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

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Abstract

We study middleman margins, trading mechanisms and the role of asymmetric information about prices between potato farmers and local trade intermediaries, in West Bengal, India. Farmers in randomly chosen villages were provided daily information on prices in neighboring wholesale markets where the traders re-sell the potatoes. We estimate a lower bound on average trader margins (net of transport and storage costs) in 2008 ranging from 34 to 89% of farmgate prices. Information provision did not change average margins, but caused traded quantities to shrink (resp. expand) significantly for farmers facing low (resp. high) wholesale prices. The evidence is inconsistent with *ex ante* contracts between farmers and traders. It is consistent with a model of *ex post* bargaining, in which lack of direct access to wholesale markets depresses farmers' outside options and prevents informational interventions from benefitting them. (JEL Codes: O120, L140)

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1 Introduction

Large middleman margins that restrict prices received by poor farmers in less developed countries (LDCs) are often believed to constrain growth and poverty reduction in these countries. Large gaps between retail and producer prices for commodity exports from LDCs have been documented: e.g., the average margin between consumer prices in the US and world (wholesale) prices for beef, coffee, oil, rice, sugar and wheat increased by 83 percent between 1975 and 1994 (Morisset (1998)). Moreover, there is limited pass-through of world price increases to ultimate producers. Fafchamps and Hill (2008) find that when the export price of Ugandan coffee increased in 2002-03, wholesale prices also rose, and the gap between wholesale and farmgate prices widened. McMillan, Rodrik and Welch (2002) claim that no more than 40-50 percent of the increased cashew export prices in the 1990s accrued eventually to farmers in Mozambique.

These facts motivate the study of the role of middlemen in agricultural marketing and trade. What margins do they earn, and what are the underlying determinants of these margins? What is the nature of trading or contractual mechanisms between middlemen and farmers? How are these affected by the opening of export markets or rising export prices? While there have been a number of recent theoretical analyses of these issues (Antras and Costinot (2010, 2011), Bardhan, Mookherjee and Tsumagari (2010), Chau, Goto and Kanbur (2010)), there is not much micro-level empirical evidence on the role of middlemen, and why they earn the margins that they do.

In this paper we focus on the role of asymmetry of price information between farmers and local middlemen. Commodity trades are often conducted in bilateral personalized transactions rather than organized markets. This can cause large informational asymmetries about prices in downstream markets. Farmers' limited access to downstream price information could conceivably account for large middleman margins and the low pass-through of these prices to farmers. If middlemen have more accurate information than farmers about prevailing downstream prices, they could strategically under-report these prices to justify paying farmers a low price. If this is true, improvements in information technology or governmental provision of market price information to farmers would increase farmgate prices, pass-through as well as quantities traded. This could be low-hanging fruit for policy makers: disseminating price information to farmers using cellphones or other low-cost IT-based interventions could generate higher incomes for poor farmers and stimulate agricultural production in a cost-effective manner.

A supplementary question concerns the nature of trading mechanisms between farmers and intermediaries. In the absence of formal insurance markets or opportunities for farmers to hedge risks through futures markets, it is conceivable that intermediaries provide informal insurance to farmers via implicit long term contracts. This may be a possible explanation of observed middlemen margins which could represent associated insurance premia, and low pass-through of price changes. To what extent can this explanation account for observed margins and pass-through?

These questions motivated us to conduct a field experiment which provided market price information to potato producers in two districts of West Bengal, a state in Eastern India. Potatoes are a leading cash crop in these districts, constituting an important source of incomes for farmers. These farmers sell most of their crop to local traders who in turn resell them in neighboring wholesale markets. Transactions between farmers and local traders, as well as between the local traders and wholesale buyers occur after private bilateral negotiations, rather than through auctions or organized markets with publicly posted prices. There is a high incidence of repeat transactions with the same trading partner, due to concerns about the reliability of partners' product quality and timeliness of payments. These create a supply chain below the wholesale level which resembles a strict vertical hierarchy. Wholesale buyers purchase potatoes in bulk only from local traders whom they trust, and delegate to them the task of procuring potatoes from farmers and ascertaining their quality. Farmers cannot sell directly to wholesalers, and they do not have direct access to information about the price at which local traders sell to wholesalers. Our experiment provided daily wholesale and retail market price information via cell phones and via public notice-boards in two different treatments in 24 villages each, with a third set of 24 villages serving as a control in which no information was provided.

Since we collected data about the price at which farmers sell their potatoes as well as the price that local traders receive when they sell to wholesale buyers, we are able to estimate the margins earned by local traders and also use the information intervention to test the predictions of models of different trading mechanisms between farmer and local trader. This allows us to shed some light on the nature of contracting in this context, with implications for the type of market reforms that could improve farmer incomes and agricultural production.

Our main results are summarized as follows.

(a) Local traders earn significant margins: Our calculations suggest that 15-40 percent of the wholesale market price accrues to the local trader. Farmgate prices were approximately 44 percent of this price. (The rest was accounted for by transport, handling and storage costs). This implies a middleman margin of at least 34% of the farmgate price. For potatoes purchased at harvest time and immediately re-sold, the average margin was closer to 89%.[1] Pass-through is also limited: only 6% of weekly changes in retail prices of potatoes are passed through to farmgate prices.

(b) Provision of wholesale market price information to farmers has a zero average treatment effect on farm-gate prices and quantity traded.

(c) Information treatment effects are heterogenous with respect to the realization of wholesale prices: the quantity sold falls (resp. rises) significantly when the wholesale price is low (resp. high). Farmgate prices tend also to move in the same direction as traded quantities, though these are not as precisely estimated.

(d) These findings are inconsistent with *ex ante* contractual arrangements between farmers and local traders. The reason is that asymmetric information in the presence of such contracting would generate a screening distortion leading to inefficiently less or smaller trades. Such distortions arise from the need to ensure incentive compatible announcements of the downstream price by the middleman to the farmer, analogous to models of underemployment in labor contracts (Hart (1983)). Reducing asymmetric information between middlemen and farmers would then cause traded quantities to rise, contrary to what we find empirically. An implication of this is there cannot be any *ex ante* risk-sharing.

(e) Instead, we show that the results are consistent with a model of *ex post* bargaining between traders and farmers with a form of limited competition among traders, in a manner which is consistent with field observations.[2]

[1] Our findings echo the conclusions of 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.

[2] In our model, the trader makes a take-it-or-leave-it price offer to the farmer after observing the wholesale price, and the farmer responds with a quantity that he wishes to sell. The only outside option farmers have is to thereafter take their produce to a local market and sell to a different trader who will also resell it in the wholesale market. This mirrors the process described by farmers and traders we have interviewed in the field, and is consistent with farmers' reports of where and to whom they sell. The key restriction is that farmers are unable to sell directly to wholesale buyers. Wholesale buyers we interviewed confirmed they are unwilling to negotiate small trade volumes directly with a large number of farmers. They delegate procurement to a small number of local trade intermediaries who act as 'aggregators', a role which involves checking the quantity and quality of potatoes supplied, and a willingness to accept delayed payments by the wholesaler due to liquidity constraints.

