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

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Abstract

In the Indian state of West Bengal, potato farmers sell to local middlemen because they lack direct access to wholesale markets. High-frequency marketing surveys reveal large middleman margins and negligible pass-through from wholesale to farmgate prices. Farmers are uninformed about downstream wholesale and retail prices. To test alternative models of farmer-middlemen trades, we conduct a field experiment where farmers in randomly chosen villages are provided with wholesale price information. Information had negligible average effects on farmgate sales and revenues, but increased pass-through from wholesale to farmgate prices. These results are consistent with a model of *ex post* bargaining between farmers and village middlemen where farmers also have the option of selling to other middlemen outside the village. They are inconsistent with models of risk-sharing contracts between middlemen and farmers, standard oligopolistic models of pass-through or search frictions. (JEL Codes: O120, L140)

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1 Introduction

It is commonly believed that middlemen margins are an important component of agricultural value chains in developing countries. Yet there is little evidence on the magnitude or determinants of these margins.[1] Trading mechanisms between farmers and traders are also not well understood.[2] Do farmers and traders engage in *ex ante* risk-sharing contracts, or do they bargain only at the time of sale? What are farmers' outside options and how much bargaining power do they have? Do they have less information than traders do about price movements in downstream markets, and does this asymmetry of information 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 can 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 would affect these outcomes.

In this paper 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. Farmers in our study area sell more than 90% of their potatoes to village middlemen, who aggregate purchases and then re-sell them at wholesale markets to buyers from distant cities or neighbouring states. They sell the remaining to other middlemen in neighboring *local* markets. Not only do farmers lack direct access to wholesale markets, they are also uninformed about the wholesale market prices at which the middlemen resell their produce. Our data reveal large gaps between these resale prices and the prices that farmers receive. In the year of our study, farmgate prices (received from middlemen) were on average 55-61 percent of the wholesale prices at which middlemen resold the potatoes. In contrast, our calculation suggests that middlemen earned at least 28-38% of the wholesale price, and 64-83% of

[1] For example, Morisset (1998) conjectures that trading companies may have caused large and increasing gaps between world commodity prices and consumer prices observed from the mid-1970s to the mid-1990s. Other research in the context of African countries argues that increases in export prices do not translate into commensurate increases in producer prices for cash crops because of high middlemen margins (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).

the farmgate price per kilogram of potatoes traded.[3] The pass-through from retail prices to farmgate prices is negligible (a statistically insignificant 2 percent), while pass-through to wholesale prices is quite high (64-81 percent in 2008).[4]

To understand why potato middlemen earn large margins, we need to understand their trading mechanism with farmers. This is difficult to gauge directly from farmer surveys: these show on the one hand that traders and farmers often engage in repeat transactions, but on the other hand that very few farmers are bound by an advance contractual arrangement. Instead, the majority of farmers describe a process of *ex post* bargaining where village middlemen make daily price offers, to which farmers respond by either selling rightaway, holding out for a future sale, or transporting to a neighboring small market (called a *haat*) to sell to a different middleman.

These trading arrangements contrast sharply with the arrangements in many other contexts. In some, middlemen play no role at all. For example in other Indian states such as Madhya Pradesh, Maharashtra and Kerala, producers sell directly to wholesale or retail markets, sometimes via auctions conducted by government regulators (Goyal 2010, Fafchamps and Minten 2012, Jensen 2007).[5] In such environments, increased access to price information facilitates spatial arbitrage across markets, thereby reducing price dispersion across markets and increasing average price (Jensen 2007, Goyal 2010).[6] In some other developing country contexts, farmers enter into advance contracts with middlemen but also have the option to sell directly in a spot market; the resulting moral hazard problem limits the extent of risk-sharing achieved (Blouin and Machiavello 2013, Machiavello and Morjaria 2015 and Saenger, Torero, and Qaim 2014). In yet other contexts similar to West Bengal potato markets, farmers have limited access to wholesale

[3]We calculate middlemen's resale prices net of transport, handling and storage costs.

[4]Unlike the "pass-through literature" that mainly examines how price fluctuations transmit from upstream producers to downstream consumers, we refer here to price transmission from wholesalers (downstream) to farmers (upstream). The same issue of market structure limiting price transmission applies in both cases.

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

[6]The marketing arrangements differ across Indian states partly as a result of differences in government marketing regulations. Cohen (2013) provides a detailed description of agricultural marketing regulations and practice in West Bengal.

markets and almost entirely sell to local middlemen. This is true, for example, for coffee in Uganda (Fafchamps and Hill 2008) and cashews in Mozambique (McMillan, Rodrik, and Welch 2002).

Little is known about how such vertical supply chains are organized, and the resulting implications for intermediary margins and pass-through. Theoretical models of vertical relationships in supply chains are models of risk-sharing contracts (Hart 1983, Ligon, Thomas, and Worrall 2002, Machiavello 2010) or spot market models of oligopolistic competition among middlemen either with or without search frictions.[7] We are not aware of any attempts to discriminate between these different models, and bargaining without any contracts. This is the main goal of this paper. We also aim to shed light on the impact of policy measures to provide market price information to farmers.

Our ground level surveys of farmers and traders indicate that while farmers sell most of their output to village middlemen, they have the option of selling to middlemen located in market areas outside the village, if they incur search and transport costs. Village middlemen typically make farmers a take-it-or-leave-it price offer. Farmers are uninformed about the price at which middlemen resell on the wholesale market. In line with these facts, we develop a model of spot transactions, where an uninformed farmer bargains with an informed village middleman. The underlying assumption is that middlemen collude on price offers *within* the village, but village middlemen compete with middlemen located *outside* the village. Middlemen outside the village engage in oligopolistic competition with one another, thereby creating an outside option for the farmer. This outside option varies with the actual wholesale price and is higher than the monoposonistic price for village middlemen, thereby creating competitive pressure on the village middlemen. The key features of this setting are sequential trading opportunities and asymmetric information, so that early price offers inform farmers about what prices they may receive

[7] For example, see Antras and Costinot (2010), Antras and Costinot (2011), Chau, Goto, and Kanbur (2009) for the former, and Atkin and Donaldson (2014), Gopinath and Itskhoki (2010), Weyl and Fabinger (2013), Villas-Boas (2007) for the latter. Mortimer (2008) and Bonnet and Dubois (2010) empirically discriminate between linear and nonlinear pricing contracts in vertical relationships between upstream and downstream agents.

if they were to reject these and continue to search for other buyers.

This bargaining game between farmers and village middlemen has a number of equilibria, ranging from fully revealing (or separating) equilibria where the village middleman's price offer co-moves monotonically with the wholesale price, to fully non-revealing (or pooling) equilibria where the price offer does not vary at all with the wholesale price. There are also partially revealing equilibria that lie in between. We show that under reasonable assumptions, the fully non-revealing equilibrium generates the highest *ex ante* profits for the village middlemen.[8] This is because this equilibrium does not involve the trade breakdowns that inevitably occur in the revealing equilibrium.[9] Irrespective of the realized wholesale price, such trade breakdowns do not occur on the equilibrium path in the non-revealing equilibrium, where middlemen offer the same price to the farmer irrespective of the wholesale price realization. This is the explanation our provides for the observed negligible pass-through from wholesale to farmgate prices.[10]

We use the bargaining model to predict the impact of an intervention that provides farmers with information about prevailing wholesale prices. In particular, the model predicts that such an intervention increases the pass-through of wholesale prices to farmgate prices. The reason is that village middlemen take advantage of their market power to bargain farmers down to their outside option. The intervention affects farmers' information about their outside option, and thereby the price offers that village middlemen make to them. Clearly, whether the effect is positive or negative depends on whether the true wholesale price is high or low: when it is high, treated farmers become aware that their outside option is high, and traders respond by offering them higher prices than they offer

[8]These assumptions are: that self-consumption of potatoes is relatively unimportant, and that farmers are risk-averse with respect to the price they receive.

[9]In the revealing equilibrium, the village middleman responds to competitive pressure from middlemen outside the village and offers a price above the monopsony price. To ensure that he does not deviate from this above-monopsony price to the monopsony price, the equilibrium requires that trades break down when a lower price is offered. In other words, farmers reject lower price offers with a high probability.

[10]Our theory has some resemblance to models of relational contracts with private information where pooling can be more efficient than separating equilibria (Halac 2012, Malcomson 2016). However ours is a static trading environment with bargaining, instead of one with implicit contracts. Our data indicate that the vast majority of traders do not have implicit advance understandings with particular farmers. Further detail about this evidence is provided in Section 2.

to uninformed farmers. When instead it is low, they offer informed farmers lower prices than they offer to uninformed farmers. Thus the model predicts that treatment effects are heterogeneous with respect to the wholesale price realization, and on average, could cancel out.

In a field experiment conducted in 2008, we randomly assigned 72 (randomly chosen) villages from two potato-growing districts of West Bengal to one of two treatment groups, or a control group. In the two treatment groups of 24 villages each, we provided farmers with daily information about the prevailing potato prices in neighboring wholesale and retail markets. In one variation, called the private information treatment, four randomly selected farmers in the village received the information through phonecalls from our team of telecallers. In the other variant, the public information treatment, the information was posted publicly in the village. In the control villages, no information was provided. Simultaneously, 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. In our analysis of the annual average quantity sold and price received by farmers, we find evidence for both the heterogeneous treatment effects (i.e., increased pass-through from wholesale to farmgate prices) and the null average effect on farmgate price and sales predicted by the bargaining model.

The static bargaining model implies that the *ex ante* welfare effects of information interventions were negligible for farmers, and were negative for traders. The *ex post* welfare implications, of course, depend on exact realizations of the wholesale prices. Both *ex ante* and *ex post* welfare effects also depend on whether information affects farmers' storage decisions, an issue that we abstract from in the static version of the model. Section 7 explains how the model extends to a dynamic setting and examines the effects of information provision on storage. We find a significant positive effect on storage only for a small minority of treated farmers who were given information directly via distributed cell phones. The observed treatment effects for other farmers were therefore driven directly by price impacts rather than induced effects on storage. This justifies our initial focus on the static bargaining model and the observed experimental impacts on yearly averages of farmgate prices.

The experimental findings contrast sharply with the predictions of contracting or search friction models. Contracts that share risk between farmers and middlemen and are not subject to any commitment problems, predict instead that the information intervention would have a *positive* effect on trading volumes when the wholesale price is *low*. As we discuss in Section 6.1, this is because providing farmers with price information reduces screening distortions in low price states. Our findings are also inconsistent with risk-sharing contracts with limited commitment. In such contracts, providing farmers with market price information might create *ex post* moral hazard in high-price states: farmers would prefer to break the contract and sell at the high price in the spot market instead. As we discuss in Section 6.2, this provides a valid explanation for our findings only if middlemen earn zero profits on average. There is no evidence to indicate that this is the case. Indeed, the bargaining model predicts a decline in trading volumes and farmgate prices in low-price states even if middlemen earn positive rents in all states. Finally, models based on search frictions predict that information reduces the dispersion in farmgate prices within a village, and across different markets outside the village where the farmer can sell.[11] The bargaining model is consistent with the absence of any such effects.[12]

These results imply that high middleman margins in the West Bengal potato trade cannot be explained as risk premia for insurance they provide to farmers, or to significant search frictions.[13] It also appears unlikely that policy interventions that improve farmers' information about resale prices would significantly reduce average middleman margins in the West Bengal potato marketing chain, although they could increase the pass-through

[11] 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 subsequently follow if he continues to search.

[12] However, our model shares with standard search models the prediction that the gap between prices offered by traders within and outside the village will narrow, which is what we actually see in the data.

[13] As search frictions converge to zero, our model predicts that village middlemen's price offers converge to market middlemen's price offers, potentially leaving average margins unaffected (although this depends on the degree of farmer risk aversion).

of wholesale to farmgate prices. The deeper underlying problem is that middlemen wield considerable market power. This is because the market institutions do not allow farmers to directly access wholesale buyers, and because there are significant barriers to entry into the middleman business.

The paper is structured as follows. Section 2 describes the institutional setting. Section 3 describes the experiment and the data we collected through farmer surveys. Section 4 then presents the bargaining model and the main theoretical results. The empirical results testing these predictions are presented in Section 5. Competing explanations of the empirical results are discussed in Section 6. Section 7 then explains how the model can be extended to incorporate multiple dates and farmers' decisions to store potatoes, followed by empirical results on storage. Section 8 concludes the paper. Proofs of theoretical results and supplementary tables are collected in the Appendix.

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). In the winter, farmers in our two study districts plant more land with potatoes than with any other cash crop (Maitra et al. 2015). Planting takes place between October and December, and the potatoes are harvested between January and March. The harvest can be sold immediately, or, if placed in home stores it can be sold up to two or three months later. Alternatively the potatoes can be placed in cold stores, and then sold any time until November, when the new planting season begins. However, due to cold storage technicalities and government regulations, cold stores must be emptied at the end of November, so that potatoes cannot be carried over from one year to the next.

