the price deviation in control villages (see the first row) turns out to be negative and significant. This is consistent with the model, for the following reason. Since the actual price is positively correlated with the expected *mandi* price, a positive price deviation relative to a low expected price may still imply a lower actual price and therefore a smaller supply response than a negative price deviation relative to a high expected price. For example, suppose the farmer's "low" expected *mandi* price was a price between 0 and 3, with a mean of 1.5. If the intervention informs him that the true price is 2.8, this is a positive price deviation. If instead he held a "high" expectation of the *mandi* price, i.e. he thought the price was between 3 and 6 with a mean of 4.5, then an intervention that informs him that the true price is 3.2, is a negative price deviation. However he will supply a larger quantity of potatoes in the negative price deviation state than in the positive price deviation state.

[45]They pass the Kleinberg-Paap test for weak instruments with an F-statistic of 24.17.

price regardless of the wholesale price. Since the middleman bears all the residual risk, he has no incentive to understate the wholesale price; his private information does not create any distortions. The middleman margins could then represent risk premia on this price insurance. While such a contract would generate the observed low transmission of the wholesale price to the farmgate price, it also implies that the experiment would have no impact at all. We summarize this prediction in the second row of Table 4. This contrasts with our result that the information provision increased pass-through.

Asymmetric information generates distortions only if middlemen are also risk-averse, so that farmers also bear some of the risk associated with wholesale price fluctuations. This causes some of the fluctuations in the wholesale price to pass through to the farmgate price. In turn, this creates an incentive for the middleman to understate the wholesale price, so as to persuade the farmer to accept a lower price. To keep the middleman honest, traded quantities would be distorted downwards when the wholesale price is low, and would be set at the efficient level when the price is at the maximum (the standard no-distortion-at-the-top result). Information interventions that reduce the asymmetry of information would reduce this screening distortion. This would cause the traded quantity to increase at low wholesale prices, but have no effect at high wholesale prices. Thus *risk-sharing contracts with asymmetric information would predict a positive average treatment effect on quantity transacted; the treatment effect would especially be positive in low-market-price states, and would vanish in high price states*. This prediction is summarized in the third row of Table 4. In contrast, our experimental results show a significant negative impact on quantity traded in low-price states.

6.2 Risk-Sharing Contracts with Limited Commitment

Limited-commitment contracting models have been used to explain insurance and marketing contracts in a range of developing countries. These models allow for the possibility of *ex post* moral hazard: when the outside spot market price exceeds the risk-sharing price, the farmer might renege on the contract and sell there instead. As a result, these contracts allow farmers and traders to share some, but not all of the price risk (Ligon, Thomas, and Worrall 2002, Blouin and Machiavello 2013, Machiavello and Morjaria 2015 and Saenger, Torero, and Qaim 2014). Providing the farmer with information about market prices increases this hazard, reducing traders' profits in the states when the guaranteed farmgate price is below the spot market price. In turn this limits traders' ability to pay the guaranteed price when it is above the spot market price. Thus, informing farmers about the market price can unravel the insurance arrangement, increasing the pass-through from the wholesale price to the farmgate price. Accordingly, the farmer would sell less (resp. more) to the middleman when the market price was lower (resp. higher) than average.

Note first that the farmers in our study were unable to sell directly to buyers at the wholesale markets. This makes *ex post* moral hazard very unlikely. Second, for our results to be consistent with limited-commitment contracting, it must be the case that traders lose money in some states of the world. In particular, they would make losses when the *mandi* price was very low, below the farmgate price. Indeed, this is a *sine qua non* of any insurance arrangement. (We summarize this prediction in the fourth row of Table 4.) We do not find empirical evidence supporting this. During the 2008 harvest, the lower bounds of the trader net margin at the four quartiles of the *mandi* price were Rs -0.10, 0.53, 1.94 and 3.21 respectively.[46] In the lowest quartile of the *mandi* price,

[46] We use selling costs incurred by farmers as an upper bound estimate of corresponding selling costs

we are unable to reject the null hypothesis that the true margin is zero. Thus even when *mandi* prices were extremely low, there is no evidence that the lower bound of the trader net margin was less than zero.[47]