In summary, we infer that traders in our study earn large margins for two reasons: there is limited competition among traders, and farmers have almost no direct access to wholesale or retail potato markets. In the presence of these barriers, providing farmers with price information is unable to change the prices they receive, because it does not change their outside options.[3]

These features of the West Bengal potato supply chain stand in contrast to certain other settings where increased access to market price information has changed prices received by producers or traders because it allows them to engage in arbitrage. In South Indian fishing markets, Jensen (2007) finds that the introduction of cellphone technology allowed fishermen to learn the prevailing price before choosing which coastal markets to steer their boats to, significantly reducing price dispersion. Aker (2010) finds that mobile phones allowed grain traders in Niger to search across multiple markets, reduce price dispersion in grain prices by 10 to 16 percent, and improve trader and consumer welfare. Goyal (2010) finds that the introduction of free internet kiosks showing daily agricultural information (and the entry of a new corporate buyer) significantly increased average market prices for soybeans in Central India.

In all of these contexts, there are no intermediaries between producers and markets, and so information could directly affect producer decisions to arbitrage across different markets. By contrast, in our context producers cannot sell directly to wholesale or retail markets, and are compelled to sell to intermediaries. As a result, the effects of the information intervention are likely to be different. In line with this, Fafchamps and Minten (2012) find that providing farmers in Maharashtra with free access to information about market prices (as well as weather and crop advisories) had no significant effects on the average prices they earned. They argue this is because most farmers sold exclusively to a nearby wholesale market, and speculate that high transport costs or lack of trustworthy buyers in other markets may have prevented them from exploiting arbitrage opportunities they may have received information about.

We therefore focus on the nature of the trading mechanism between farmers and intermediaries, and the effects of altering the extent of information asymmetry between them. This resembles more closely the nature of vertical relations between upstream and downstream firms, or between manufacturers and retailers in studies of industrial organization, rather than analysis

[3] We abstract from possible effects of information provision on the extent of competition between intermediaries, mainly because there is no evidence of any systematic differences in trader concentration between treatment and control villages.

of search or price dispersion in decentralized markets.[4] Our analysis shows that the effects of altering asymmetries of information depends fundamentally on the nature of the trading mechanism between farmer and trader. Our approach provides a novel way of making inferences about the nature of vertical trading mechanisms, which may be useful in other industrial organization contexts.

The paper is organized as follows. Section 2 describes the context of potato production and trades in West Bengal. In Section 3 we present the *ex ante* contract model and their predictions about the effect of reducing information asymmetry. Section 4 describes the experiment conducted and the nature of data collected. Section 5 tests the predictions of the *ex ante* contract model in the data and shows that this model is definitively rejected. Section 6 then presents the *ex post* bargaining model and shows that it can explain the patterns in the data. Section 7 concludes.

2 The Empirical Context: Potato Production and Sale in West Bengal, India

The state of West Bengal accounts for about 40 percent of the total volume of potatoes produced in India. It is the leading cash crop in West Bengal in terms of value added per acre (Bardhan and Mookherjee (2011, Table 4)), and has the highest acreage planted among all winter crops in the two districts in our study, Hugli and West Medinipur. Potatoes are planted between October and December, and harvested between January and March. Farmers have a long time horizon over which they can sell their harvest: they can be sold immediately at the time of harvest, or, if placed in home stores they can be sold up to two or three months later. Alternatively they could be placed in cold stores, and then the farmer has the option to sell them any time until October, when the new planting season begins. However in this paper we abstract from decisions about the timing of sales within the year, and study the returns from sale of potatoes over the entire year.

The local supply chain is organized as shown in Figure 1. Our baseline survey shows that in 2006 (before our intervention began), sample farmers sold 98 percent of their produce to local intermediars (known as *phorias*), other larger traders or moneylenders. They sold only 1 percent of potatoes directly at the market. *Phorias* aggregate purchases from local farmers and

[4] However, we are not familiar with any empirical industrial organization literature that studies the effect of varying asymmetric information between vertical trading partners.

sell them up the chain to wholesale buyers. Wholesalers in turn sell to traders in city markets or in neighboring states. Potatoes from Hugli district are usually sold ultimately in Kolkata retail markets, and in states in Northeastern India. Potatoes from West Medinipur are sold in the Bhubaneswar market in neighboring Odisha, or in the southern state of Andhra Pradesh. As we shall see below, price movements in these city retail markets that are the destination of these potatoes explain much of the movement in local wholesale prices that we observe.

2.1 Local Farmer-*Phoria* Trades and Market Structure

The principal focus of this paper is on trades occurring between farmers and *phorias*, and in this section we provide further detail about this layer of the supply chain. In 2008, our sample farmers sold approximately 8 percent of their (sold) potatoes in small local markets (*haats*) located outside the village.[5] In these transactions, the farmer transported his potatoes to the *haat* and sold them to an intermediary operating in that market. Whereas the average distance from a village to the nearest *mandi* was 8.5 kilometres, the average distance to the neighboring *haat* was 5 km. The remaining 92 percent of potatoes were sold within the village to a local *phoria*, larger trader or moneylender, who picked up the potatoes directly from the farmer and transported them to the neighboring *mandi* or cold store.

Phorias are either entrepreneurs selling to wholesalers on a case-by-case basis, or are commissioned agents of wholesalers entrusted with the responsibility of sourcing potatoes. Most *phorias* have a network of farmers from whom they buy on a regular basis – farmers with a track record of selling potatoes of uniform quality and not cheating them by mixing potatoes of different grades into their sacks, or putting less potatoes into the sack than they claim. *Phorias* appear to exert effort to ensure that the farmers they buy from supply good quality potatoes: in surveys of 144 *phorias* we and our other co-authors have conducted in 2012, 56 percent of *phorias* reported that before they started buying from their oldest regular supplying farmer, they checked the person's reliability.[6] The aspect checked most commonly was the quality of his potatoes. However the moral hazard problem is two-sided, because payments to farmers are often delayed. This is because *phorias* themselves must wait a few weeks after selling to wholesalers before receiving full payment. Sixty percent of *phorias* surveyed told us that at the outset of a rela-

[5] This fraction is higher than the 1 percent reported for 2006.

[6] These surveys were conducted as part of a separate but related project, described in Maitra et al. (2012).

tionship their oldest supplying farmer had checked their reliability: 51 percent had checked the *phoria's* credit-worthiness and 70 percent had checked the size of their sales network. The relationship between the *phorias* and wholesalers is similarly marked by importance of trust and reputation. Each wholesaler purchases from a set of *phorias* on the basis of bilateral transactions. Eighty-eight percent of the *phorias* reported that they checked the reliability of their longest purchasing wholesaler, with the aspects checked most commonly being the size of the sales network, credit-worthiness and stability of demand.