2.1 Farmer-Trader Transactions and Market Structure

The local supply chain is organized as in Figure 1. Our baseline survey reveals that in 2006 sample farmers sold 98 percent of their produce to local intermediaries or village traders, who tend to be residents of the same or neighboring villages.[14] These village traders aggregate purchases from local farmers, transport them to wholesale markets (called *mandis*) to sell to traders coming from city markets or in neighboring states.[15] Potatoes from Hugli district are usually sold ultimately in Kolkata retail markets, and in states in Eastern and Northeastern India such as Assam, Bihar and Jharkhand. Potatoes from West Medinipur district are sold in the Bhubaneswar market in neighboring Orissa, or in the southern state of Andhra Pradesh. As we will discuss in Section 2.3, price movements in the city retail markets explain much of the movement in local *mandi* prices that we observe.

There are on average 10 middlemen operating in a village. They usually buy from a network of farmers who have a track record of selling potatoes of uniform quality and not cheating them in various ways, such as for example, by including potatoes of a lower grade into the sack, or lying about the weight of the sack.[16] In 2007, sample farmers sold nearly 72 percent of their potatoes to buyers whom they had been selling to for a year or more, and 32 percent to buyers whom they had been selling to for two years or more.

This high incidence of repeat transactions among the same partners raises the possibility, but does not imply the existence, of contractual arrangements. Our surveys suggest that contracts are not widespread. For instance, in 2007 sample farmers sold only 21 percent 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. Table 1 throws more light on the nature of the trading mechanism using data from surveys we conducted in 2012 with 144 randomly selected middlemen who purchased in

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[14]Throughout this paper our analysis is restricted to the two most important varieties of potatoes grown in this region: *jyoti* and *chandramukhi*. Together these made up 90 percent of the potatoes grown by sample farmers.

[15]In addition to buying potatoes, village middlemen 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, making it unlikely that either farmers or village traders incur large search costs of finding each each other. However as we argue below farmers find it very difficult to find out the prevailing *mandi* price.

[16]Village traders typically only weigh the first few sacks of any lot.

these 72 villages. Traders were asked about the nature of their trading relationship with the farmer from whom they had been buying potatoes the longest (oldest continuous supplier), as well as with the farmer from whom they had started buying most recently (newest supplier). Only 25 percent of traders said they had a prior agreement to buy from their newest supplier that year. What is more striking however, is that only 33 percent had an agreement with their oldest supplier. Focusing on the relationship with the oldest supplier, only 6 percent reported an explicit contractual understanding about the quantity that they would buy, and only 16 percent reported either an explicit or implicit understanding about the price they would pay.

Direct sales to large buyers from distant markets are extremely rare. In informal interviews, these large buyers told us that it was "not worth their while" to negotiate small trades with many different farmers whom they did not know personally, and therefore could not trust to provide reliable quality. From the farmer's perspective, the alternatives to selling to a particular village trader are either to sell to some other village trader, or to sell to traders located outside the village. However, village traders admit to discussing among themselves the price offers they make to farmers, and checking with farmers the prices at which they recently sold to other traders, suggesting that traders located within the village tacitly collude on prices they offer to farmers. It is less likely that they collude with traders from other villages or traders at the local markets (called *haats*), since they meet them less frequently and are unable to monitor their transactions. When responding to a price offer from a village trader on any given day, farmers perceive their main outside option as taking their potatoes to the *haat* and selling to a trader in that market, or waiting to sell later in the year.[17] Our model of *ex post* bargaining with sequential competition between a village trader and a trader at a *haat* builds on these institutional details.

Ultimately, the market power of middlemen rests on barriers to entry into this line of business. To understand what these barriers are, in our 2012 middleman survey, we

[17] In 2006, sample farmers sold only 1 percent of their harvested potatoes in small local markets (*haats*) located on average 5 kilometres outside the village.

asked traders about the arrangements a hypothetical entrant into the trader business would need to make. They reported that the most important requirement to start a potato trading business was capital. The median capital needed was ₹50,000 (mean = ₹94472).[18] (See Table 2.) They said the next most important requirement was a prior apprenticeship with a trader, for an average of 3.5 years. An average of 3 years' experience cultivating potatoes was the third-most important requirement. It was also considered necessary to have prior contacts with at least 25 farmers, and large buyers in at least 3 distant markets. This suggests that entry requires financial investments as well as investments in relationships, which take time to build.

It should also be noted that 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 rarely provides such licenses. In the villages we study, there was no presence of any agri-retail purchasers that farmers had the option to sell to. It follows that village middlemen do not face strong competition from potential entrants into the middleman business, or from alternative buyers.

2.2 Price Information of Farmers

Since transactions between the traders and the buyers from distant markets whom they sell to are often bilateral, information about the trader's resale price at the wholesale market (*mandi*) is not in the public domain. Instead, in our 2007 baseline farmer surveys, 71 percent of sample farmers reported they learnt about *mandi* prices from the village trader they sold to, and 46 percent said this trader was their only source of information.[19] Only 13 percent reported asking friends and neighbours, and 6 percent received information through the media, although the media reports prices from much larger wholesale

[18] 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.

[19] These statistics can be seen in Table 6, Panel E, column 1.

markets, many of which are in different districts, and may sell different varieties.[20] Although public telephone booths, landline phones at home and mobile phones were all available to varying extents, in informal interviews farmers told us that they had no contacts at *mandis* who would tell them the prevailing *mandi* price.

Our fortnightly farmer survey data (collected from February to November 2008) also indicated substantial information asymmetry between farmers and traders. When we asked farmers what the price in the neighboring market had been recently, their reports (average ₹2.57 per kg) did not match the prices that village traders received in the *mandi* in that week (average ₹4.82 per kg), but instead were much closer to the prices received by *farmers* who sold at a *haat* in that week (average ₹2.55 per kg).[21][22] In other words, they interpreted the "market price" as 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*.

Notwithstanding this misinterpretation of our survey question, we can use the survey data to examine the gap between farmers' selling prices and traders' selling prices. We do this by matching the farmer price reports to the actual traders' selling price in the market they reported tracking. In 2008, for control group farmers, the mean squared error of the tracked price (i.e. the sum of squared gaps between the farmer's reported price and the actual price at which traders sold) was 0.221. This corresponds to a mean absolute deviation equal to 42.5 percent of the true price. In Section 3.3 we present evidence that the information intervention significantly reduced this mean squared error.

We received the *mandi* and *haat* price reports from market "insiders", who were either employees of the distant buyers, or small entrepreneurs (e.g. tea shop owners) located at the markets, and observed trades at the wholesale level. They were persuaded

[20] Consistent with this, when we attempted to match the official data on wholesale prices with the time series of *mandi* prices collected through our project, only 3 *mandis* matched successfully.

[21] We collected this information from farmers only in our 2008 survey, not in the 2007 survey. We also asked them the name of the market they had tracked the price for, how many days ago they had tracked this price. Combined with the date of the survey, this allows us to estimate the week that they reported their tracked price for, and match their report to the actual price in that week.

[22] 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*.

by our investigators to give us this information on a daily basis, in return for a fee.[23]

2.3 The Unpredictability of *Mandi* Prices

Our key premise is that farmers are uninformed about the prices at which traders resell their potatoes in the *mandis*. We have already described anecdotal evidence that farmers cannot directly collect information from the *mandis*. We now argue that farmers also could not have extracted much information about *mandi* prices from the data that they do have access to, such as past farmgate prices or current local yields.

First, there is considerable variation in *mandi* prices from year to year. The average price per kilogram in the post-harvest period across all *mandis* in our sample was ₹7.60 in 2007, ₹4.83 in 2008, ₹5.55 in 2011 and ₹10.99 in 2012.[24] Second, there is considerable volatility in weekly *mandi* prices both over time and across *mandis*, and a substantial part of the variation remains unexplained even after controlling for location-specific characteristics, seasonality and annual shocks.[25] To see this, consider the analysis of variance of weekly *mandi* prices for weeks 13 and beyond in 2007, 2008, 2011 and 2012 presented in Table 3. As the F-statistics show, the highest variability occurs across years, followed by period-year variations and spatial *mandi*-level variations. Different *mandis* also follow different patterns from year to year. All of this suggests that predicting the price in any given *mandi* in a given year or period is very difficult, even for someone who observes the *mandi* price each week in each *mandi* over several years. As noted above, farmers do not even observe these data.

It is also unlikely that farmers could infer the current prices at their local *mandi* from data they could readily observe, such as the distance of the *mandi* from the city market,

[23]Importantly, they did not participate in trade themselves, and so we have no reason to believe that our information collection exercise affected *mandi* prices.

[24]Weeks 13 and beyond are considered to be the post-harvest early period when farmers could be selling home-stored potatoes, and weeks 26-52 are the post-harvest late period, when any potatoes being sold are coming out of cold storage.

[25] Although in 2008 we collected *mandi* price data from January to November, for 2007, 2011 and 2012 we have these data only for the period May-November, and so this analysis is restricted to the post-harvest period. However in Section 5 we will analyze all sales that occurred in 2008, regardless of the time of sale.

transport cost fluctuations or potato output shocks in their area. The first column in Table 4 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 various factors that could explain the weekly variation: the weekly retail price in the relevant destination city market (Kolkata for Hugli, Bhubaneswar for West Medinipur), and *mandi*-specific (annual) potato yields estimated from output data for sample farmers located in each *mandi* area. Year dummies control for annual shocks, *mandi* dummies control for *mandi*-specific factors, and week dummies control for seasonal variation. As we can see, the pass-through from city prices to the prices that traders receive when they sell at the *mandi* is considerable: when the city price increases by ₹1, the *mandi* price increases by ₹0.81. 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, the pass-through from a ₹1 increase in city prices to weekly farmer prices in 2008 is a statistically non-significant ₹0.02. Note that *mandi*-specific factors and weekly variation are controlled for by the inclusion of the relevant dummies. In column 4 we check the pass-through from *mandi* prices to farmer prices, and once again, the coefficient is small (0.04) and non-significant.

These results imply not only that pass-through from retail prices to farmer prices is limited, but also that it would be very difficult for farmers to back out the prevailing *mandi* price from observation of the price that the trader offered them.

2.4 Margins Earned by Traders

Estimating the margins that middlemen earn is not straightforward because they often hold potatoes after buying them, and sell them later in the year when the price is high. However since they have the option of re-selling at the same time as they buy, the difference between their selling and buying prices at the same point of time provides a lower bound to their expected gross margin.[26] Since we do not have data on the actual

[26] By the same argument, 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.

costs that traders incurred in 2008, we use unit cost data for transport, handling and storage from farmer surveys as estimates. Since traders can avail of economies of scale and connections with store-owners, we expect that they incur lower unit costs than farmers do; subtracting them from gross margins then gives us a lower bound to trader net margins.

These lower bounds to trader net margins need to be calculated separately for the harvest and post-harvest periods.[27] We present this calculation in Table 5. Using the distribution of quantities sold in the sample in different weeks as weights, we estimate average prices that 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.[28] After subtracting the relevant unit costs, we have lower bounds on mean net trader margins in 2008, of ₹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 farm-gate price, depending on which part of the year they bought and sold the crop in.[29]

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 a minimum distance of 10 kilometres

[27]This is because for potato transactions occurring in the harvest period, storage costs would not be incurred, while transport costs would be incurred: the trader would buy potatoes from the field, have them cleaned, sorted and transported to the *mandi* and then loaded directly onto trucks sent by buyers. In transactions occurring after June, the trader would buy potato bonds from farmers, pay storage charges to release the potatoes from the cold store, then have them dried, sorted, colored and loaded into the buyers' trucks. (Most cold storage facilities are located near *mandis*.) They would incur storage costs, but no transport costs because these would have been incurred by farmers who had earlier placed them in the store.

[28]Cold stores charge a flat rate regardless of how long the potatoes are stored. Also, since farmers transport potatoes to *haats* that are on average 5 kilometres away from the village, whereas traders transport them to *mandis* on average 8 kilometres away, we make a proportional adjustment and revise traders' unit cost of transport downward accordingly.

[29]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.

from each other.[30] Sample villages in each block were randomly assigned to three groups of 24 villages each.[31] In two groups we conducted two different information treatments, while the third served as the control where no information was provided. In the two treatment groups, we delivered daily information about the prices in the one or two nearby *mandis* and the nearest city market. This was the average daily price at which traders at these *mandis* re-sold potatoes to large buyers from markets further away, collected by our field team from market "insiders", as described in Section 2.2. In our analysis below we refer to this as the *mandi* price.[32]

In the 24 private information villages, the price information was given 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 from the previous evening to each of these farmers via mobile phones that were given to them for the purpose of the project. To ensure that the phones were used only for the information treatment and did not improve the farmers' connectivity more generally, we asked the service provider to block outgoing calls from the phones, and changed the phone settings so 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.[33] In the private information villages, our telecaller records indicate that 62% of all calls were received, and in 92% of the villages at least one cell phone recipient took 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

[30] In informal interviews conducted in the area in 2006 before our sample was drawn, we found that in the regular course of events the typical farmer tended to travel no more than 10 kilometres out of the village. We therefore chose this distance to ensure that information would not spread from information villages to control villages.

[31] 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 most villages in a block have the same one or two *mandis* under their purview, this effectively ensures that under a given *mandi* there are villages randomly assigned to different information treatments.