6.3 Standard Oligopoly Models

Standard trade and industrial organization models of price pass-through in vertical supply chains assume monopolistic competition in the spirit of Dixit and Stiglitz (1977). They involve a simultaneous move game where each middleman (who may be differentiated on non-price dimensions) selects his price (see e.g., Atkin and Donaldson 2014, Gopinath and Itskhoki 2010, Weyl and Fabinger 2013 and Villas-Boas 2007). Perfect competition and perfect collusion are limiting special cases. Such models would correspond to a variant of our model where village and market traders make simultaneous price offers to the farmer. The farmer responds by selecting one of the offers and a corresponding quantity to sell, or else remains in autarky. Providing information to farmers would not change anyone's payoff function: farmer payoffs depend only on the price offers of the traders since they cannot sell directly in the market themselves, and traders know their resale price regardless of the intervention. Hence, unlike the significant heterogenous treatment effects that we observe, this class of models predicts that the information interventions should have no effect.[48] (See the fourth row of Table 4.)

Finally, models with costly search frictions à la Salop and Stiglitz (1977) predict that if information interventions lower farmers' costs of searching for traders offering the

incurred by traders. It suffices to estimate net margins at the harvest time, since the trader has the option of selling immediately upon purchase, instead of storing the potatoes for later sale. Hence net margins at the time of the harvest represent a lower bound to their expected margin.

[47] *Mandi* price realizations were lower than average in 2008. Since we do not find evidence for negative trader net margins even in this year, it is very unlikely that traders make losses in low-price states in most other years.

[48] The key difference is that in our model the village and market traders move sequentially rather than simultaneously, and farmers are uninformed about resale prices.

highest price, then price dispersion would decrease across farmers and sales locations. (See the fifth row of Table 4.) However since village middlemen and farmers in our study areas live within close proximity of each other and meet frequently, we expect that these search costs are negligible. Therefore we do not expect any effects on the dispersion of prices across farmers.[49] Table 8 verifies this. Using either variance or range of prices as measures of dispersion, we find no evidence that either intervention caused farmgate prices to become more similar within the village or, the *haat* price to become more similar across *haats*.

7 Conclusion

Unlike other settings where producers have direct access to markets, large transactions costs and regulations prevent potato farmers in West Bengal from selling to wholesale buyers directly (Cohen 2013). We have provided evidence that marketing middlemen earn large margins on average. Our surveys as well as experimental evidence provide support for a model of *ex post* bargaining in which wholesale price fluctuations are not passed through to farmers. While by itself this might suggest that farmers and traders enter into insurance contracts, we have shown that the entire set of empirical findings is inconsistent with insurance arrangements. Hence insurance premia cannot account for the large middleman margins. Instead, we argue that the margins reflect barriers to entry into the trading business, and farmers' limited access to markets. Our results also show that in the context of such vertical supply chains, improving farmers' access to price information is unlikely to have positive outcomes on farmgate prices. Hence researchers and policy-makers need to focus greater attention on promoting competition among buyers and enhancing farmer access to wholesale markets.

[49]However, both kinds of models predict that the gap between farmgate and *haat* prices would narrow.

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Table 1: Potato Cultivation & Sales by Sample Farmers, 2008

	Mean/(SE)
Area planted (acres)	0.663
	(0.017)
Quantity harvested (kg)	6553.3
	(177.2)
Fraction sold from field	0.428
	(0.009)
Fraction stored at home	0.165
	(0.007)
Fraction stored in cold store	0.285
	(0.008)
Fraction spoiled	0.0262
	(0.001)
Quantity sold (kg)	5962.6
	(184.5)
Fraction sold at market *haat*	0.0786
	(0.006)
Fraction sold to village trader	0.908
	(0.007)
Gross revenue (Rs)	12887.2
	(413.0)
Net revenue (Rs)	11974.72
	(364.6)
Gross price received (Rs/kg)	
sold to village trader	2.156
	(0.016)
sold at market *haat*	2.896
	(0.050)
Net price received (Rs/kg)	
sold to village trader	2.03
	(0.016)
sold at market *haat*	2.428
	(0.050)
Mandi price (reported by vendor) (Rs/kg)	4.821
	(0.160)
Tracked price (reported by farmer) (Rs/kg)	2.763
	(0.027)

Statistics are computed from farmer survey data collected in 2008. Standard errors are in parentheses.