These numbers indicate the importance of trust and reputation in these networks, and shed light on the nature of the role that *phorias* play as middlemen between the farmers and wholesalers. On average, each wholesaler buys from 7-8 *phorias* in each village, although there is considerable variation across wholesalers. The number of farmers selling in any village ranges from 150 to 200 farmers. In interviews wholesalers confirmed they do not negotiate transactions directly with farmers because it 'is not worth their while' to negotiate small trade volumes with so many individual farmers.

Nevertheless, nearly all *phorias* tell us that they do not have any explicit *ex ante* contractual agreements with particular farmers about quantity or price. They also do not have any exclusive dealing clauses. However, given the pervasiveness of repeat transactions with the same partners, this leaves open the possibility of implicit contracts. It is not uncommon for potato purchases by *phorias* to be bundled with credit market transactions, or transactions of other inputs: about 31 percent of *phorias* told us that they had provided inputs or credit to their newest supplying farmer; this number was higher at 47 percent for the oldest supplying farmer. Yet, the *phorias* and farmers also told us that none of them were bound to sell to the trader who had provided these inputs or credit, but instead were free to sell to someone else and to use the proceeds to repay the loan.

The mean number of *phorias* operating in any given village is 9.5, with the modal value being 6. Farmers have a choice among different *phorias* within the village to sell to. The median market share of a *phoria* in our sample is 5%, and the median Herfindahl index is 0.2. In this sense the market for potato sales to *phorias* within a village is not highly concentrated. Nevertheless the majority of *phorias* reported discussing price offers with other *phorias* in the same village, and checking with farmers the prices at which they had recently sold to other *phorias*. It is quite possible that *phorias* within a village tacitly collude on prices they pay farmers. It is less likely that they can collude with *phorias* operating in other villages or at local markets. Farmers perceive their main outside option when responding to a price offer from a village *phoria* on any given day as taking their potatoes to these local markets to try to sell to some other *phoria* located in that market (besides the possibility of waiting to sell later in the year). These facts will motivate our *ex post* bargaining model with limited competition between a local *phoria* and another one located at a local market.

2.2 Price Information of Farmers

Since transactions between the *phorias* and wholesalers are bilateral, information about what price the *phoria* receives in the *mandi* is not in the public domain. Farmers therefore do not have the opportunity to learn directly about prices at which the *phorias* are able to resell their potatoes. Their main source of information is the *phoria* whom they deal with most frequently: 75% of the farmers in our control villages reported they learnt about wholesale prices from the *phoria*. Note that telecommunication facilities are available: 51% of the villages in our sample had telephone booths, 23% of the households in control villages reported they had landline phones and 32% had mobile phones in 2007. Note also that 33 percent of the farmers reported that they found out about prices at which farmers were selling to other *phorias* in neighbouring markets. When asked in informal interviews why they could not find out the price at which *phorias* were selling in the wholesale market, they reported having no contacts in the wholesale market who would be willing to give them this information.

Consistent with the idea that farmers do not know the *mandi* price, when farmers in control villages were asked in the fortnightly surveys in 2008 what the price in the neighboring market had been recently, the prices they reported did not match prevailing prices at which *phorias* were selling in the *mandi*, but the price that the farmers expected to receive if they were to make a sale to a *phoria* in a local market (*haat*). The average price they reported (Rupees 2.57 per kg) was much closer to the gross price at which farmers sold in *haats* (Rupees 2.55 per kg), and substantially different from the average gross price received by *phorias* in the wholesale market (Rupees 4.85 per kg).

Our estimates of the mandi price are generated by price reports submitted to us by ‘insiders’ in the wholesale markets, who happened to either be employees of the wholesale traders buying from the *phorias*, or their commission agents, who happened to observe the trades at the wholesale level. They were persuaded by our investigators to give us this information on a daily basis, in return for a monthly fee.

2.3 Margins Earned by *Phorias*

When they sold to *phorias*, farmers received an average price of Rupees 2.18 per kg (if sold in the harvest season) or Rupees 2.30 (if sold in the post-harvest season). Thus there is a substantial gap between the price at which *phorias* sell (Rupees 4.85) and the price at which they buy potatoes. To what extent can this gap be explained by the transport, handling and storage costs they incur? Although we do not (yet) have estimates of these costs directly from the *phorias*, we can obtain estimates for the unit costs from data provided by farmers who incurred these costs themselves. Under the plausible assumption that *phorias* benefit from economies of scale in transport and handling in a way that farmers with smaller and less regular shipments do not, these estimates are likely to be upper bounds for the unit costs actually incurred by *phorias.* The mean unit costs (per kg) incurred by sample farmers who sold potatoes at a *haat* are as follows: transport costs Rs. 0.23/0.28 in the harvest/post-harvest period, handling and other costs Rs. 0.35/0.45, and storage costs Rs. 0.91 (incurred only if the sale occurred in the post-harvest period). Note that cold storage charges are a flat rate irrespective of the duration for which the potatoes are stored. We make an adjustment to the unit cost of transport: since farmers tend to transport and sell potatoes only in *haats* which are on average 5 kilometres away from the village whereas *phorias* tend to transport them to *mandis* which are on average 8 kilometres away, we make a proportional adjustment and revise *phorias'* unit cost of transport to Rs. 0.39/0.48.

This allows us to estimate a lower bound on the average middleman margin in 2008 as

$$\text{Middleman margin} = \begin{cases} \text{Rs.}4.85 - 2.18 - 0.39 - 0.35 = \text{Rs.}1.93 & \text{per kg when sold at harvest time,} \\ \text{Rs.}4.85 - 2.30 - 0.48 - 0.45 - 0.91 = \text{Rs.}0.71 & \text{per kg when sold in the post-harvest period.} \end{cases}$$

This calculation generates a lower bound for middlemen margins in 2008, net of costs, ranging from 15 to 40 percent of the wholesale market price, and 34 to 89 percent of the farm-gate price, depending on which part of the year they sold the crop in.

2.4 Price Variations

The key premise in this project is that farmers have less information about prices prevailing in the *mandi* than *phorias* do, and thus the information intervention should have decreased this asymmetry. We now discuss the evidence in favor of the hypothesis of a significant informational asymmetry.

While we have described anecdotal evidence from farmers who say they do not have anyone to contact for this information, farmers may be able to infer the prevailing mandi price from past experience and their observations of past prices, the farmgate prices they are being offered, or from the realization of local potato harvests. How much information about the current mandi price can be extracted from these observations?