[32] The volumes sold in our sample villages represent a very small proportion of the volumes traded in the *mandis*, so it is unlikely that the treatments affect the *mandi* price.

[33] Since we had access to the log of calls for each phone, we were able to check that our restrictions were effective.

fee, he wrote the price information on charts and posted them in three public places in each village.[34] Through random checks we were able to verify that the price information was posted publicly every day.

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.

The size of our sample is extremely small relative to the catchment area of a *mandi*, so that it is unlikely that our experiment changed the prevailing *mandi* prices. 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.[35]

3.1 Data

Our datasets come from surveys conducted with a stratified random sample of 24 potato-growing households in each of the 72 villages in our study.[36] The analysis in this paper is restricted to the 1545 sample farmers who planted either of the two main varieties (*jyoti* and *chandramukhi*) of potatoes in 2008.[37]

A production survey was conducted in February to collect data about the planting and cultivation of potatoes, including area planted, inputs used, output harvested, and allocation of harvest across different uses. The questionnaire also included questions about household demographics, assets, land ownership and credit. Next, a trade survey was

[34] If asked why they were giving out this information, telecallers and vendors were instructed to say this was for a research study, but that they did not know why this was being done or how the information could be used.

[35] Data on trade volume in large *mandis* were taken from the Government of India's Agmark dataset that reports daily price information in the large *mandis* in all states of India, for major agricultural crops.

[36] 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.

[37] These two varieties accounted for 70 and 20 percent, respectively, of the potatoes grown by all sample farmers in 2008.

administered to all sample households each fortnight between February and November. This collected information on each individual potato sale that the farmer had made in the previous fortnight: whether the potatoes were sold from the field, from home stores or cold stores, the variety and (self-reported) quality of potatoes, the quantity sold, place where the exchange took place, costs incurred by the farmer to undertake the sale, and the payment received.[38]

3.2 Descriptive Statistics

Table 6 shows a number of village and households characteristics by treatment groups, from data collected before the pilot information interventions began in June 2007. Villages were on average 8.5 kilometres away from the *mandis* whose price information we provided. About half the villages had a public telephone booth.

As Panel B shows, the average landholding size of sample households was 1.1 acres. Since we drew the sample from a list of households that had been identified as potato-farming households through a house-listing in 2006, it is unsurprising that in 2007 nearly all farmers in the survey reported planting potatoes (Panel C). Among these farmers, nearly 94% had planted the *jyoti* variety in 2007, and 10% had planted *chandramukhi*. The total area planted with potatoes in 2007 was 0.9 acres, and on average farmers harvested 7056 kilograms. They sold about 80 percent of these through the year, at an average price of ₹2.9. Nearly all of this was sold to traders in the village, and less than 1 percent was sold to traders located outside the village. As the p-values at the bottom of Table 6 show, across all household characteristics, the pre-intervention differences across treatment groups were jointly insignificant.

3.3 Effect of Information Treatments on Farmers' Price Information

In the fortnightly trade surveys, we asked farmers about the frequency with which they tracked prices in wholesale and retail potato markets and whom they gathered the price

[38] When payment was deferred, we followed up with the farmer in subsequent rounds to record the date and the amount of each installment received.

information from.[39]

To analyse whether the interventions changed farmers' price tracking behavior, we use the specification

$$y_{ivt} = \beta_0 + \beta_1 \text{Private Information}_v + \beta_2 \text{Phone Recipient}_{iv} + \beta_3 \text{Public Information}_v + \beta_4 X_{ivt} + \epsilon_{ivt} \tag{1}$$

where y_{ivt} measures the following dependent variables for farmer i in village v in fortnight t: whether he reports tracking wholesale prices (Table 7, 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. When we asked farmers to report their information source, we attempted to avoid "demand effects" and so did not offer a category indicating our intervention. The list of categories provided was, 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. Accordingly, we re-code the variable to an indicator of whether the information was received through the intervention, and then run a logit regression. 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 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, a dummy for the potato

[39] To guard against "demand effects" caused by survey questions that made our intervention salient, these questions were asked only to a randomly selected one-half of the sample. As a result we have these data at the fortnightly level for 853 farmers. As we show in Table A3 in the Appendix, the results reported in Tables 9 and 10 continue to hold even if we analyze only the subset of households that were *not* asked questions about their price-tracking behaviour.

variety (*jyoti* or *chandramukhi*), district, and the survey month. For convenience we report exponentiated coefficients in all three columns.

The results in columns 1 and 2 indicate that the intervention did work as planned: farmers who received the interventions were significantly more likely to say that they track market prices and, conditional on this, they had done so more recently. Column 3 shows that farmers in the information intervention groups were more likely to have received price information from a source that included the intervention. 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 7 shows that the intervention improved the precision with which farmers tracked prices. As we explained in Section 2, we match the prices that farmers reported with the actual prices in the markets that they reported tracking. The average sum of squares of the normalized error in reported price is a significantly lower 0.18-0.19 for intervention households than the 0.22 for control households. This represents a decrease of 13.9 percent in the mean absolute deviation from the true price.[40]

In what follows we develop a model where uninformed farmers bargain with informed middlemen in the village, with the outside option of selling to a trader at the local *haat*. We then discuss the predictions of the model and provide empirical evidence that supports them.

4 Theory: Bargaining with Asymmetric Information

Consider a context where a farmer F with an exogenous stock of potatoes Q meets a village trader VT who makes him a price offer p. VT can resell the potatoes at the wholesale market at price w. The farmer does not know the realization of w, and has beliefs over the realization of w represented by a prior distribution G on support $[\underline{w}, \bar{w}]$

[40]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 a market, 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*.

where $\infty > \bar{w} > \underline{w} \geq 0$.[41]

Let the quantity the farmer sells to VT at price p be denoted by $q \in [0, Q]$. The remainder $Q - q$ is consumed. The farmer's utility is increasing in sales revenue and consumption, represented as $W(pq + \beta U(Q - q))$ 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 utility function. VT's payoff is $(w - p)q$. We assume $\underline{w} > \beta U'(Q)$, so there are always gains from trade.

The game is structured so that the farmer first receives a price offer and then decides how much to sell, trading off increases in sales revenue against increases in self-consumption. Let $q(p)$ denote the farmer's supply function, which maximizes $pq + \beta U(Q - q)$. Let $\Pi(p) \equiv pq(p) + \beta U(Q - q(p))$. 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. We assume the supply function is weakly concave ($q'' \leq 0$), which includes the case of constant elasticity consumption utility ($U(c) = \frac{c^{1-\sigma}}{1-\sigma}$ when $\sigma > 0$ and different from 1; $\sigma = 1$ corresponds to log utility).[42]

In this formulation, higher price offers generate a supply response from the farmer on both the extensive margin by increasing the likelihood that the farmer agrees to sell a positive quantity, and on the intensive margin by increasing the quantity sold, conditional on selling something. When the value β of self-consumption is small the intensive margin becomes relatively less important, since the farmer tends to sell a larger fraction of his output at any given price. In the limiting case where $\beta = 0$, the farmer either sells the entire output Q or nothing at all; in other words, the intensive margin vanishes. The game is then equivalent to a standard bargaining game with an individual good. We extend the game to incorporate both margins so that we can match the empirical possibility that farmers may sell only part of their output. As we have seen in the previous section,

[41] We consider a finite support to avoid some technical complications.

[42] In the constant elasticity case, the supply function is $q(p) = Q - p^{-\frac{1}{\sigma}}$ if this is positive, and zero otherwise.

farmers typically sell close to all their output. It follows that many of our theoretical results will correspond to this case, i.e., where β is close to 0.

In the same spirit, we will assume that the composition of W and the profit function $W(\Pi(p))$ is concave. That is, farmers do not prefer increasing uncertainty of the farmgate price. This requires that W be concave enough to counteract the convexity of $\Pi(p)$. In the case where β equals zero, this requires W to be weakly concave, thereby including the case where the farmer is risk-neutral. Hence our main results depend on the assumption of at least a mild level of risk-aversion, with the required lower bound vanishing as β approaches zero.[43]

In the absence of any competition from other traders, VT will behave monopsonistically. We assume that if there are two or more village traders, they collude perfectly on the price offer. They select the monopsony price $m(w)$, which is the value of m that maximizes $(w - m)q(m)$. The concavity of q ensures this is a concave maximization problem; the monopsony price $m(w)$ satisfies $w = m + \frac{q(m)}{q'(m)}$. Since $q(p)$ is concave, the right-hand-side of this equation is strictly increasing; hence $m(.)$ is strictly increasing. Note that as β approaches zero, the monopsony price $m(w)$ approaches zero for every w.

However, village traders compete with traders located outside the village.[44] However, village traders are located closer to the farmers in their village, and so have a first-mover advantage: at the beginning of the game they are costlessly matched with the village farmer and can make a price offer to him. The farmer then decides whether to accept the offer, and conditional on accepting, chooses the quantity he will supply. If he rejects the offer, he can visit the market at a search cost of $s > 0$. For simplicity we assume that the village trader observes Q and s before he makes the offer.[45]

[43] 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. We shall see that such a natural lower bound does exist in the model: the farmer's reservation price in state $\underline{w}$.

[44] Our assumption that VTs and MTs cannot collude is justified by the greater distance between them and the attendant communication costs, lack of social capital and monitoring capabilities.

[45] Heterogeneity in harvested output and search costs across farmers in the village account for within-village heterogeneity in the offer price.

Market traders behave oligopolistically, and can each resell the good in the wholesale market at price w. If F sells to MT, he can get price $h(w)$, which is strictly increasing in w and satisfies $m(w) \leq h(w) < w$ for all w. The gap between w and $h(w)$ reflects the extent to which competition among market traders is imperfect.[46]

Suppose that F were informed about the realization of w. He would then accept a price offer v from VT at the first stage if and only if $v \geq M(w)$ where for any $w \in [\underline{w}, \bar{w}]$:

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

In other words, $M(w)$ is the farmer's outside option or reservation price in negotiating with VT when he knows the wholesale price is w. Clearly this function is strictly increasing and smaller than w. We assume that $\Pi(h(\underline{w})) > s$, ensuring that this reservation price is always well-defined and positive.

Of course the farmer does not know the realization of w *a priori*, but may be able to infer from VT's price offer. We now turn to the first stage game between VT and the farmer.

Our first key assumption is that the market traders exert enough competitive pressure on the village trader that F's reservation price $M(w)$ always exceeds VT's monopsony price $m(w)$: for all $w \in [\underline{w}, \bar{w}]$

$$M(w) > m(w) \tag{3}$$

In particular, we assume that as β approaches zero, the farmer's reservation price approaches some strictly positive and increasing function $M^*(w)$. In other words, there is some non-trivial competition between market traders in the case where the farmer's

[46] A specific example is where there are k market traders arranged equidistant from one another in a concentric circle of unit length, on which farmers are located uniformly, as in Salop (1979). With linear transport cost t per unit distance traversed by farmers, the result of simultaneous price competition between the market traders will yield a price of $h(w)$ which solves for h in the equation $w - h = [\frac{q'(h)}{q(h)} + \frac{k}{t}]^{-1}$.[47] Here $\frac{k}{t}$ is a parameter representing the competitiveness of the market outside the village in which farmers can sell. An alternative scenario which delivers the same conclusion is that there is a single trader in the market area, who is able to sell in the wholesale market at a price higher than w, and $h(w)$ is the monopsony price of this market trader.

supply responses exhibit no variation on the intensive margin: the farmer has a positive reservation price, which exceeds the VT's monopsony price (which equals zero when $\beta = 0$).

In what follows we use Weak Perfect Bayesian Equilibrium (WPBE) as the equilibrium concept. Formally, it is a price-offer and acceptance strategy $p(w), a(p)$ for VT and F respectively, with supporting posterior beliefs $G(.|p)$ of F obeying Bayes rule on the equilibrium path, where (with V denoting the composition of W and Π):

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: with probability $\alpha(w) \equiv a(p(w))$, F sells $q(p(w))$ to VT, and $q(h(w))$ to a market trader (upon incurring search cost s) otherwise. A necessary condition is that VT behaves optimally on the equilibrium path, given F's acceptance strategy, i.e., no type w of VT benefits from mimicking the offer of any other type w':

$$w' = w \quad \text{maximizes} \quad \alpha(w')[w - p(w')]q(p(w')) \tag{4}$$

This condition implies the following Lemma, which is useful in classifying the set of all possible equilibria into different categories.[48]

Lemma 1 *In any WPBE, the price offer function $p(.)$ is non-decreasing. If $p(.)$ is locally constant over some subinterval, the same is true for the acceptance probability $\alpha(.)$.*

[48] Here is the proof of this Lemma. First note that (4) implies that the expected sale $\bar{q}(w) \equiv \alpha(w)q(p(w))$ is non-decreasing, via a standard revealed preference argument. Next suppose that $p(.)$ is decreasing somewhere: $p(w') < p(w), w' > w$. Then type w would benefit from deviating from $p(w)$ to $p(w')$, as $w - p(w') > w - p(w)$ and $\bar{q}(w') \geq \bar{q}(w')$. Hence $p(.)$ must be non-decreasing. Now suppose $p(w') = p(w)$ for any $w' > w$. Then $\alpha(w') \equiv a(p(w')) = a(p(w)) \equiv \alpha(w)$.