Table 2: Pass-through of City Prices to *Mandi* and Farmer Prices

	Weekly *mandi* price		Weekly farmgate price	
	all years	2008	2008	2008
	(1)	(2)	(3)	(4)
City price	0.809***	0.663***	0.023	
	(0.009)	(0.048)	(0.068)	
Mandi price				0.043
				(0.048)
Local yield ('000 kg/acre)	-0.030			
	(0.020)			
Year 2008	0.401***			
	(0.067)			
Year 2011	1.384***			
	(0.083)			
Year 2012	2.254***			
	(0.073)			
Constant	-0.587***	0.346	1.768***	1.727***
	(0.185)	(0.245)	(0.342)	(0.204)
Mandi dummies	Yes	Yes	Yes	Yes
Week dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	No	No	No
Observations	*2,691*	*790*	*596*	*596*
R-squared	*0.977*	*0.913*	*0.530*	*0.531*

The unit of observation is a *mandi* in a week. In columns 1 and 2 the dependent variable is the mean weekly *mandi* price, in columns 3 and 4 it is the mean weekly price received by farmers in the catchment area of the *mandi*. Only price data for weeks 13 and beyond are included for 2007, 2011 and 2012. Robust standard errors are in parentheses. $^{***}: p < 0.01, ^{**}: p < 0.05, ^{*}: p < 0.1$.

Table 3: Effect of Interventions on Farmers' Tracking Behavior and Precision

Panel A: Effect on Price Tracking Behavior

	Track wholesale price	Days since tracked	Source of information "other"
	(1)	(2)	(3)
Private information	0.805	0.692***	3.530**
	(0.378)	(0.069)	(2.085)
Phone recipient	1.818**	0.796***	11.161***
	(0.549)	(0.041)	(5.987)
Public information	8.596***	0.736***	52.173***
	(5.696)	(0.081)	(33.083)
Land	1.578***	0.988	0.932
	(0.209)	(0.012)	(0.071)
Constant	8.197***	4.945***	0.005***
	(4.431)	(0.501)	(0.004)
Observations	*11,719*	*10,267*	*10,267*
Prob > χ^2	*0.000*	*0.000*	*0.000*
Pseudo R-squared	*0.159*		*0.302*

Panel B: Effect on Error in Tracked Price

	Mean	N
	(1)	(2)
Control	0.221	3046
Private information:		
Phone non-recipient	0.190	2588
Phone recipient	0.179	688
Public information	0.181	4714
F-test of ratio of sum of squares (p-values)		
Control/Private Info without phone	*0.000*	
Control/Private Info with phone	*0.000*	
Control/Public Info	*0.000*	
Private Info/Public Info	*0.112*	
Private Info without phone/Private Info with phone	*0.151*	

In Panel A, dependent variables are farmers' reports in 2008 of whether they tracked prices in markets, the number of days since they last tracked prices, and their source of information, for a given potato variety, in the past fortnight. Columns 1 and 3 present odds-ratios of binary logit regressions and column 2 presents the odds-ratios from a Poisson regression. In column 3, we recode the farmer's reports of their source of information into a binary variable indicating "experimental intervention" or not. Further details are in Section 2.2 in the text. Dummy variables for potato variety, district and survey month are included in all columns. Standard errors in parentheses are clustered at the village level. In Panel B, the normalized "error" is the difference between the market price the farmer reports for a market in a given week and the average actual price in that market in that week. The reported means are the mean sums of squared normalized errors. $^{***}: p < 0.01, ^{**}: p < 0.05, ^{*}: p < 0.1$.