To examine this, we look at spatial and temporal price patterns. Over time there is substantial volatility of wholesale prices at the mandi. The average price per kilogram (across all *mandis* in our sample) was Rs 7.60 in the second half of 2007, Rs 4.85 in 2008, Rs 10.72 in 2011 and 12.37 in the first half of 2012. A significant part of these large year-to-year differences are explained by corresponding differences in city prices, which depend on market demand shocks in city markets, and demand and supply shocks in other states to which potatoes are exported. Supply shocks in West Bengal as a whole could also play some role. The first column of Table 1 shows a pooled cross-section time-series regression of average yearly mandi price for the second half of 2007, 2011 and the first half of 2012, on corresponding averages of the price in the relevant city market (Kolkata for Hugli, Bhubaneswar for West Medinipur), distance to this city, interactions between distance and city price (representing transport costs) and local potato yields (from output data for sample farmers located in each mandi area), and a variety of local village infrastructure measures. The regression coefficient on the city price is 1.12, significant at 1%, while none of the other variables are significant. Hence supply shocks in the local areas where our study was conducted did not play any role.

Prices also fluctuate substantially within the year. Table 2 shows a panel regression of weekly prices at the mandi-variety level, which shows that fluctuations in weekly city prices pass-through almost exactly one-for-one to weekly mandi prices, controlling for week, mandi and year dummies besides local potato yields. Column 1 shows this regression across the second half of 2007, 2008, 2011 and first half of 2012. Controlling for city prices reduces substantially the variations across year dummies, compared with the raw differences in prices across years reported above. Column 2 shows results of this regression restricting the data to 2008 alone: the pass-through to mandi prices is now 0.67, also significant at 1%. In contrast, there was very low pass-through of city prices to farmgate prices in 2008 (the only year for which we were able to compute farmgate prices), as shown in Column 3. The pass-through coefficient in column 3 is 0.06, and is statistically insignificant. In other words, farmgate prices do not co-move with city prices, whereas *mandi* prices do. In turn this suggests that it is very difficult for farmers to back out the prevailing *mandi* price from the current farmgate price.

To add to this, intra-year patterns also appear to vary from year to year. The graph in Figure 2 plots weekly averages of *mandi* price data for jyoti potatoes for each year from 2005 to 2008, taken from the Indian government's Agmark dataset for West Bengal. The sample used here includes *mandis* from all over the state.[7] For most years prices rise as the year progresses, as one would expect for traders and farmers to have the incentive to store potatoes from harvest time to sell later in the year. This did not happen in 2008, when prices dropped throughout the course of the year.

Moreover, prices vary spatially across mandi areas, and the spatial patterns can also vary from year to year. Table 3 provides analysis of variance of weekly mandi prices in our sample from the period from mid-2007 until mid-2012 (excluding 2009 and 2010 when our survey was suspended). The largest source of variability is across-years, followed by within-year-period variations and period-year interactions.[8] Prices also vary significantly across mandis, and the mandi-year interactions are also significant.

An added complication is caused by the fact that in 2008 price patterns for the main variety *jyoti* varied from the usual pattern in more ways than one. Not only was the average *jyoti* price unusually low in 2008 and failed to rise in the course of the year as we have shown above, the spatial patterns also varied markedly from other years: *mandis* that would usually have had higher prices than others, turned out not to. For Figure 4, we assigned to each *mandi* in our sample a rank based on its annual price average in 2008, and then plotted it against its rank in 2007 and

[7]Agmark has a much longer time series of *mandi* price data than we collected, but it appears to cover only *mandis* that are much larger than the *mandis* in our sample, so there is very limited overlap of actual *mandis* between that dataset and our list of *mandis*. This prevents us from using only the overlapping *mandis* for these graphs.

[8]We divide a year into three periods: weeks 1 to 12 are the harvest period, weeks 13 to 26 are the post-harvest early period when farmers could be selling the last of their home-stored potatoes, and the remaining weeks are the post-harvest late period, when any potatoes being sold are coming out of cold storage.

its rank in years after 2008. While the 2007 and post-2008 ranks are positively correlated with a correlation coefficient of 0.95, the correlation between the 2007 and 2008 ranks is negative and insignificant. The plot shows a group of mandis with below-median prices in 2007 and post-2008 that were above the median in 2008.

In most years the large year-to-year fluctuations make it difficult for farmers to predict what price the *phorias* are receiving in the neighboring wholesale market, except for what they can infer from price reports or offers made by the *phoria*. The gap between farmer's expectations of the *mandi* price and what traders were actually receiving in the *mandi* was compounded further in 2008, due to the unusual spatial and intra-year patterns occurring that year. We conclude that asymmetric information about the prevailing wholesale price was particularly salient in 2008.

3 Theoretical Analysis: Ex Ante Contracts

We now describe the theoretical model of *ex ante* bilateral trade contracts between a farmer and a local trader with asymmetric information, which constitutes the primary null hypothesis of this paper. This borrows from analyses of implicit wage-employment contracts (Hart (1983)) and efficient bilateral trading mechanisms (Myerson-Satterthwaite (1983)). It is assumed that a farmer-trader pair enters into an *ex ante* implicit contract that specifies farmgate price and quantity (conditional on quality verification by the trader) as functions of the realized mandi price as reported by the trader to the farmer. The aim of the contract is to achieve efficiency in trade, as well as in risk-sharing if either the trader and farmer are risk-averse. The efficiency that can be achieved is constrained by asymmetric information about the mandi price. There is a prior market for such contracts. The extent of competition in this market determines the Pareto weights applying to the *ex ante* welfare levels of the two parties. We assume that information provision to the farmer will not affect the extent of competition, so the Pareto weights are taken to be exogenously given.

A farmer F has an exogenous quantity $\bar{q}$ of potatoes to sell to a trader T, who can re-sell it to a wholesaler at a price of v (net of transport costs). T is informed about the realization of v. The farmer receives a signal σ concerning the realization of v. Conditional on this signal, the farmer's beliefs are represented by a distribution function $G(.|\sigma)$ with support $[\underline{v}, \bar{v}]$, which has a density $g(.|\sigma)$ which is assumed to be positive throughout the interior of the support. We impose the standard regularity condition that the inverse hazard rate $\frac{1-G}{g}$ is non-increasing in v.[9] The farmer can sell directly in the market at an additional cost of t relative to the trader, i.e., the farmer would obtain a price of $v - t$ if he were to sell directly. In this section we take t to be exogenous and independent of v. It represents differences in transport cost (owing to economies of scale) and in marketing connections at the mandi. The existence of this differential cost makes it efficient for the farmer to sell to the trader.

If the farmer sells q to the trader at a price of p, his *ex post* payoff is $pq + u(\bar{q} - q)$, where u represents the value to the farmer of consuming unsold potatoes, or using them as seeds in the following year, and is strictly increasing and strictly concave. The trader's ex post payoff equals $(v - p)q$. Their risk attitudes are represented by von-Neumann Morgenstern utility functions $\mathcal{U}$ and $\mathcal{V}$ respectively, which are strictly increasing and concave.