4.1 Fully Revealing Equilibrium

An equilibrium is said to be *fully revealing* or separating if the associated price offer function $p(.)$ is strictly increasing. In this equilibrium F can infer the exact realization of w from the observed price offer. Panel (a) in Figure 3 illustrates this equilibrium.

Proposition 2 *When (3) 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 satisfies the differential equation*

$$\frac{\alpha'(w)}{\alpha(w)} = \frac{M'(w)}{w - M(w)}[1 - \frac{(w - M(w))q'(M(w))}{q(M(w))}] \tag{5}$$

The reasoning is straightforward. 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. This implies that any price offer below $M(\underline{w})$ is definitely rejected, and any price offer above $M(\bar{w})$ is definitely accepted. Any price offer v between $M(\underline{w})$ and $M(\bar{w})$ leads F to believe that $w = M^{-1}(v)$, and he is indifferent between accepting and rejecting it, making it optimal for him to randomize his acceptance decision. Finally, when the randomization satisfies condition (5), it is optimal for VT in state w to offer price $M(w)$ rather than any other price in the interval $[M(\underline{w}), M(\bar{w})]$.[49]

These assumptions above ensure that $\alpha(.)$ is strictly increasing. Hence offers will be rejected on the equilibrium path with positive probability. The equilibrium must satisfy the endpoint condition $\alpha(\bar{w}) \leq 1$. The greater the likelihood that the offers are accepted, the better off the village trader will be in every state w. The farmer is indifferent. Hence it makes sense to select the equilibrium corresponding to $\alpha(\bar{w}) = 1$.

[49]Selecting a price $M(\hat{w})$ would lead VT to earn an expected profit of $\alpha(\hat{w})[w - M(\hat{w})]q(M(\hat{w})$. (5) is the first-order condition corresponding to the condition that $\hat{w} = w$ is locally optimal. Standard arguments ensure that it is also globally optimal under the assumptions imposed above.

The randomization of acceptances in the fully revealing equilibrium according to (5) curbs VT's temptation to lower the offered price in state w below the farmer's true reservation wage $M(w)$ to the monopsony price $m(w)$. This temptation arises from condition (3) and the concavity of VT's payoff in the price. It is deterred by the lower probability of a trade occurring when the price is lower, which offsets the higher profit that VT would earn conditional on the offer being accepted. The possibility that trade will 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.

The separating equilibrium has the feature that F endogenously infers the true realization of the wholesale price. If this equilibrium were being played, farmers would be able to predict the wholesale price accurately. An exogenous provision of information would have no effect on F's ability to predict the wholesale price w, or the price $h(w)$ he would get by selling to a market trader. Nor would it affect the equilibrium price offer and trades. In equilibrium, F would reject VT's price offers and sell in the market with a non-negligible probability. These are all testable implications of the fully revealing equilibrium hypothesis.

The rationale for the "competitive pressure" assumption can now be explained. If inequality (3) is reversed for all w, there exists a fully revealing equilibrium where VT always offers the monopsony price $m(w)$.[50] Since the monopsony price function is strictly increasing, this equilibrium fully reveals the realization of the wholesale price to F. The reverse of condition (3) ensures that F will accept this offer for sure, since it exceeds the farmer's reservation price. Since in every state w the village trader attains his monopsony profit, this equilibrium will dominate any other equilibrium from his point of view (both *ex post* and *ex ante*). Hence this is the equilibrium that would naturally be selected by the village trader. In this case the model would predict that provision of information to farmers will have no effect at all.

[50] These are supported by off-equilibrium-path beliefs where any price offer below $m(\underline{w})$ leads F to be believe $w = \underline{w}$ with probability one, and any price offer above $m(\bar{w})$ leads F to be believe $w = \underline{w}$ with probability one.

4.2 Fully Non-Revealing Equilibrium (FNRE)

At the other extreme, an equilibrium that reveals no information at all to the farmer has VT offering the same price $\bar{p}$ irrespective of the realization of w, which is accepted with some (positive) probability $\bar{\alpha}$. When such an FNRE exists, and $\bar{\alpha} \in (0, 1)$, F must be indifferent between accepting and rejecting. Any such equilibrium would be Pareto dominated by an equilibrium involving the same pooled price $\bar{p}$, which F instead accepts with probability one. For this reason we focus on FNRE of this second kind.[51] The equilibrium is illustrated in Panel (b) of Figure 3.

Proposition 3 *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:*

(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 want to deviate from offering $\bar{p}$ to offering $M(\bar{w})$, when $M(\bar{w})$ is also accepted with probability one.

To show sufficiency, we assign the following off-equilibrium-path beliefs: If the price offer is $p \leq \bar{p}$, then F does not update his beliefs. If $p \geq \bar{p}$, then he believes $w = \bar{w}$. Condition (FP1) then implies that every type of VT is better off trading with F at price $\bar{p}$ than not trading with him, while F is indifferent between accepting and rejecting this offer given his prior beliefs. F will definitely reject any offer below $\bar{p}$ because it does not cause him to alter his beliefs about what he will get at the market, and he expects to do better by rejecting the offer and going to the market instead. Any price higher than $\bar{p}$ causes F to believe that $w = \bar{w}$, so VT would have to offer at least $M(\bar{w})$ to induce F

[51] There may also exist FNRE involving a pooled prices higher than $\bar{p}$ where F is strictly better off accepting than rejecting, and where the price offer is accepted with probability one. Such an FNRE cannot be Pareto compared with the one we focus on below, as F is better off while VT is worse-off. We ignore such FNRE in what follows, on the basis of the assumption that the equilibrium is selected to maximize VT's payoff.

to accept. Condition (FP2) ensures that type $\bar{w}$ does not benefit from such a deviation. This also implies that no other type of VT benefits from deviating, as their benefits would be smaller than they would be for type $\bar{w}$.

If we refine the equilibrium concept to require that F never plays a dominated strategy off the equilibrium path, then these conditions are also necessary. If VT were to offer him a price above $M(\bar{w})$, then accepting this offer strongly dominates the option of refusing it, since F would be strictly better off accepting the offer than rejecting it and going to the market, no matter what the realization of w is. With such a restriction, any price offer above $M(\bar{w})$ would be accepted for sure. Then condition (FP2) is necessary; the necessity of (FP1) is obvious.

In this equilibrium, the price $\bar{p}$ lies between $M(\underline{w})$ and $M(\bar{w})$: it is the reservation price for F when he is uncertain about the realization of w, and this uncertainty is represented by his prior beliefs. Hence it lies above the price $M(.)$ in the fully separating equilibrium in low w states, and lies below it in high w states. *Ex post* the farmer is better off in the pooling equilibrium when the wholesale price is low, and worse off when it is high. The farmer's *ex ante* welfare is, however, exactly the same in the two equilibria.

When we compare VT's payoffs in the fully revealing with the fully non-revealing equilibria we must consider a number of conflicting effects. In the FRE trade does not occur some of the time, but in the FNRE trades always take place. Conditional on the occurrence of trade, VT pays a lower price in the FNRE when w is high, and a higher price when w is low. Below we shall discuss which equilibrium generates higher profits for the village middleman *ex ante*.

Note also that the fully non-revealing equilibria will not exist whenever (FP1) or (FP2) fail to hold, whereas the fully revealing equilibrium always exists. An example of this is when $\underline{w}$ is 0 or sufficiently close to 0: the fixed price in a pooling equilibrium has to be positive, so has to be larger than $\underline{w}$; this cannot happen when $\underline{w} = 0$. When the wholesale price is sufficiently low, VT will be unwilling to pay F higher than the wholesale price. Alternately, if the upper bound $\bar{v}$ of the support of the wholesale price is sufficiently large while the pooling price is bounded, condition (FP2) will be violated: the fixed price will be too much below $M(\bar{w})$, and VT will offer a higher price than $\bar{p}$. So if the support of the wholesale price distribution is large enough, a fully non-revealing equilibrium will fail to exist.

However, when this happens, partially revealing equilibria generally exist. We describe these next.

4.3 Step-Function Partially Revealing Equilibrium

In a step-function partially revealing equilibrium (SPRE) the price offer is a step function. Panel (c) of Figure 3 illustrates this equilibrium. The support of w is partitioned into a set of consecutive intervals $I_i \equiv [w_i, w_{i+1}], i = 1, \ldots, n$ with $w_1 = \underline{w}, w_{n+1} = \bar{w}$ with VT offering 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 $W(\Pi(\bar{p}_i)) = E_{w|w \in I_i]}[W(\Pi(M(w)))]$, whence F is indifferent between accepting and rejecting it after learning that $w \in [w_i, w_{i+1}]$.

F updates his beliefs restricting the support to I_i when receiving an offer in the interval $(\bar{p}_{i-1}, \bar{p}_i]$. 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 $(\bar{p}_{i-1}, \bar{p}_i)$.

Proposition 4 *The following conditions are sufficient and (almost) necessary for a partially revealing equilibrium of the kind described above to exist. 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 want to deviate from offering* $\bar{p}_n$ *to offering* $M(\bar{w})$, *when* $M(\bar{w})$ *is accepted with probability one.*

Conditions (PP1) and (PP3) ensure that the two terminal types $\underline{w}, \bar{w}$ of VT are behaving optimally, given the acceptance strategy of F. Condition (PP2) ensures that the "corner" type at the intersection of two adjacent pooled intervals is behaving optimally. The single-crossing property then ensures that all other types are also behaving optimally. Conditions (PP1) and (PP2) are necessary for the two terminal types to pool at the end-point prices assigned to them, given the restriction on off-equilibrium-path play to undominated strategies. The necessity of the indifference condition (PP2) follows from the optimality of assigned strategies to intermediate types, which switches from $\bar{p}_i$ to $\bar{p}_{i+1}$ when w transits from slightly below w_i to slightly above.

A partially revealing equilibrium can be viewed as intermediate between a fully non-revealing and fully revealing equilibrium. The price offered by VT varies in a coarse way with the wholesale price: rising when the latter crosses over from one interval to the next, but not 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. VT with a wholesale price w near the bottom w_i of interval I_i will be tempted to drop the price offer from $\bar{p}_i$ to $\bar{p}_{i-1}$, since $\bar{p}_i$ must exceed $M(w_i)$, which in turn exceeds $m(w_i)$. The penalty for dropping the price is that the lower price will be accepted 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 probabilities of F accepting $\bar{p}_i$ and $\bar{p}_{i-1}$ is selected to ensure that condition (PP2) holds. This is analogous to (5) in a fully revealing equilibrium.

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 F's *ex ante* welfare is the same between the separating, fully non-revealing and partially revealing equilibria. How VT's ex ante welfare compares across these equilibria is not obvious. We turn to this issue next.

4.4 Comparing Profitability of Alternative Equilibria

We start by comparing the *ex ante* profits earned by VT between the selected FRE and FNRE.

Proposition 5 *If β is sufficiently small, VT earns higher ex ante profit in the FNRE defined above than any FRE.*

The proof of this (and of subsequent Propositions) is provided in the Appendix. The key force driving the result is that there exists the possibility that trade does not occur at all in the FRE. (This is necessary to ensure that the equilibrium is incentive compatible for VT.) By contrast, the FNRE always results in trade.

Besides this, the FRE results in a sale price that varies with the state, resulting in risk that neither VT nor F likes: VT is 'worse off *ex ante* since his profit function is concave in the price. Since F does not benefit from *ex ante* risk and 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). When F places a low value on personal consumption then this benefit is small, because the intensive margin is small. 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 higher 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.[52]

[52] If the FNRE does not exist, a similar result applies to 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 6 *Suppose $\beta = 0$, and an FNRE exists. Then the FNRE with a constant price offer $\bar{p}$ which is accepted with probability one, generates the highest ex ante profit amongst all WPBE allocations.*

The proof is based on the following idea. Any variation in price offers necessitates corresponding variations in acceptance probabilities to ensure incentive compatibility. The lower price must be accepted with a strictly lower probability. This trade breakdown can be avoided in a corresponding WPBE which involves a constant price offer. The reduction in price variability is mutually beneficial, and $\beta = 0$ implies that only the extensive margin matters for trade volumes. Hence, extending the range of price pooling allows VT to earn higher profits.

4.5 Effects of Information Provision

The effects of providing price information to farmers depends on the prevailing equilibrium. There will be no effect at all if the equilibrium is fully separating. 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 before the intervention.

It is easiest if we assume that 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 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. This is illustrated in Figure 4. The effects on the average price and quantity may thus be negligible.[53]

The results are also qualitatively similar when the equilibrium prior to the intervention is partially revealing. In such an equilibrium the farmer learns something from the price offer of VT, namely that w belongs to some interval I_i. As long as the external price signal generates a different information partition than the partition that the price offer created, it provides the farmer with new information, and thus affects the equilibrium allocation. The price offers in the new equilibrium then co-move more with the wholesale price.

Similar predictions obtain even 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.