Table 4: Predictions of Alternative Theoretical Models

	Middleman margin		Effect of information intervention: Average *mandi* price		Low *mandi* price		High *mandi* price		Farmgate price dispersion
	Low *mandi* price	High *mandi* price	Quantity sold	Farmgate price	Quantity sold	Farmgate price	Quantity sold	Farmgate price	
Bargaining model			none	none	decrease	decrease	increase	increase	none
Contracts with full commitment & …									
…risk-neutral middleman	none	none	none	none	none	none	none	none	
…risk-averse middleman					increase				
Contracts with limited commitment	negative	positive	none	none	decrease	decrease	increase	increase	
Simultaneous move oligopoly			none	none	none	none	none	none	
Search frictions									decrease
Our empirical results	positive (weakly)	positive (strongly)	none	none	decrease	decrease	increase	increase	none

We assume that in the bargaining model the fully non-revealing equilibrium exists and is selected at baseline.

Table 5: Average Treatment Effects of Information Interventions on Farmer Sales and Price Received

	Quantity sold (kg) (1)	(2)	Net price received (Rs/kg) (3)	(4)
Private information	457.64	-30.71	-0.08	0.02
	(552.92)	(531.37)	(0.13)	(0.11)
Phone	639.89	567.28	0.09	0.08
	(417.83)	(433.75)	(0.10)	(0.09)
Public information	230.54	-289.75	-0.10	-0.05
	(522.08)	(512.66)	(0.12)	(0.11)
Land	2,251.88***	2,215.65***	-0.10***	-0.08***
	(174.77)	(178.39)	(0.02)	(0.02)
Constant	2,817.06***	3,034.08***	2.17***	2.33***
	(551.66)	(452.42)	(0.12)	(0.09)
Observations	*2,318*	*2,318*	*2,318*	*2,318*
R-squared	*0.353*	*0.387*	*0.332*	*0.400*
Mandi fixed effects	no	yes	no	yes
Mean DV	3855		2.021	
SE DV	213.3		0.0325	

In columns 1 and 2 the dependent variable is the quantity of potatoes a farmer sold of a particular variety and quality in a week in 208. Revenue (net of transport, handling and storage costs) is discounted to account for the implicit interest cost of delays from the time of sale to the receipt of payment, and is then divided by the quantity sold to arrive at the net price received, which is the dependent variable in columns 3 and 4. In columns 1 and 3 we include dummy variables for variety, quality and district of farmer's residence. In columns 2 and 4 we include dummies for the quality as well as the *mandi* whose catchment area the farmer resides in. A *mandi* is defined as a (physical) market-variety combination. Standard errors in parentheses are clustered at the village level. $^{***}: p < 0.01, ^{**}: p < 0.05, ^{*}: p < 0.1$.

Table 6: Heterogeneous Impacts of Interventions on Quantity Sold

Sample:	Full sample	Full sample	Full sample	Full sample	Farmers with long-term relationships	Full sample
Dependent variable:	Quantity sold	Quantity sold	Quantity sold	Quantity sold	Quantity sold	Fraction sold at harvest time
Price regressor:	Farmer-specific average of *mandi price*	Weighted average of *mandi* price	Farmer-specific deviation from expected *mandi* price	Farmer-specific instrumented *mandi* price	Farmer-specific average of *mandi* price	Farmer-specific average of *mandi* price
	(1)	(2)	(3)	(4)	(5)	(6)
Price regressor	76.6		-252.2***	205.6	-819.3*	-0.05***
	(242.8)		(93.6)	(657.7)	(476.0)	(0.02)
Private info	-3,155.5**	-3,910.5**	562.5	-4,109.4*	-5,838.1*	-0.03
	(1,358.7)	(1,774.3)	(676.3)	(2,303.9)	(3,144.5)	(0.11)
Private information × Price regressor	708.2**	913.9**	827.6**	932.3*	1,429.5*	0.00
	(320.5)	(429.3)	(344.9)	(534.7)	(815.1)	(0.02)
Phone	1,418.3	-66.8	621.8	-2,048.8	3,344.0	-0.14*
	(1,419.8)	(1,578.9)	(664.6)	(3,706.1)	(4,040.3)	(0.07)
Phone × Price regressor	-200.9	145.0	-68.9	855.7	-724.8	0.03
	(332.1)	(411.2)	(338.0)	(1,021.2)	(1,058.4)	(0.02)
Public info	-2,946.1**	-3,173.8*	-140.1	-4,153.1	-6,570.7***	-0.03
	(1,263.4)	(1,776.2)	(541.7)	(2,741.3)	(2,435.1)	(0.10)
Public information × Price regressor	602.4**	663.5	145.2	829.1	1,599.8***	0.00
	(287.9)	(413.2)	(200.6)	(649.9)	(563.6)	(0.02)
Land	2,186.8***	2,198.2***	2,253.3***	2,601.4***	2,463.8***	-0.03***
	(181.7)	(178.2)	(162.3)	(236.9)	(405.4)	(0.01)
Constant	2,794.0**	3,084.0***	3,158.3***	3,612.9	6,241.7***	0.70***
	(1,078.8)	(423.0)	(558.0)	(3,495.6)	(2,060.1)	(0.09)
Observations	*2,300*	*2,317*	*2,283*	*1,508*	*443*	*2,291*
R-squared	*0.392*	*0.390*	*0.362*	*0.447*	*0.515*	*0.358*
Mean DV	3872	3859	5019	3872	3780	0.324
SE DV	214.9	213.5	172.9	214.9	437.1	0.0132