The key distortion resulting from asymmetric information arises irrespective of risk attitudes. To simplify exposition it helps to focus on the case where both parties are risk neutral, so that optimal contracts can be explicitly computed. The main qualitative results continue to apply when they are risk-averse, as will be explained subsequently.

The farmer's supply function $q^*(p)$ is defined by the solution to $\max_{q \leq \bar{q}}[pq + u(\bar{q} - q)]$. Let $\Pi(p)$ denote the corresponding profit function. The ex post autarky payoff for the farmer is then $\Pi(v - t)$.

Following Myerson and Satterthwaite (1983), we analyze incentive efficient bilateral contracts. Let λ denote the welfare weight of the trader relative to the farmer, which is treated as an exogenous parameter. Perfect monopsony corresponds to $\lambda = \infty$. At the other extreme is perfect competition, where $\lambda = 0$. Applying the Revelation Principle, attention can be confined to the following trading mechanism.

On any given date, the farmer receives the signal σ of the mandi price v at which the trader can re-sell the potatoes, while the trader observes the actual realization of v. At this (interim) stage there is asymmetric information. The trader and farmer then independently decide whether to participate in the trade. If either of them decides not to, there is no trade. If both agree to participate, the trader makes a report $\tilde{v}$ of the price he has observed to the farmer. The contract specifies prices and quantities to be traded as functions of the farmer's signal and the price report

[9] This assumption is inessential. In its absence the ironing techniques of Myerson (1981) can be utilized to generate similar results.

made by the trader: they exchange $q(\tilde{v})$ units of the good for an amount of money $r(\tilde{v})$ paid by the trader to the farmer. The price $p(\tilde{v})$ is defined by the ratio $\frac{r(\tilde{v})}{q(\tilde{v})}$.

The optimal contract $q(v|\sigma), r(v|\sigma)$ solves for functions $q(v), r(v)$ that maximize

$$\int_{\underline{v}}^{\bar{v}} [\mathcal{U}(r(v) + u(\bar{q} - q(v))) + \lambda \mathcal{V}(vq(v) - r(v))] dG(v|\sigma) \tag{1}$$

subject to the incentive constraint

$$vq(v) - r(v) \geq vq(v') - r(v') \quad \text{for all} \quad v' \in [\underline{v}, \bar{v}] \tag{2}$$

and the interim participation constraints

$$vq(v) - r(v) \geq 0 \tag{3}$$

and

$$\int_{\underline{v}}^{\bar{v}} \mathcal{U}(r(v) + u(\bar{q} - q(v))) dG(v|\sigma) \geq \int_{\underline{v}}^{\bar{v}} \mathcal{U}(\Pi(v - t))] dG(v|\sigma) \tag{4}$$

The case of symmetric information forms a benchmark: here the farmer's signal σ is the same v observed by the trader. It is easy to check in this case that the optimal contract is $q^F(v) = q^*(v)$ and $r^F(v) = vq^*(v) - s(v)$ where $s(v)$ maximizes $\mathcal{U}(\Pi(v) - s) + \lambda \mathcal{V}(s)$ subject to $\Pi(v) - \Pi(v - t) \geq s \geq 0$.[10] In other words, the efficient quantity traded is the farmer's supply response to the price v, since this maximizes the overall surplus $vq + u(\bar{q} - q)$ of the two parties. Then the financial transfer between the parties divides up this surplus according to their relative welfare weights and risk attitudes.

Proposition 1 *Suppose both parties are risk-neutral. Then the optimal contract with asymmetric information (i.e. where $g(v|\sigma) > 0$ for all $v \in [\underline{v}, \bar{v}]$) satisfies*

$$q(v|\sigma) = q^*(v - \mu \frac{1 - G(v|\sigma)}{g(v|\sigma)}) \tag{5}$$

for some $\mu \in [0, 1]$, which is strictly positive (unless $\lambda > 1$ and t exceeds some threshold t^*). If $\lambda < 1$, μ equals $(1 - \lambda)$. The transfer satisfies

$$r(v|\sigma) = vq(v|\sigma) - \int_{\underline{v}}^{v} q(\tilde{v}|\sigma) d\tilde{v} - \underline{V} \tag{6}$$

[10]Define $s(v) \equiv vq(v) - r(v)$, so the efficient contract selects $s(v)$ and $q(v)$ to maximize $\mathcal{U}(vq(v) + u(\bar{q} - qv) - s(v)) + \lambda \mathcal{V}(s(v)$ subject to $vq(v) + u(\bar{q} - q(v) - \Pi(v - t) \geq s(v) \geq 0$.

where $\underline{V} \geq 0$ is the trader's ex post payoff in state $\underline{v}$ which depends on λ, and equals 0 if $\lambda < 1$.

The result states that asymmetric information causes quantities traded to be lower than the symmetric information benchmark. In state (v, σ) the trader earns a markup of $\mu \frac{1-G(v|\sigma)}{g(v|\sigma)}$. Effectively the trader understates v by this markup, and offers a net price of $v - \mu \frac{1-G(v|\sigma)}{g(v|\sigma)}$ to the farmer, who responds to this with his optimal supply response. The markup causes the farmer to supply less than he would under symmetric information. This is a consequence of the trader's monopoly over information about v. The bargaining power of the two parties (i.e, the welfare weight λ and the outside option of the farmer defined by the transaction cost t) affects this markup only through μ, the weight applied to the inverse hazard rate of G.

The main implication is that asymmetric information causes quantities traded to be inefficiently low, except in the case where the trader has greater bargaining power than the farmer ($\lambda > 1$) and t is large, i.e., the farmer's outside option is low. We shall refer to this as the *unconstrained monopsony* case, since it corresponds to situations where the trader acts as a monopsonist, and the participation constraint (4) of the farmer is not binding. In this case, the efficient quantity is traded in each state ($q(v) = q^*(v)$), essentially since the contract maximizes the payoff of the trader and so the incentive constraints do not bind: the trader has no incentive to 'deceive himself'. If $t < t^*$ this solution is not feasible: i.e., the farmer's outside option of selling in the market directly binds. Then both the farmer's payoff and the traders payoff co-move with v. Here an inefficient contraction in trade volume must occur. Intuitively, the co-movement of the farmers payment with the mandi price v tempts the trader to understate v. To counteract this, a claim that v is low must be accompanied by a contraction in the traded quantity below the efficient level. Such a contraction occurs at every v except the highest possible realization of v — the standard 'no distortion at the top' result. Proposition 1 also shows that the lower the v, the larger the contraction in traded volume.