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 $E_{w|w\in I_j}][W(\Pi(M(w)))]$, 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 preceding arguments 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.

[53] 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.

5 Experimental Results

We now turn to empirical tests of the theoretical predictions above.

5.1 Average Treatment Effects

Clearly at the weekly level, farmers solve a dynamic optimization problem to choose when and how much to sell. To analyze the weekly decisions of potato sales we would have to build a dynamic model taking into account the effect of the interventions on farmers' price expectations. Instead, in this section we take advantage of the fact that all potatoes must be sold within a year of being harvested, and abstract from the timing of sales within the year. Accordingly we simplify the empirical analysis by aggregating the data to the annual level. In Section 7 we examine storage and the inter-temporal allocation of sales.

We start by estimating the effect of the interventions on the farmers' sales and revenues. For each farmer we know each variety produced and sold, and the self-reported quality of potatoes in each transation. Our data thus measure how many kilograms of potatoes a given farmer sold in 2008, of a particular variety (*jyoti* or *chandramukhi*) and a particular quality (high or low), the gross revenue he received for these potatoes, and the net (of transport, handling and storage costs) revenue and price per kilogram he received. All regressions include dummies for the potato variety and quality, so that we can be assured that our results are not driven by farmers/traders responding to the intervention by adjusting either the variety or quality of potatoes that they sell/buy.

We evaluate impacts on annual quantity sold and the annual average of farmgate price. These are constructed by aggregating sales of any given variety-quality combination by a given farmer across the entire year. The average farmgate price is the ratio of aggregate revenues received to the aggregate quantity sold. This allows us to examine the predictions of the static bargaining model.[54]

[54] In Section 7 we show how the static model can be extended to incorporate these dynamic considerations, and subsequently investigate experimental impacts on storage.

Table 8 examines 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 price received, which is the ratio of the annual revenue received to the quantity sold.[55]

The identifying assumption here is that access to information is exogenous to farmer or *mandi* characteristics that might drive sales and revenues. This assumption is delivered by the randomization of the information treatment. Recall also from Table 6 that there are no significant differences in observable characteristics of the villages in the three treatment groups.

In alternative columns, *mandi* fixed effects are included to control for fixed differences at the *mandi* level.[56] 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.[57] Columns (3) and (4) show that there is also no significant average impact of the intervention on farmgate prices. Figure 2 provides a visual illustration of average weekly farmgate prices throughout the entire year corresponding to the information treatments and the control areas, plotted on the same graph as the corresponding *mandi* prices. In line with our regression results, there is no discernible difference between the different farmgate price series.

[55] Note that we discount the revenue for delays between the time of sale and the date when payment is received.

[56] Sample villages are mapped to the wholesale market whose catchment area they lie in, and in the information interventions, farmers/village vendors received the price information from that market. We define a *mandi* as a market-potato variety combination. For example, both *jyoti* and *chandramukhi* potatoes are traded at Bhandarhati market, which generates two *mandis* for the purposes of our analysis: Bhandarhati-*jyoti* and Bhandarhati-*chandramukhi*.

[57] 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 a lack of statistical power.

5.2 Heterogeneous Treatment Effects

The second prediction of the *ex post* bargaining model in Section 4 is that the intervention would increase the volatility of the quantity farmers sold and the price they received per kilogram. In other words, informing farmers about the *mandi* price would have increased the quantity they sold and price they received if the *mandi* price was high, and lowered it if the *mandi* price was low. Figure 5 plots the weekly farmgate prices in control and information villages against the *mandi* price, and graphically illustrates the increased co-movement in the data.

However to verify this prediction rigorously we use the regression specification:

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

where ν_{ikm} is the realized average price (or price shock) in the *mandi* m that this farmer's village is in the catchment area of. Once again, 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 was not correlated with variation in unobserved characteristics that might also affect the pass-through of prices. Note first that our experiment affected a small fraction of villages supplying to each market, so wholesale *mandi* prices were unlikely to be affected by our treatments.[58] As Table A2 shows, within 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

[58] 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. Also, the randomization took place before 2008 *mandi* prices were realised, and it follows from Section 2.3 that previous years' prices could not predict 2008 prices.

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, these differences will be controlled for in our regressions by the *mandi* fixed effects and so cannot be driving our results.[59] Below we also discuss a robustness check where we instrument for the *mandi* price with the city price.

The results in Tables 9 and 10 correspond to quantity sold and price per kilogram, respectively. The different columns in Table 9 use different specifications of the *mandi* price, different samples and different dependent variables. Focus first on Columns 1 through 4, where the full sample of 1545 farmers is included, and the total quantity of potatoes sold (in kilograms) is regressed on the intervention dummies and their interactions with the price regressor.[60] In column 1 the price regressor is the *mandi* price for each farmer-variety combination in the sample, averaged over those weeks in which the farmer sold the variety. Thus it represents the average resale price the trader could have received for potatoes he purchased from this farmer, which is the relevant price with respect to which we must measure the fluctuations in farmer outcomes.

As expected, we see a positive coefficient on the *mandi* price average, although it is not significant. The intercept effect on both the private and public information treatments are negative, and the interaction of the treatment with the average *mandi* price is 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 for a (phone non-recipient) farmer facing the 10th percentile of *mandi* price, the private information intervention caused sold quantity to go down by 1090 kg (or 28 percent of the control mean, significant at 10%), and the public information intervention caused it to go down by 1189 kg (or 31 percent, significant at 5%). For a farmer facing the 90th percentile of *mandi* price,

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

[60] Columns 5 and 6 will be discussed in Sections 6 and 7 respectively.

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 10 we calculate that for a (phone non-recipient) farmer facing the 10th percentile of *mandi* price, the private information intervention lowered the farmgate price by 18 paise (or 9%), whereas for a farmer facing the 90th percentile of the *mandi* price, it increased the farmgate price by 24 paise (or 12%).

The weights used in the farmer-specific *mandi* price average in Column 1 are endogenous to a farmer's decision to sell: if a farmer chooses to sell only when the actual *mandi* price is high, then this average is an overestimate of the true average *mandi* price the farmer was facing. This concern is addressed in Column 2 by instead using an average where the *mandi* prices in the different weeks of the year 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.

As a robustness check, column 3 presents estimates that use a different price regressor. Note that in the bargaining model, the information intervention has an effect because it informs the farmer that the *mandi* price is either higher or lower than the expected price. To test this idea directly, 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.[61] Note the intercept effect of the interventions now measure the effect of the treatment for

[61]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.

farmers selling in states where the expected *mandi* price equalled the actual (rather than a hypothetical price of zero, as in the previous specifications). According to the model, in this case the intervention can have no effect on the equilibrium. The interpretation of the interaction of the treatment with the slope coefficient remains the same: 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 on the private intervention is statistically significant. The effect of the price deviation (see the first row) is negative and significant, which is consistent with the model. 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.[62]

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*, then the exclusion restriction is satisfied. As we know from Section 2.3, there is considerable pass-through from the city price to the *mandi* price, and so it is unsurprising that the instruments are not weak.[63] As we see in Column 4, our results for the private information treatment are quantitatively and qualitatively similar when we use the instrumented *mandi* price instead of the actual.

[62]For example, suppose the farmer's "low" expected *mandi* price is 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, and then the intervention informs him that the true price is 3.2, this 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.

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

6 Testing Alternative Models

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

6.1 Contracts with Full Commitment

An *ex ante* contract would specify, for each possible realization of the wholesale price w as reported by the trader to the farmer, the quantity that the farmer sells and the price the middleman pays. This would allow the middleman and farmers to share price risk. The middleman margins could then represent risk premia on such insurance.[64] A risk-neutral middleman would insure risk-averse farmers perfectly, by paying them a constant 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. While this would be consistent with the observed lack of pass-through of the wholesale price to the farmgate price, it also implies that the experiment would have no impact at all. 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 in the equilibrium contract, 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, and cause the quantity traded to increase when the wholesale price is low, while there would be no

[64] This is a similar set-up as implicit wage-employment contracts where workers do not know the price at which employers sell the firm's product (Hart 1983).

effect when the price is high. 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 is clearly inconsistent with our experimental results, which show a significant negative impact on quantity traded in low-price states.

6.2 Contracts with Limited Commitment

Limited-commitment contracting models have been used to explain insurance and marketing contracts in a range of developing country contexts. In these models, the possibility of *ex post* moral hazard implies that some, but not all, of the price risk can be shared between the farmer and the middleman (Ligon, Thomas, and Worrall 2002, Blouin and Machiavello 2013, Machiavello and Morjaria 2015 and Saenger, Torero, and Qaim 2014). This is because the trader cannot prevent the farmer from selling in the outside spot market when the price there exceeds the trader's offer. Providing the farmer with information about market prices increases this hazard, thereby reducing traders' profits when the guaranteed farmgate price falls below the spot market price. If traders break even on average, then this limits their ability to sustain the losses from paying the guaranteed price when it falls below the spot market price. Hence providing farmers with information can unravel the insurance arrangement. The wholesale price would then pass through to the farmgate price more, and the farmer would sell less (resp. more) to the middleman when the market price was lower (resp. higher) than average.

However, this explanation is only valid if middlemen break even on average. If instead they earn positive profits on average, then the information treatment would have no impact in low market price states.[65] Then limited-commitment contracting requires that they earn losses in low wholesale-price states which are recouped through profits in high price states. However we see no evidence that farmgate prices are ever higher than the wholesale price (net of transport and storage costs). Figure 6 provides a non-parametric

[65] Note that since traders are informed about the market price anyway, the information treatment does not change their information and therefore does not change any incentive they may have to renege.

plot of the lower bound to trader gross margins against the *mandi* price, averaging for the year as a whole. Note that the gross margin lower bound is always positive, even at the bottom end of the wholesale price distribution. The mean gross trader margin was Rs. 2.24, ranging from a low of Rs. 1.04 in the first quartile of the *mandi* price, to a high of Rs. 4.06 in the fourth quartile. It is not possible to compute the corresponding distribution of the lower bound net margin averaged for the entire year, due to the asymmetry of costs between harvest and post-harvest seasons, but we can provide these separately for the harvest and post-harvest seasons. During the harvest, the lower bounds of the trader net margin at the four quartiles of the *mandi* price were Rs 0.71, 0.83, 2.13 and 3.48 respectively. Hence, traders earned a sizeable margin in the harvest season even when *mandi* prices were very low. Post-harvest, these were Rs -0.71, -0.08, 1.33 and 2.60 respectively for the four quartiles. Since these are lower bounds, we cannot infer the sign of the trader's net margin at the bottom two quartiles of *mandi* price during the post-harvest season. Hence there is no evidence that traders earned net losses in low *mandi* price states, and some positive evidence (from the harvest season) that they earned positive profits in low price states.

6.2.1 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 middlemen (who may be differentiated on non-price dimensions) select their respective prices (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. This 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 prior to 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.[66]

Finally, models with costly search frictions à la Salop and Stiglitz (1977) predict that if information interventions decreased farmers' search costs, then price dispersion would decrease across farmers and sales locations. The increased arbitrage that is facilitated might also raise average farmgate prices. Jensen (2007) and Goyal (2010) confirmed these predictions in Indian contexts where producers can sell directly in wholesale or retail markets. We have argued above that in our context farmers cannot sell directly in the wholesale or retail market. Moreover, since middlemen and farmers live in close proximity, the search costs between them tend to be negligible. For this reason, we do not expect any effects on price dispersion either across different farmers within a village, or across prices in neighboring markets that farmers can sell outside the village.[67] Table 11 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 Extension of the Model to a Dynamic Setting, and Effects on Storage

Our theoretical model considered a static context where farmers can sell their output at a single date, after which all unsold stocks are consumed. In practice, farmers have the option of spreading sales between multiple dates, from the time of the harvest until the end of the year when the cold stores have to be cleared. In such a dynamic setting, farmers have more options: instead of selling either to village or market traders at a given date, they can choose to sell at a later date. This makes farmer supply more elastic with

[66] The key difference in our model is that the village and market traders move sequentially rather than simultaneously, combined with the asymmetry of resale price information.

[67] However, in one respect the two kinds of models make a similar prediction (which we do observe): a narrowing of the gap between farmgate and *haat* prices.

respect to price offers than in the static context, which affects village traders' strategic pricing decisions. Also, improved access to information increases the pass-through of wholesale prices to farmgate prices, which could benefit farmers by allowing them to time their sales better, and thus change their returns from storage.

Below we provide a simple extension of our bargaining model to a two period context. This extension shows conditions under which the results of the static model continue to hold. It will become evident how the results can be extended to incorporate an arbitrary (finite) number of dates when trading can occur. The model also helps explain how storage decisions of farmers are affected by the information treatments, which we subsequently examine empirically.