A *mandi* is defined as a (physical) market-variety combination. Columns differ in the definition of the price regressor. In columns 1 & 5 it is the relevant *mandi* price averaged over the weeks in 2008 when the farmer sold potatoes of that variety. In column 2 it is the relevant *mandi* price averaged over all weeks in 2008, with each week weighted in proportion to the quantity sold that week by sample farmers in control villages in that district. In column 3 it is the average deviation of the relevant *mandi* price in 2008 from the predicted *mandi* price for 2008, where the prediction is from a linear regression of weekly *mandi* prices for 2007, 2011 and 2012 on *mandi* dummies, period dummies, year dummies and their interactions. In column 4 the sample is restricted to farmers who likely were in long-term relationships with buyers, as assessed from their reports in 2010 of selling to a buyer whom they had been selling to for longer than 5 years. In column 6 it is the mean *mandi* price the farmer faced during the harvest season. In column 4, in the (unreported) first stage we instrument the *mandi* price with the city retail price and its interaction with the distance between the *mandi* and the city. The Kleibergen-Paap F-statistic for weak instruments is 24.17, i.e. we do not find evidence for weak instruments. All columns include dummies for the quality of potatoes sold, and column 3 also includes dummies for the potato variety. Columns 1, 2, 4, 5 & 6 include dummies for the *mandi* whose catchment area the farmer resides in. Standard errors in parentheses are clustered at the village level in columns 1, 2, 4, 5 & 6, and are village-cluster bootstrapped in column 3. $^{***}: p < 0.01, ^{**}: p < 0.05, ^{*}: p < 0.1$.

Table 7: Heterogeneous Treatment Effects of Information Interventions on Price Received

Sample:	Full sample	Full sample	Full sample	Full sample	Farmers with long-term relation-ships
Price regressor:	Farmer-specific average of *mandi price*	Weighted average of *mandi* price	Farmer-specific deviation from expected *mandi* price	Farmer-specific instru-mented *mandi* price	Farmer-specific average of *mandi* price
	(1)	(2)	(3)	(4)	(5)
Price regressor	0.2**		0.0	0.5***	0.2
	(0.1)		(0.0)	(0.2)	(0.2)
Private information	-0.6*	-0.7*	0.1	-0.5	0.4
	(0.3)	(0.4)	(0.1)	(0.4)	(0.7)
Private information × Price regressor	0.1*	0.2*	0.2***	0.1	-0.1
	(0.1)	(0.1)	(0.1)	(0.1)	(0.2)
Phone	0.0	0.0	0.1	0.3	-0.3
	(0.1)	(0.1)	(0.1)	(0.3)	(0.2)
Phone × Price regressor	-0.0	0.0	-0.0	-0.1	-0.2
	(0.1)	(0.1)	(0.0)	(0.1)	(0.2)
Public information	0.0	0.0	0.2	0.5	1.1
	(0.3)	(0.3)	(0.1)	(0.4)	(0.8)
Public information × Price regressor	0.1	-0.1	-0.1	-0.1	0.7
	(0.3)	(0.4)	(0.1)	(0.1)	(0.7)
Land	-0.1***	-0.1***	-0.1***	-0.1***	-0.1**
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Constant	1.6***	2.3***	2.2***	-0.4	1.4
	(0.3)	(0.1)	(0.1)	(0.9)	(0.9)
Observations	*2,300*	*2,317*	*2,283*	*1,508*	*443*
R-squared	*0.423*	*0.406*	*0.356*	*0.339*	*0.513*
Mean DV	2.015	2.018	2.151	2.015	2.131
SE DV	0.0325	0.0325	0.0203	0.0325	0.111