Now consider the impact of providing information about the realization of v to the farmer, thereby eliminating the asymmetric information. Excepting the unconstrained monopsony case, this will raise the traded volumes in all states v except only the very highest value. The lower the v, the greater the expansion. See Figure 5 for an illustration. In the unconstrained monopsony case there will be no effect at all. Hence *to the extent there is an effect of removing asymmetric information at all, it will cause traded quantities to expand.* The results of Hart (1983) show that this result extends to the case where both parties are risk-averse, essentially because a reduction in the traded quantity relaxes the truth-telling constraint.[11] This is the central prediction of the *ex ante* contract theory, which is robust with respect to bargaining weights, technology or preference parameters.

It turns out that the theory makes no comparably robust predictions about effects on farmgate prices. Suppose we are in the competitive case, where $\lambda < 1$. Under symmetric information $p^F(v) = v$, but with asymmetric information

$$p(v) = v - \frac{1}{q(v)} \int_{\underline{v}}^{v} q(\tilde{v}) d\tilde{v} \tag{7}$$

So if traded quantities are always strictly positive, the level of prices must be lower everywhere with asymmetric information: $p(v) < v$, except at $\underline{v}$ where $p(\underline{v}) = \underline{v} = p^F(\underline{v})$. This is just the statement that the trader earns information rents, even if farmers have disproportionate bargaining power. Moreover, on average, prices must co-move less with v under asymmetric information, in the sense that $p(\bar{v}) - p(\underline{v}) < \bar{v} - \underline{v} = p^F(\bar{v}) - p(\underline{v})$. It is harder to provide a condition for the slope of p to be uniformly lower under asymmetric information, as the comparison can go either way in general.[12] Hence in the competitive case we only get a general result about the level of farm-gate prices, but not the extent to which they co-move with v (except 'on average').

Even with respect to the level of prices, the results are sensitive to the allocation of bargaining power. For instance, in the unconstrained monopsony case, better information can lower the price that the farmer receives. At $v = \underline{v}$, under symmetric information the price is $p^F(\underline{v}) = \underline{v} - \frac{\Pi(\underline{v}) - \Pi(\underline{v} - t)}{q^*(\underline{v})}$ which is lower than the price with asymmetric information $p(\underline{v}) = \underline{v}$. Asymmetric information may reduce the trader's ability to extract monopsony rents from the farmer.

Hence the more robust prediction of the *ex ante* contract model is that quantities traded rise as a result of better information, if there is any effect at all.[13] We test this prediction experimentally, as described in Section 5.

[11] The quantity traded is distorted downwards except in the polar cases where there is an unconstrained monopsony or the farmer is risk-averse while the trader is risk-neutral. In these polar cases, the quantity traded is efficient. Hence, the overall prediction of the effects of providing price information is that quantity traded will either increase, or remain the same.

[12] This requires $\int_{\underline{v}}^{v} q(\tilde{v}) d\tilde{v}$ to be rising in v at a faster rate than $q(v)$. This condition may or may not be satisfied, depending on the slope of q at v.

[13] As shown in the Appendix, these results concerning the effects of reduced informational asymmetry also hold locally, i.e., when we have a slight reduction in the asymmetry instead of going from asymmetric to symmetric information.

4 The Experiment

Our experiment was conducted in 72 randomly chosen villages in the potato growing areas of Hugli and West Medinipur districts. They were divided into three groups of 24 villages each: two groups were used for two different information treatments and one group served as control. To reduce the chance of information spillovers, villages were selected such that they were at a minimum distance of 8 kilometres from each other. In the two treatment groups, we delivered daily information about the prices in one or two nearby wholesale markets (*mandis*) and the nearest metropolitan market. This information was reported by the market 'insider' we hired, who called in the lowest and highest prices at which trades occurred to an information center located in Kolkata. Both bond and spot prices were reported, for the two major varieties of potatoes sold in that market. Price information was collected daily from June to November 2007 and from January to November 2008.

In the 24 private information villages, the price information was given individually to 4 households selected randomly from our survey households. To deliver this price information, we gave each of these households a mobile phone. Each morning, the "tele-callers" based in our Kolkata information center made phone calls to each of these farmers and relayed the market prices from the previous evening. The mobile phone was to be used merely as a device for relaying price information to the farmer, and was not meant to improve the farmer's connectivity to the outside world. For this reason, the service provider blocked outgoing calls from this phone. They also changed the phone settings so that it was not possible to find out one's phone number by pressing keys on the instrument itself. Finally, we did not inform the farmer of the phone number for his phone. In this way we aimed to prevent the farmer from receiving any incoming calls except from us. Since we had access to the log of calls for each phone, we were able to check that our restrictions were effective.[14]

In the 24 public information villages, we delivered the market price information to a single individual (called the "vendor") in the village. This person was usually a local shopkeeper or phone-booth owner. For a nominal fee, he wrote the price information on charts and posted them in three public places in each village. These were places that we expected farmers to pass by as they went about their daily business. Each chart had room to write down 7 days' worth of

[14]Except for a few initial situations where farmers tried to download ringtones (a feature that was subsequently blocked as well), our plan succeeded without exception.

information: this was so that farmers could see how prices were changing and detect short-term trends if there were any. At the end of 7 days the chart was changed.[15]

One may wonder whether our experiment changed the prevailing *mandi* prices in the areas where the information treatments were delivered. Since we delivered price information in only 48 villages, this is unlikely to have happened. Note also that 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.[16] Our data come from surveys of 1599 potato farmers in a random sample (stratified by landholdings) in the 72 villages in our study. Although we collected a larger sample of 1726 farmers, we analyze data only for producers of the jyoti and chandramukhi varieties of potatoes, which respectively accounted for 70 and 20 percent of the potatoes grown in 2008. Sampled households answered survey questions about (a) demographics, assets, land ownership and credit; (b) crops planted and input use during the potato growing season; and (c) harvest of potatoes, sales 'from the field' at the time of the harvest, and subsequent sales from home stores and cold stores.

By the time we started delivering price information in June 2007, sample farmers had sold about 80% of the 2007 potato harvest. The majority of households had no stocks of potatoes left. This dampened the effectiveness of our intervention; farmers were unable to act on the information we provided. For this reason tests of hypotheses are carried out only using data from the 2008 round of the intervention and surveys, while we use the 2007 and pre-2007 data as a baseline. All villages and households were in the same treatment or control group in 2008 as they had been in 2007.

4.1 Descriptive Statistics

Table 4 shows a number of village and households characteristics by treatment groups, from data collected before the intervention began in June 2007. For most characteristics, the pre-intervention differences across treatment groups were small and insignificant. A notable exception is that control villages had a much higher probability of having a public telephone box. However

[15] Our tele-callers and village information vendors were given strict instructions not to reveal our research question to the information recipients. In cases where the farmers asked them why they were being given this information, they were instructed to say that they were part of a research study where price information was being relayed to farmers, but that they did not know why this was being done or how farmers could use this information.