7.1 The Bargaining Model with Two Dates

To simplify the analysis, we abstract from the self-consumption option by assuming that $\beta = 0$. There are two dates $t = 1, 2$.[68] Date 1 corresponds to the harvest date. The harvest output is normalized to 1, while q_t denotes the fraction of output sold at $t = 1, 2$. All output must be sold by the end of the year. Since there is no value for self-consumption, $q_2 = 1 - q_1$. The farmer's prior belief about the wholesale price w_1 at date 1 is represented by the distribution function $G_1(.)$ on support $[\underline{w}, \bar{w}]$. In the presence of year-specific shocks, the prices at the two dates could be correlated; $G_2(w_2|w_1)$ denotes the conditional distribution over date 2 wholesale price w_2, conditional on w_1. At each date t, the farmer's outside option of selling to market traders outside the village is represented by the same reservation price function $M(w_t)$. The farmer now has an additional outside option: instead of selling at $t = 1$, he can store the crop and wait to sell at $t = 2$. The wholesale price w_2 at date 2 is measured net of storage costs, so in what follows we can abstract from such costs.

Farmers are credit-constrained, resulting in payoff function $W(y_1) + \delta W(y_2)$ where

[68] The model can be extended in a straightforward fashion to more than two dates, using backward induction; the equilibrium will involve the village middleman making a non-revealing price offer at every date which equals the expected reservation price of the farmer.

y_t denotes sales revenue realized at t, $W(.)$ is strictly concave and strictly increasing satisfying $W'(0) = \infty$, and $\delta \in (0, 1)$ is a discount rate. Middlemen are risk-neutral, and can smooth incomes perfectly across the two dates by borrowing and lending at constant interest rate i.

We proceed via backward induction. Consider the subgame at the beginning of date 2, following the sale of q_1 at price p_1 at date 1. Since $t = 2$ is the last date, the analysis of the static model applies to trades at this date. The equilibrium in the absence of any information provision to farmers is a FNRE where the farmer sells $1 - q_1$ to the village trader at a price of $p_2^* = E[M(w_2)|p_1]$.

Now consider how the farmer will react to a price offer p_1 at date 1. If the equilibrium offer is non-revealing, a necessary condition for this offer to be accepted is that $p_1 \geq E[M(w_1)]$. If this condition holds, the farmer will decide to sell q_1^* which maximizes $W(p_1 q_1) + \delta W(p_2^*(1 - q_1))$, and is thereby characterized by the first order condition

$$p_1 W'(p_1 q_1^*) = \delta p_2^* W'(p_2^*(1 - q_1^*)) \tag{6}$$

This generates a supply function where $q_1 = q_1^*(p_1; p_2^*)$ over the range $p_1 \geq E[M(w_1)]$, and $q_1 = 0$ if $p \leq p_1$. The comparative statics of q_1^* with respect to p_1 are ambiguous in general, because of conflicting wealth and substitution effects. The wealth effect is represented by the concavity of $W(\cdot)$, causing $W'(p_1 q_1^*)$ to be decreasing in p_1 for any q_1^*. The p_1 term that pre-multiplies $W'(\cdot)$ on the left-hand side of (6) represents the substitution effect. The net effect depends on the curvature of $W(\cdot)$. If $W = \frac{y^{1-\theta}}{1-\theta}, \theta > 0, \neq 1$, then q_1 increases (resp. decreases) in p_1 depending on whether θ is smaller (resp. larger) than one. In what follows we assume that $\theta > 1$, so the wealth effect dominates. Then the farmer supply function is backward-bending.[69]

Continuing to restrict attention to non-revealing price offers, the (constant) price offer

[69]If $\theta = 1$ then the supply function is inelastic. Note that the backward-bending feature is only with respect to harvest vis-a-vis post-harvest supply, not with respect to aggregate yearly supply.

that maximizes VT's *ex ante* profits solves the following problem: choose p_1 to maximize $(E[w_1] - p_1)q_1^*(p_1; p_2^*) + \frac{E[w_2]-p_2^*}{1+i}[1 - q_1^*(p^1; p_2^*)]$, subject to $p_1 \geq E[M(w_1)]$.

If $E[w_1 - M(w_1)] < \frac{E[w_2]}{1+i} - p_2^*$, the village middleman would want to purchase nothing at $t = 1$. There would then be a shortage of potatoes on the market at date 1, causing w_1 to rise until this inequality is reversed. In equilibrium there must be positive purchases by middlemen at both dates, and $E[w_1 - M(w_1)] \geq \frac{E[w_2]}{1+i} - p_2^*$ must hold. Then it is profitable for the village trader to purchase at $t = 1$, and offer $p_1 \geq E[M(w_1)]$. Since the farmer supply function is backward-bending, it is not profitable for the village trader to offer a price above $E[M(w_1)]$. Hence the VT will offer $p_1 = E[M(w_1)]$ at $t = 1$, just as in the static model.

The same justification for restricting attention to non-revealing price offers applies here as in the static model: the village middleman wants to lower the price offer as much as possible as long as the farmer agrees to sell to him at $t = 1$, which requires $p_1 \geq E[M(w_1)]$. In separating equilibria trades will not occur with some probability, which will result in reduced profit for traders.

Now consider the effect of information interventions. As in the static model, there will be greater pass-through of the wholesale price to the farmgate price at every date. For simplicity consider information in the form of a binary signal at each date σ_t which is either low (L) or high (H). The signal is low when w_t lies between $\underline{w}$ and $\hat{w}$, and is high when $\hat{w}$ lies in $(\underline{w}, \bar{w})$. The farmgate price p_t^k at each date will depend on the signal realization $k = H, L$; it will satisfy $p_t^L < p_t^* < p_t^H$ where p_t^* denotes the pre-intervention price. The proportion of output the farmer sells at $t = 1$ will now satisfy the first order condition

$$p_1^k W'(p_1^k q_1) = \delta[\alpha_k^H p_2^H W'(p_2^H(1 - q_1) + (1 - \alpha_k^H)p_2^L W'(p_2^L(1 - q_1)] \tag{7}$$

where α_k^H denotes the probability that F assigns at $t = 1$ (after observing signal $k = H, L$) that the date 2 price will be high. Under the plausible assumption that the wholesale price shocks at the two dates are positively correlated, $\alpha_H^H \geq \alpha_L^H$.

If w_1 and w_2 are independent, the right-hand-side of (7) is independent of k, and the farmer will sell a larger proportion when the first period signal is low compared to when it is high. But if they are positively correlated, then a low date 1 signal also makes the farmer more pessimistic about the post-harvest price, thus raising the value of storage. The net result is then ambiguous: the farmer may sell less at date 1 when the wholesale harvest price is low. In general, the model makes no prediction about how harvest sales will vary with the wholesale price at the time of harvest.

When we compare the storage decision of farmers without and with the intervention, there is the additional source of ambiguity caused by the fact that better informed farmers face a higher pass-through from the wholesale price to the farmgate price in the post-harvest season; this increases the risk of storing the potatoes. While the precautionary demand for saving increases the amount stored, risk-aversion reduces it. The model therefore places no restriction on how storage varies with the information treatment, or with the harvest wholesale price.

Column 6 in Table 9 examines how our information treatment affected the proportion of output sold immediately following harvest. We see that in the absence of the intervention, the proportion sold at harvest time decreased in the harvest time wholesale price, as well as in the land owned by the farmer. Both findings are consistent with our model above, on the plausible assumption that farmers who own more land are less credit constrained.[70] The information interventions have a negative effect on the proportion of output sold at harvest time; this effect is significant only for those who received the phones in the private information treatment villages. There were no significant interactions of the information treatments with the harvest time wholesale price.

Thus the information treatment had a significant effect only on the small proportion

[70]It is easily verified that with $W(y) = \frac{y^{1-\theta}}{1-\theta}$, the proportion of output sold at the harvest in control villages satisfies $\frac{q_1}{1-q_1} = \frac{1}{\delta}(\frac{p_1}{p_2})^{\frac{1}{\theta}-1}$. Given $p_2 \geq p_1$, it follows that q_1 is increasing in θ. Wealthier farmers will have a lower θ, hence they will sell a smaller proportion during the harvest.

of farmers who received the information directly through the distributed cell phones. These farmers were induced to store 17% more of their harvest output. For all other treated farmers, the point estimate of the effect on storage is small (3%) and statistically insignificant. In 2008, prices did not rise after the harvest period and so the returns to storage turned out to be low. This contributed to the limited average treatment effect on the yearly average farmgate price for phone recipients. For all other treated farmers, the effects on storage were insignificant. Thus we do not believe that impacts on storage account for the pattern of observed treatment effects; instead the evidence suggests they were driven by the bargaining effects highlighted in the static model.

However, one general point is reinforced: the effect of the information treatments depends on the particular realizations of *mandi* prices. The static model already predicted that the treatment effects would be positive (resp. negative) if wholesale prices were high (resp. low). This pattern was reinforced when we took dynamic effects on storage into account. However, we also found that storage effects are unlikely to account for the observed heterogeneity of treatment effects for the majority of treated farmers. This rationalizes our focus on a static context in our empirical analysis in Section 5 above.

8 Conclusion

We have reported the results of a field experiment where market price information was provided to potato farmers in the state of West Bengal in eastern India. Unlike other settings where producers have direct access to markets, large transactions costs and regulations prevent farmers in our context from selling to wholesale buyers directly, so that they must rely on local trade intermediaries (Cohen 2013). Our findings are novel in that they show that price fluctuations may not pass through from traders to farmers even in a setting where they bargain with each other over spot transactions. Moreover, our predictions about sales in low price states contrast with the predictions of conventional models based on risk-sharing arrangements. These results lead us to infer that in our setting insurance premia are unlikely to account for the large middleman margins; instead they reflect barriers to entry into the trading business, and farmers' limited access to markets. Our results also suggest that in the context of the West Bengal potato supply chain, improving farmers' access to price information is unlikely to have the positive outcomes on farmgate prices that we have seen elsewhere. Instead researchers and policy-makers need to focus on understanding why these farmers lack access to markets.

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Table 1: Self-reported contracting between trader and farmer

	with oldest continuous supplier of potatoes (1)	with newest supplier of potatoes (2)
Prior agreement existed	0.326	0.246
	(0.039)	(0.036)
Nature of agreements:		
Explicit agreement on the quantity of purchase	0.056	0.042
	(0.019)	(0.017)
Explicit agreement on the price	0.014	0.035
	(0.010)	(0.016)
No explicit agreement but implicit understanding about price	0.146	0.070
	(0.030)	(0.022)
Understanding that farmer would not sell to anyone else	0.215	0.141
	(0.034)	(0.029)
Understanding that trader would buy from farmer	0.118	0.113
	(0.027)	(0.027)
Farmer free to sell to anyone	0.236	0.155
	(0.036)	(0.030)
Trader under no obligation to buy from farmer	0.049	0.014
	(0.018)	(0.010)
Trader dictated date of harvest	0.007	0.007
	(0.007)	(0.007)

Data are for survey questions where we asked a random sample of traders operating in our sample villages about the kinds of agreements they had with the farmers they bought from. Standard errors in parentheses. Traders could select multiple options, but they also could report none of the options provided, so there is no reason to expect the columns to add to any particular total.

Table 2: Barriers to Entry into the Potato Trading Business

	Mean (1)	Median (2)
Capital (Rs.)	94471.83	50000
	(8640.44)	
Apprentice experience in phoria business (years)	3.65	3.5
	(0.14)	
Experience in potato cultivation (years)	3.64	3
	(0.191)	
Farmers one needs prior contact with (number)	32.03	25
	(2.57)	
Traders one needs prior contact with (number)	6.39	5
	(0.525)	
Different markets one needs to have contacts in (number)	3.575	3
	(0.142)	

Data are for survey questions where we asked a random sample of traders operating in our sample villages about the arrangements a hypothetical potential entrant into the trader business would need to make.

Table 3: Analysis of Variance of Weekly *Mandi* Prices

Source	MSE (1)	F (2)
Year	5117.97	8106.78***
Period	36.20	57.35***
Year × Period	87.43	138.49***
Mandi	81.57	129.2***
Mandi × Year	26.55	42.06***
Observations	*2845*	
R-squared	*0.92*	

An observation is a *mandi*-week for weeks 13 and beyond in years 2007, 2008, 2011 and 2012. $^{***}: p < 0.01, ^{**}: p < 0.05, ^{*}: p < 0.1$.

Table 4: 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 5: Lower Bounds on Average Middleman Margins

	Harvest period (1)	Post-harvest period (2)
Traders sold at	4.81	4.83
Traders bought at	2.22	2.11
Traders' gross margin	2.59	2.72
Transport costs	0.39	-
Handling costs	0.35	0.45
Storage costs	-	0.91
Traders' net margin	1.85	1.36

The price that traders sold at is the average *mandi* price per kilogram we collected through market "insiders". The price that traders bought at is the average price per kilogram farmers in our survey received when they sold to traders. Both averages are computed by using the distribution of quantities sold in the sample in different weeks as weights. All transactions costs are averages per kilogram of costs incurred by farmers when they sold at *haats*, and are considered to be upper bounds to the costs traders would incur in order to buy and sell. Transport costs are adjusted upwards to account for the fact that traders transport potatoes longer distances on average than farmers do. Further details of the calculations are in footnotes 27 and 28.