Notes below Table 6 apply. Revenue (net of transport, handling and storage costs) is discounted to account for the implicit interest cost of delays from the time of sale to the receipt of payment, and is then divided by the quantity sold to arrive at the net price received.

Table 8: Effect of Information Interventions on Price Dispersion

	Within the village				Across villages	
	Variance of gross price received	Range of gross price received	Variance of net price received	Range of net price received	Variance of *haat* price	Range of *haat* price
	(1)	(2)	(3)	(4)	(5)	(6)
Private information	-0.134	0.176	-0.113	0.239	0.241	0.070
	(0.154)	(0.253)	(0.152)	(0.248)	(0.386)	(0.262)
Public information	-0.049	0.306	-0.001	0.373	1.235	0.351
	(0.161)	(0.288)	-0.16	(0.275)	(0.818)	(0.318)
Constant	0.648***	2.543***	0.675***	2.645***	0.914***	0.854***
	(0.138)	(0.225)	(0.136)	(0.217)	(0.266)	(0.184)
Observations	*100*	*100*	*100*	*100*	*458*	*458*
R-squared	*0.068*	*0.109*	*0.067*	*0.114*	*0.480*	*0.337*

Columns (1)-(4) report regressions of measures of within-village dispersion of the average annual prices that farmers received for each variety in 2008. Variety dummies are included, and robust standard errors are in parentheses. Column (5) & (6) report regressions of measures of across-*haat* dispersion of *haat* prices within a week, for each variety. Variety and week dummies are included, and standard errors in parentheses are clustered at the village level.

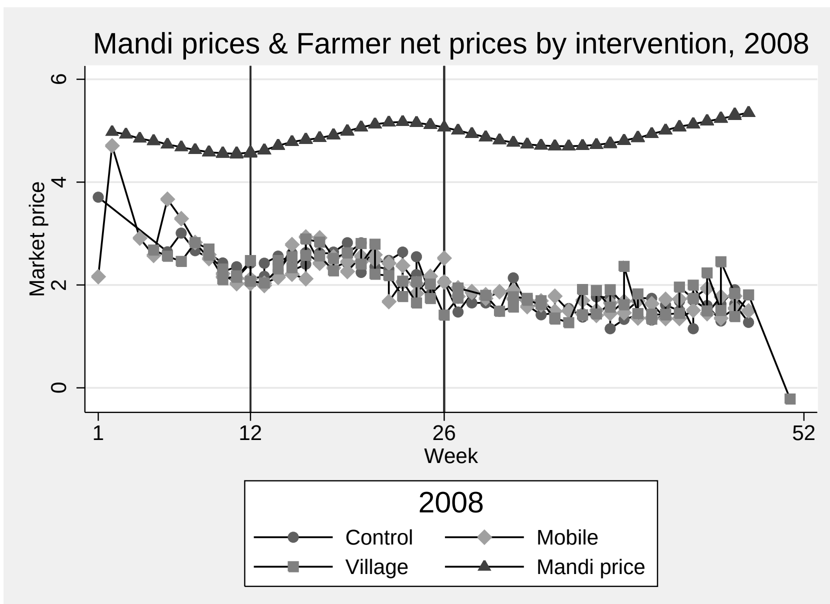

Figure 1: Intervention Impacts