[16] Data on trade volume in large *mandis* were taken from the Agmark dataset.

this is the result of a random draw. We include *mandi* fixed effects in all our regressions, which control for such fixed differences at the village level. We run joint tests of significance of all the household-level variables for each treatment group pair. All three tests are rejected (p=0.34, p=0.23 and p=0.98).

4.1.1 Effect of Information Treatments on Farmers' Price Information

In our fortnightly surveys conducted between June and November 2008, we asked farmers if they tracked wholesale and retail potato prices. If they did, they were asked for more detail about the markets they tracked, when last they had tracked the price, what the price was when tracked, and who their source of information was. To avoid the concern that through asking these questions we might make our information intervention more salient to the farmers, we asked these questions only to a randomly selected one-half of the sample. As a result we have these data at the fortnightly level for 853 farmers.[17]

Table 5 presents regressions run on this sample of farmers, with one observation for each fortnight in which we ask the question. We include monthly dummies to control for seasonal changes in price information tracking behavior. Column 1 indicates that the public information treatment increased tracking: in villages where we posted daily price information in public locations, farmers were more likely to report that they tracked prices. With private information the positive significant effect is smaller and only seen on farmers who received phonecalls from us. Column 2 shows that among those tracking prices, the treatments increased the frequency with which they tracked prices: they were likely to report that they had last tracked prices much more recently. Moreover, this effect was similar across the three groups of recipients: they reduced the time since they last tracked price information by roughly the same rate. Columns 3, 4 and 5 present results from a single multinomial logit regression where the dependent variable was the source of information for the price information. The intervention had no effect on the interaction among friends and neighbours about the prevailing potato price. There is a suggestion that it reduced the reliance on the trader (for phone-non-recipients and public information farmers) but this effect is not significant. However, there is a large and significant increase in the use of "other" as the source of information. To avoid making our intervention salient to the farmers, we did not offer a category indicating our intervention. Since the farmers chose the category "other" instead

[17] Our main results reported in Tables 7 and 8 continue to hold even if we analyse only the subset of households that were *not* asked questions about their price-tracking behaviour.

of a long list of categories available we interpret their report as indicating the price information intervention.[18]

There is thus evidence that the intervention did work as planned: farmers who received the intervention were more likely to track market prices and were likely to have tracked prices more recently. We shall also show later (in Table 9) that those receiving the intervention tracked local prices with a significantly lower error rate.

4.1.2 Effect of Information Treatments on Market Structure

In our theoretical model, the bargaining power of the trader is denoted by parameter λ, and it is assumed that λ is unchanged by the information intervention. This assumption seems reasonable because we observe that trust and reputation about product quality and creditworthiness play an important role in the farmer-*phoria* relationship in our context, and it is unlikely that our interventions made it easier for new *phorias* to enter the market. However we provide some evidence in favour of this assumption in Table 6.

Unfortunately we do not have the appropriate data from our 2007-08 surveys to estimate *phoria* concentration in the sample villages. However, in 2010 we started another study (which is still on-going) in the same set of villages, and we collected relevant data through questionnaires administered in 2011-12. In this new study, the public information treatment was implemented once again in the same set of villages where it was administered in 2007-08, and the control villages were once again control. There was no private information treatment; instead a randomly selected one-half of the private information treatment villages were assigned to the public intervention, and the other half were control.

Each time a farmer reported selling potatoes to a *phoria* in our surveys, he was also asked the name of the buyer. We use these data to create a list of *phorias* operating in each village (who trade with our sample farmers). We then compute each *phoria's* average share of the volume sold in the village, and village-level Herfindahl indices of *phoria* share. We then test if these measures are significantly different across control and treatment villages. We use two alternative definitions of treatment assignment: in the first definition, we only consider those 45 villages that remained in the same treatment arm in both study periods: 2007-08 and 2010-onwards. There

[18] The list of categories we provided for this question was, in order: friends, relatives, neighbours, caste members, traders, local government officials, NGO employees, cooperative members, other.

are 23 information villages and 22 control villages by this definition. In the second definition, all 72 villages that exist in the study 2010-onwards are included, and are assigned to their current treatment arm (36 control and 36 information villages).[19]

Column (3) in Table 6, Panel A show the results of Kolmogorov-Smirnov tests of equality of distributions of within-village market share of *phorias* between the treatment arms. In Panel B columns (1) and (2) report means of the Herfindahl index of within-village market share, and column (3) reports the test that these means are equal. In all cases, we cannot reject the null hypotheses that the distributions or their means are equal between the information and control villages. This is suggestive evidence that that *phorias'* bargaining power was unaffected by the information interventions.

5 Testing the Ex Ante Contracting Model

We now examine the effect of the interventions on the farmers' sales and prices received, and test the predictions of the ex ante contract model. Although we have detailed data about potato sales transactions collected through fortnightly surveys, we aggregate these to form a yearly average. We do this to abstract from the dynamics of farmer decisions of whether and when to sell in any given week, and the non-stationarity across different times of the year because their stocks and the time horizon over which they are optimizing changes. Sales decisions are likely to also vary with seasonal changes in *mandi* price, and with changes in expectations about future prices. While these may be interesting for their own sake, they are not of first order importance for the questions addressed in this paper. Since potatoes produced in any given year must be sold the same year, this enables us to abstract from storage decisions and ensures that sales in any given year are unaffected by any stock of unsold potatoes from the previous year.[20]

For each farmer we know each variety that he produced and the amount of his harvest of each variety that was of (self-reported) high or low quality. Our data are thus at the level of farmer-variety-quality. Our regressions will include variety and quality dummies, which thereby control for possible strategic responses with regard to quality choice by either farmers or traders

[19] Four villages in West Medinipur district that were in the original 2007-08 sample of 72 villages had to be dropped in 2010 because of Naxalite violence, and were replaced. Two of the dropped villages were control villages and one each was a private and public information village.

[20] Potatoes stored at home perish within a few months of harvest, and all potatoes must be removed from cold storage in November to allow for annual cleaning.

in response to price fluctuations. This helps address concerns that farmers may react to low farmgate prices by lowering the average quality of potatoes they sell, or that traders react to low *mandi* prices by purchasing lower quality potatoes.

We first show the average effects of the information intervention in Table 7, on annual quantity sold and average price received by a farmer (net of transactions costs paid by the farmer). The unit of observation is a farmer-variety-quality combination. Besides the variety and quality dummies, we include a district dummy for Medinipur, and control for the landholdings of the farmer. All standard errors are clustered at the village level to account for correlated error terms across different farmers in the same village. The regression specification is as follows:

$$y_{ijq} = \beta_0 + \beta_1 \text{Private information}_i + \beta_2 \text{Phone recipient}_i + \beta_3 \text{Public information}_i + \beta_4 X_{ijq} + \epsilon_{ijq}$$

where y_{ijq} is the dependent variable: net price received, or quantity sold for farmer i, variety j and quality q. Private information and Public information are dummy variables indicating the treatment group. In the villages that received the private information treatment, four sample households were also phone recipients; those four households also received a value of 1 for the Phone recipient dummy. Hence the coefficient of 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 about the calls received by phone recipients.