Table 6: Baseline Characteristics of Sample Villages and Households

	Total (1)	Control (2)	Private info. (3)	Public information (4)	Public v. Control (4)-(2)	Private v. Control (3)-(2)	Public v. Private (4)-(3)
Panel A: Village Characteristics							
Distance to *mandi* (km)	8.52	8.93	8.558	8.071	-0.859	-0.372	-0.487
	(0.700)	(0.882)	(1.648)	(1.014)	*0.526*	*0.843*	*0.802*
Public telephone	0.514	0.667	0.417	0.458	-0.208	-0.250*	0.042
	(0.059)	(0.098)	(0.103)	(0.104)	*0.152*	*0.085*	*0.777*
Factory/mill	0.556	0.458	0.667	0.542	0.083	0.208	-0.125
	(0.059)	(0.104)	(0.098)	(0.104)	*0.573*	*0.152*	*0.387*
Metalled road	0.361	0.250	0.458	0.375	0.125	0.208	-0.083
	(0.057)	(0.090)	(0.104)	(0.101)	*0.361*	*0.137*	*0.568*
Panel B: Household Characteristics							
Land owned (acres)	1.114	1.123	1.079	1.144	0.021	-0.045	0.065
	(0.0305)	(0.0497)	(0.0503)	(0.0584)	*0.889*	*0.675*	*0.653*
Cultivator's age (yrs)	48.84	49.5	48.92	48.05	-1.451	-0.577	-0.874
	(0.404)	(0.682)	(0.682)	(0.737)	*0.304*	*0.644*	*0.385*
Cultivator's schooling (yrs)	6.989	6.597	7.01	7.4	0.803	0.413	0.39
	(0.116)	(0.204)	(0.201)	(0.192)	*0.062*	*0.356*	*0.333*
Panel C: Potato Cultivation							
Planted potatoes	0.995	0.987	0.998	1.00	0.013**	0.011*	0.002
	(0.002)	(0.005)	(0.002)	(0.00)	*0.047*	*0.099*	*0.316*
Planted *jyoti*	0.935	0.949	0.954	0.901	-0.048	0.005	-0.053
	(0.006)	(0.010)	(0.009)	(0.013)	*0.195*	*0.844*	*0.172*
Planted *c'mukhi*	0.096	0.051	0.111	0.126	0.076	0.06	0.016
	(0.007)	(0.010)	(0.014)	(0.015)	*0.123*	*0.192*	*0.763*

continued on next page

Table 6 – Continued

	Total (1)	Control (2)	Private information (3)	Public information (4)	Public v. Control (4)-(2)	Private v. Control (3)-(2)	Public v. Private (4)-(3)
Area planted (acres)	0.904	0.822	0.851	1.051	0.229	0.029	0.2
	(0.058)	(0.087)	(0.048)	(0.151)	*0.243*	*0.833*	*0.27*
Harvest (kg)	7056.3	6396.6	7186.7	7641.4	1244.84	790.14	454.70
	(224.5)	(282.7)	(376.7)	(496.8)	*0.429*	*0.432*	*0.778*
Fraction of harvest consumed	0.046	0.049	0.041	0.048	-0.001	-0.009**	0.007*
	(0.002)	(0.003)	(0.002)	(0.004)	*0.81*	*0.01*	*0.07*
Fraction of harvest sold	0.798	0.811	0.783	0.801	-0.01	-0.028	0.018
	(0.006)	(0.009)	(0.010)	(0.010)	*0.764*	*0.4*	*0.601*
Average price	3.935	3.879	3.844	4.093	0.214	-0.035	0.249*
	(0.023)	(0.036)	(0.040)	(0.039)	*0.126*	*0.832*	*0.094*
Frac. sold to trader	0.986	0.989	0.986	0.984	-0.005	-0.002	-0.003
	(0.003)	(0.005)	(0.005)	(0.006)	*0.62*	*0.766*	*0.781*
Frac. sold at market	0.008	0.006	0.01	0.009	0.003	0.004	-0.001
	(0.002)	(0.004)	(0.005)	(0.004)	*0.725*	*0.498*	*0.846*
Panel D: Telecommunications							
Has landline phone	0.238	0.231	0.23	0.254	0.023	-0.001	0.023
	(0.011)	(0.019)	(0.019)	(0.020)	*0.797*	*0.992*	*0.774*
Has cellphone	0.332	0.323	0.316	0.361	0.039	-0.006	0.045
	(0.012)	(0.021)	(0.021)	(0.023)	*0.65*	*0.941*	*0.551*
Panel E: Source of Price Information							
Trader	0.712	0.795	0.68	0.659	-0.136*	-0.115	-0.021
	(0.012)	(0.018)	(0.021)	(0.022)	*0.064*	*0.172*	*0.804*
Only trader	0.455	0.487	0.443	0.434	-0.053	-0.043	-0.009
	(0.013)	(0.023)	(0.022)	(0.023)	*0.525*	*0.663*	*0.916*
Market	0.177	0.148	0.186	0.197	0.049	0.037	0.012
	(0.010)	(0.016)	(0.017)	(0.019)	*0.48*	*0.61*	*0.876*
Friends	0.131	0.15	0.141	0.101	-0.049	-0.009	-0.04
	(0.009)	(0.016)	(0.015)	(0.014)	*0.34*	*0.89*	*0.525*
Media	0.06	0.081	0.055	0.044	-0.037	-0.026	-0.011
	(0.006)	(0.012)	(0.010)	(0.010)	*0.266*	*0.482*	*0.749*
Doesn't search	0.005	0.004	0.006	0.004	0.000	0.002	-0.001
	(0.002)	(0.003)	(0.003)	(0.003)	*0.949*	*0.779*	*0.839*
Test of joint significance (χ^2 p-value)					*0.283*	*0.255*	*0.408*

Table 7: Effect of Interventions on Farmers' Tracking Behavior and Precision of Information

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 $> \chi^2$	*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 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 8: Average Treatment Effects of Information Interventions on Farmer Sales and Price Received

	Quantity sold (kg)		Net price received (Rs/kg)	
	(1)	(2)	(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 in a week of a particular variety and quality. 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 9: 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 when the farmer sold potatoes of that variety. In column 2 it is the relevant *mandi* price averaged over all weeks in the year, 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 10: Heterogeneous Treatment Effects of Information Interventions on Price Received

Sample:	Full sample	Full sample	Full sample	Full sample	Farmers with long-term relationships
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
	(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 9 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 11: Effects of Information Intervention 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	-0.106	0.239	0.241	0.070
	(0.154)	(0.253)	(0.152)	(0.248)	(0.386)	(0.262)
Public information	-0.049	0.306	0.009	0.373	1.235	0.351
	(0.161)	(0.288)	(0.161)	(0.275)	(0.818)	(0.318)
Constant	0.648***	2.543***	0.671***	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*	*0.079*	*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. Variety dummies are included. 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. Standard errors in parentheses are clustered at the village level.

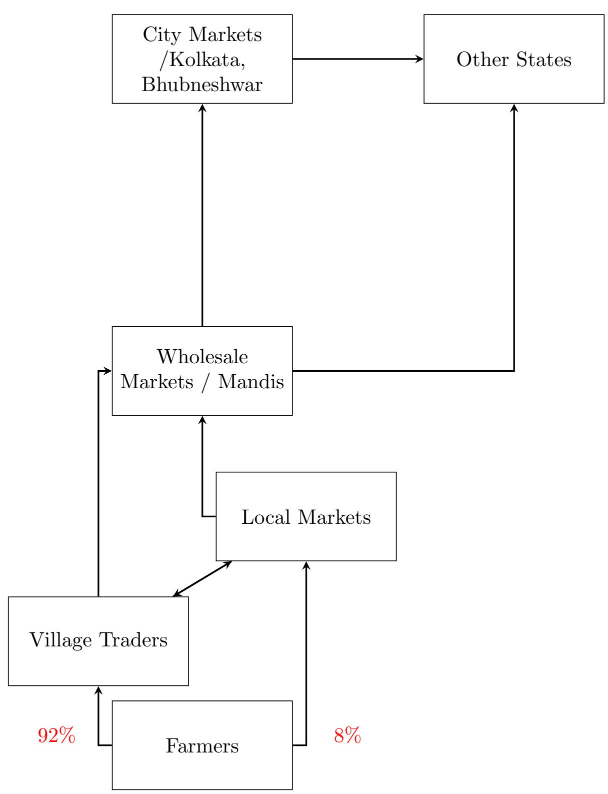


Figure 1: Potato Supply Chain

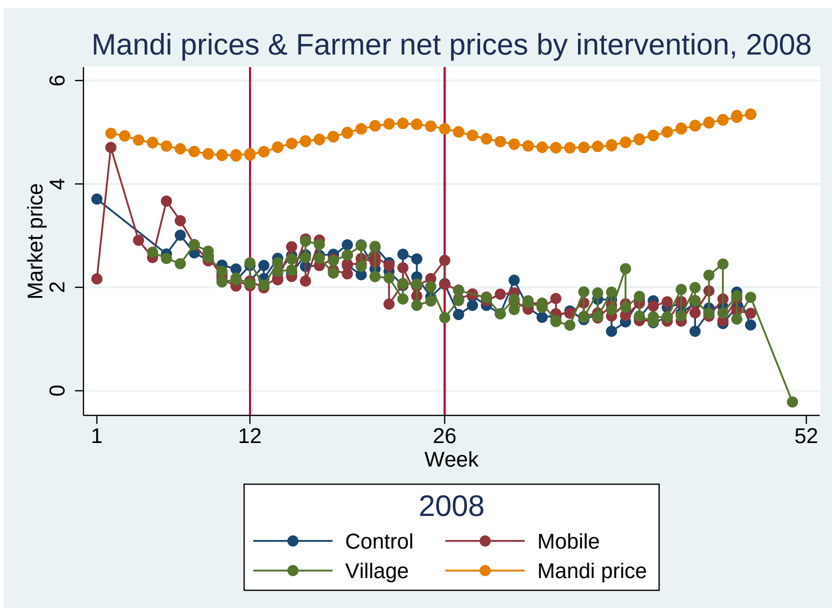
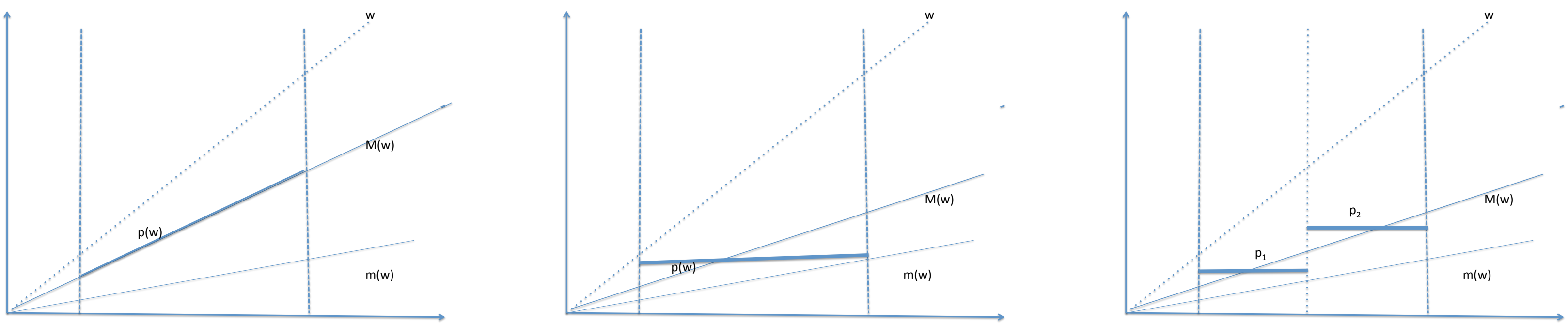


Figure 2: Intervention Impacts



(a) Fully Revealing Equilibrium

(b) Fully Non-revealing Equilibrium

(c) Partially Revealing Equilibrium

Figure 3: Equilibria in the Bargaining Model

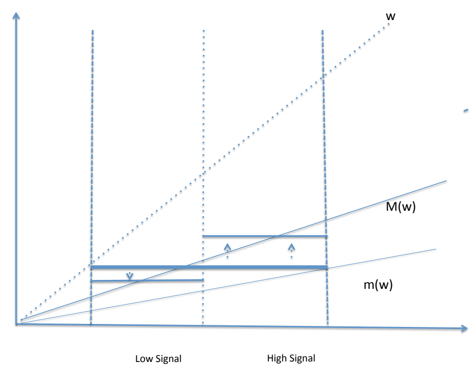


Figure 4: Effect of Intervention on Fully Non-revealing Equilibrium

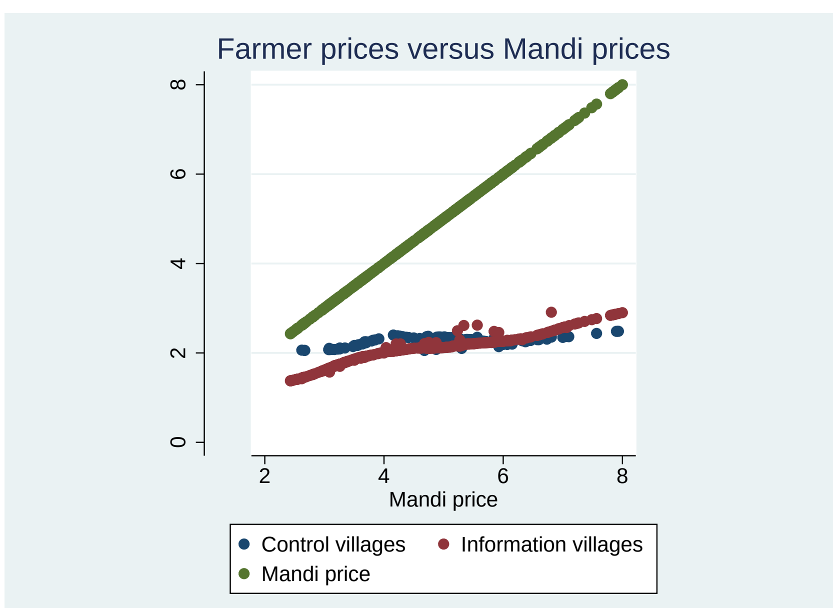


Figure 5: Co-movement of Farmer Prices with *Mandi* Prices

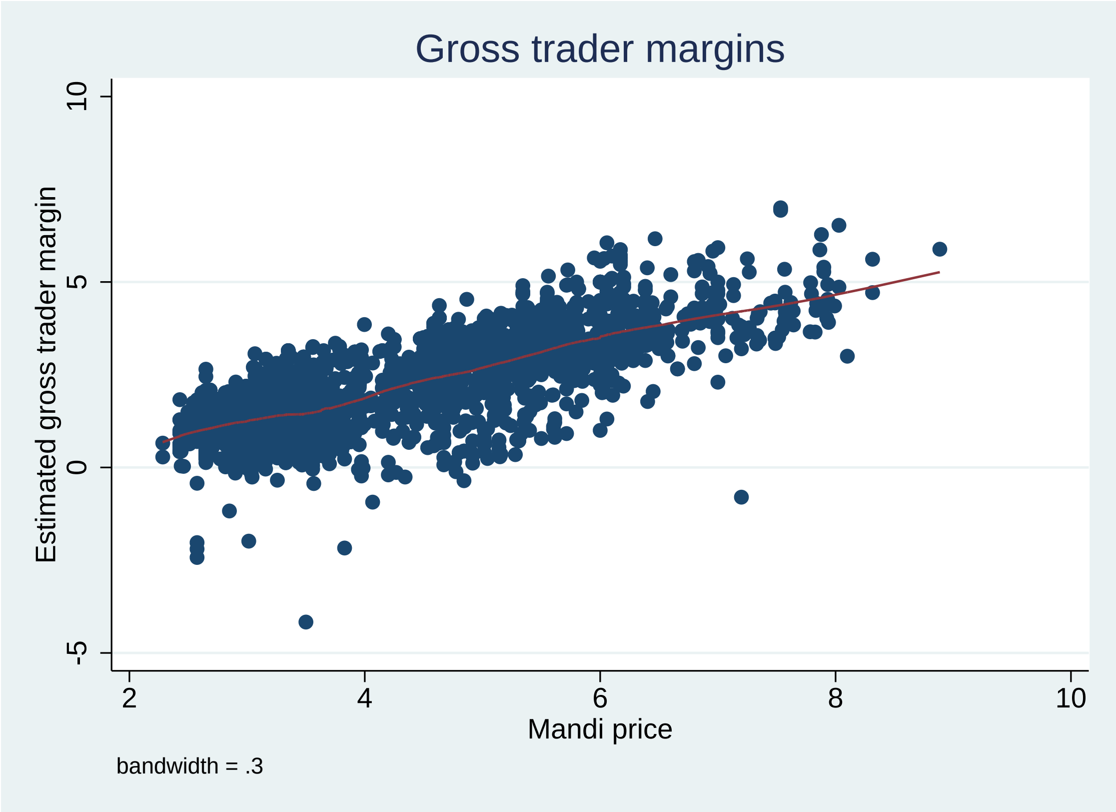


Figure 6: Gross Trader Margins

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

Theory Appendix

Proof of Proposition 5: The *ex ante* profit of VT in the FNRE and FRE respectively given consumption benefit parameter β are given by

$$\Pi^N(\beta) \equiv E[(w - \bar{p})q(\bar{p}; \beta)] \tag{8}$$

$$\Pi^R(\beta) \equiv E[(1 - \alpha(w; \beta))\{w - M(w; \beta)\}q(M(w; \beta); \beta)] \tag{9}$$

Asβ approaches 0, $M(w; \beta)$ approaches $M^*(w) \in (0, w)$ and $m(w; \beta)$ approaches 0 for any w. Moreover, $q(p; \beta)$ approaches Q for all $p > 0$. And $\alpha(w; \beta)$ approaches $\alpha^*(w)$, where

$$\frac{\alpha^{*'}(w)}{\alpha^*(w)} = M^{*'}(w)\frac{1}{w - M^*(w)} \tag{10}$$

so $\alpha^*(.)$ is strictly increasing, with $\alpha^*(\bar{w}) = 1$.

Since $W(\Pi(\bar{p})) = E[W(\Pi(M(w))]$, the concavity of $W(\Pi(.))$ implies via Jensen's inequality that

$$\bar{p} \leq \bar{M}(\beta) \equiv E[M(w; \beta)] \tag{11}$$

Hence

$$\Pi^N(\beta) \geq E[(w - \bar{M}(\beta))q(\bar{p}; \beta)] \longrightarrow QE[(w - M^*(w)] \tag{12}$$

as $\beta \to 0$.

On the other hand,

$$\Pi^R(\beta) \longrightarrow QE[(1 - \alpha^*(w))\{w - M^*(w)\}] \tag{13}$$

which is strictly smaller than the lower bound to the limiting FNRE profit given at the right end of (12), since $1 > \alpha^*(w)$ for all $w < \bar{w}$. This completes the proof of Proposition 5.

Proof of Proposition 6: Any other WPBE involves offer strategies in which the set of types can be partitioned into intervals $W_i = (w_i, w_{i+1}), i = 1, \ldots, n$ with $\underline{w} = w_1, \bar{w} = w_{n+1}$ such that it is either strictly increasing or locally constant over W_i. As long as this equilibrium is not an FNRE, the price offer must be strictly lower on intervals $W_1, \ldots W_{n-1}$ than at w_{n+1}. To ensure incentive compatibility it must be the case that offers will be accepted with probability strictly less than one on intervals $W_1, \ldots W_{n-1}$. Hence over these intervals, F must be indifferent between accepting and rejecting.

The same will be true in interval W_n if the price function is strictly increasing over W_n. If it is constant over W_n, and is accepted with probability one, F is at least as well off accepting it rather than rejecting it. If F is strictly better off, the offer p_n can be reduced slightly to p'_n and will still be accepted with probability one. This will raise VT's profits when the type of VT is in W_n. Some types from other intervals $W_{n-1}, W_{n-2}, ..$ may now be induced to deviate to offering p'_n. So we can rearrange the intervals so that W_n is expanded (all the types offering p'_n) while other intervals below are shrunk or dropped to take account of the types who chose to deviate to p'_n from some $p_i, i = n - 1, ..$ F's beliefs must now be readjusted accordingly. Since the set of types that are now added to W_n correspond to lower values of w, this only serves to lower F's reservation price. Hence it will continue to be optimal for F to accept p'_n with probability one. This argument shows that we can find another WPBE generating higher profit for VT, if F is strictly better off from accepting p_n to rejecting it. Hence we can limit attention to WPBE's in which F is indifferent between accepting and rejecting every price offer that is made on the equilibrium path.

Let P denote the set of elements i of the partition over which the price offer is constant (denoted $\hat{p}_i$), and S the remaining set of elements over which the price offer is strictly increasing. Let F_i denote the prior probability of W_i. Then the expected profit of VT in the non-FNRE is

$$\Pi^R \equiv Q[\sum_{i \in P} F_i \alpha_i [\hat{w}_i - \hat{p}_i] + \sum_{i \in S} \int_{w_i}^{w_{i+1}} \alpha(w)[w - p(w)] dG(w)] \tag{14}$$

where $\hat{w}_i$ denotes the mean of w conditional on $w \in W_i$, and $\alpha(w), p(w)$ denote the acceptance probability and price over intervals in S. Since the equilibrium is not FNRE, there exists at least one element i over which acceptance probabilities are strictly less than one. Hence

$$\begin{aligned} \Pi^R \quad < \quad & Q[\sum_{i \in P} F_i [\hat{w}_i - \hat{p}_i] + \sum_{i \in S} \int_{w_i}^{w_{i+1}} [w - p(w)] dG(w)] \\ & = Q[\sum_{i \in P} F_i [\hat{w}_i - \hat{p}_i] + \sum_{i \in S} F_i [\hat{w}_i - \hat{p}_i]] \\ & = Q[\sum_{i} F_i [\hat{w}_i - \hat{p}_i]] \\ & = Q[\hat{w} - \hat{p}] \end{aligned}$$

where $\hat{p}_i$ for $i \in P$ denotes the mean price offer conditional on $w \in W_i$, and $\hat{p}$ denotes the unconditional mean price offer.

Now consider the FNRE with a constant price offer $\tilde{p}$ satisfying

$$W(\Pi(\tilde{p})) = E[W(\Pi(M(w))] \tag{15}$$

Since for every W_i, F is indifferent between accepting the price and rejecting it, the right-hand-side of (15) equals the expected payoff of the farmer in the original equilibrium, given by $E[W(\Pi(p(w))]$. Hence

$$W(\Pi(\tilde{p})) = E[W(\Pi(p(w))]. \tag{16}$$

Since $W(\Pi(.))$ is concave, it follows that $\tilde{p} \leq \hat{p}$. Hence using (15), the expected profit in the original equilibrium is smaller than expected profit $Q[\hat{w} - \tilde{p}]$ in the FNRE. This concludes the proof of Proposition 6.

A Additional Tables

Table A1: Potato Cultivation by Sample Farmers, 2008

	Mean/(SE)
Area planted (acres)	0.663
	(0.017)
Quantity harvested (kg)	6553.3
	(177.2)
Pct sold from the field	0.428
	(0.009)
Pct stored at home	0.165
	(0.007)
Pct stored in cold store	0.285
	(0.008)
Pct spoiled	0.0262
	(0.001)
Quantity sold (kg)	5962.6
	(184.5)
Pct sold at market	0.0786
	(0.006)
Pct sold to 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 trader	2.156
	(0.016)
sold at market	2.896
	(0.050)
Net price received (Rs/kg)	
sold to trader	2.03
	(0.016)
sold at market	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)

Table A2: Tests of balance in *mandi* characteristics by relation to median *mandi* price

	Hugli			W. Medinipur		
	Below median	Above median	p-value	Below median	Above median	p-value
	(1)	(2)	(3)	(5)	(6)	(7)
Retail price (Rs/kg)	4.91	4.91	*1.000*	7.78	7.78	*1.000*
	(0.00)	(0.00)		(0.00)	(0.00)	
Distance from retail market (km)	0.51	0.45	*0.262*	3.22	3.23	*0.882*
	(0.02)	(0.05)		(0.05)	(0.05)	
Average yield (kg/acre)	10.58	10.08	*0.074*	9.80	9.05	*0.202*
	(0.09)	(0.27)		(0.29)	(0.47)	
Agricultural wages for males (Rs/day)	56.04	53.4	*0.638*	52.74	55.56	*0.675*
	(3.52)	(4.20)		(4.16)	(4.37)	
Pct. households with landlines	0.07	0.10	*0.022*	0.03	0.06	*0.589*
	(0.00)	(0.01)		(0.02)	(0.05)	
Pct. villages with metalled roads	0.60	0.58	*0.856*	0.12	0.07	*0.640*
	(0.09)	(0.11)		(0.08)	(0.07)	
Pct. villages with factories/mills	0.56	0.54	*0.896*	0.56	0.42	*0.521*
	(0.11)	(0.11)		(0.13)	(0.13)	

Standard errors in parentheses.

Table A3: Heterogeneous Treatment Effects of Interventions on Households Not Asked About Price Tracking Behavior

	Quantity Sold	Net Price
	(1)	(2)
Price regressor	-1.3	0.212***
	(322.4)	(0.072)
Private information	-2,944.8*	-0.428
	(1,678.5)	(0.314)
Private information × Price regressor	544.5	0.121*
	(381.9)	(0.071)
Phone	2,609.0	-0.096
	(2,029.4)	(0.446)
Phone × Price regressor	-479.9	0.027
	(445.9)	(0.102)
Public information	-3,972.9**	0.358
	(1,676.5)	(0.328)
Public information × Price regressor	766.8**	-0.074
	(376.9)	(0.077)
Land	2,002.4***	-0.076***
	(201.2)	(0.018)
Constant	3,520.8**	1.396***
	(1,408.7)	(0.319)
Observations	*1,139*	*1,139*
R-squared	*0.405*	*0.472*
Mean DV	4060	2.033
SE DV	348.5	0.0453

Notes for Table 9 Column 1 apply. The sample is restricted to farmers who were randomly chosen not to be questioned about price-tracking behavior.