We have explained previously that prices in 2008 were lower than normal. Hence the *ex ante* contract model predicts that on average the effect of the information treatment on traded volumes should be positive or zero. In Table 7 column (1) which does not include mandi fixed effects, the sign of the coefficient is positive for all intervention dummies, but they are not significantly different from zero. In column (2) we include mandi fixed effects. This reverses the sign of the public information coefficient, and they all remain insignificant. Columns (3) and (4) show that analogous to the findings of Fafchamps and Minten (2012), there is no significant impact of the intervention on the average net price. Figure 7 provides a visual illustration of average weekly farmgate prices throughout the entire year corresponding to the two information treatments and the control areas, plotted on the same graph as the corresponding mandi prices. There is no apparent difference between the different farmgate price series.

The absence of any significant average treatment effects is consistent with versions of the *ex ante* contract theory, such as the case of an unconstrained monopsony. A more fine-grained test of the theory would utilize its prediction of heterogenous treatment effects: how the effects of information provision would vary with the mandi price. We have previously explained how variations in the yearly mandi price are driven principally by temporal variations in retail prices rather than local infrastructure or supply shocks. So we can treat variations in the mandi prices as exogenous. In the *ex ante* contract model we saw that the quantity distortion caused by asymmetric is larger if the farmer faces lower *mandi* prices. Translating this to the empirical context, uninformed farmers facing a low v will distort their quantities more, and uninformed farmers facing a high v will distort their quantities less. Giving them information should therefore generate a larger quantity response for farmers facing a lower mandi price.

We therefore estimate heterogenous treatment effects with respect to the realized mandi price. The regression specification is now (ignoring the separate dummy for phone recipients in the Private information treatment, for the sake of parsimony):

$$
\begin{aligned}
y_{ijq} \quad = \quad & \beta_0 + \beta_1 p_{ijq} + \beta_2 \text{Private information}_i + \beta_3 \text{Public information}_i + \beta_4(\text{Private}_i \times v_{ijq}) \\
& + \beta_5(\text{Public}_i \times v_{ijq}) + \beta_6 X_{ij} + \epsilon_{ijq}
\end{aligned}
$$

where v_{ijq} is the realized *mandi* price (or price shock), the calculation of which is explained below. The *ex ante* contract theory predicts either no effect at all ($\beta_2, \beta_3 = 0$) or positive intercept effects ($\beta_2, \beta_3 > 0$) and negative interaction effects ($\beta_4, \beta_5 < 0$) when the dependent variable is the traded quantity – see Figure 5. In addition, the regressions we run include a dummy for phone recipients.

The results are presented in Table 8. Panel A presents the regressions for quantity sold, while Panel B shows corresponding results for net price received by farmers. For the sake of parsimony, we only show results from regressions that include mandi fixed effects.[21] This ensures that the effects are not being driven by across-mandi fixed characteristics. The different columns in this table use different specifications of the *mandi* price and different samples. Columns 1-3 use different yearly averages of the actual *mandi* price, each corresponding to different sets of weights. Column 1 averages the mandi price for each specific farmer-variety combination in the data, over those weeks in which this farmer sold this variety. Thus it captures the average *mandi* price prevailing at times when this farmer made a sale. According to the model, this *mandi* price is the relevant one for the farmgate price. However, this farmer-specific average has the problem

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

that the average *mandi* price is relatively high or low for a particular farmer-variety depending on whether he chose to sell that variety at times when the *mandi* price was high or low, and therefore it is not exogenous. This problem is addressed in Columns 2 and 3 by creating weighted averages. In Column 2, the actual *mandi* prices in the different weeks of the year are weighted by the volume of potatoes sold in that week by all sample farmers from villages in the catchment area of that *mandi*. In Column 3 the weighted average uses as weights the volume sold in that week by all sample farmers in that district. These averages are less prone to endogeneity bias, but lower the precision of the price estimate.

These columns show a negative intercept effect and a positive slope effect of the private information interventions which are large and statistically significant. The same is true for the public information treatment except that the coefficients tend to be smaller in absolute magnitude and are not as precisely estimated. These results are the opposite of those predicted by the *ex ante* contract theory. In mandis with higher v, providing farmers price information seems to have increased the quantity sold by *more* instead of increasing it by less, as the model had predicted. In addition, instead of the predicted expansion of quantity traded across the range of v, farmers facing low *mandi* prices lowered quantity sold significantly. This is shown in Panel A of Table 9, which computes the implied treatment effects at the 10th and 90th percentiles of the distribution of the explanatory variable, for each of the regressions in Panel A of Table 8. In Column 1, both the private and public information treatments caused output sales at the 10th percentile of *mandi* price to shrink by over 1000 kg per farmer. Since the mean quantity sold by a farmer in the sample was 4171 kg, this represents a 25-27% contraction, significant at the 10% level.[22]

Column 6 restricts the sample only to sales made at the time of the harvest, and uses the same *mandi* price averaging procedure as in Column 1. In 2008, about half of all potatoes produced were sold at the time of harvest. Focusing on those sales enables us to abstract from the problem of aggregating prices across the weeks when the farmers sold. As we see, the pattern in Column 6 matches that in Columns 1-3, although there is some loss of statistical significance. In Column 7, we restrict the sample to farmers who were likely to have long-term relationships with the buyers of their potatoes. Since *ex ante* contracts require long-term relationships, it is for these farmers that we are more likely to see effects of the intervention that match those predicted by the *ex ante*

[22]The mean quantity sold by farmers facing the 10th percentile of the *mandi* price distribution was 3751 kg, which suggests a 28-30% contraction.

model.[23] Instead, we see that the pattern of the results in Column 7 matches that in Columns 1-3. Thus, we do not find evidence in favour of *ex ante* contracts even for the sub-sample where such contracts are more likely to occur.

The regressions in columns 1-3 and 6-7 abstract from the possibility that farmers in distinct *mandis* may have had different price expectations in 2008. Since the theory is about distortions caused by asymmetric information, what matters are *mandi* price shocks, or deviations from the expected *mandi* price. So the first three columns are subject to the concern that variations in realized mandi prices may reflect heterogenous beliefs rather than deviations of realized prices relative to expectations. Column 4 in Table 7 addresses this concern by using the estimated *mandi*-year effect for 2008 as a measure of the 2008 shock to the *mandi* price for the variety in question, from a regression of weekly mandi prices on *mandi* dummies, period and year dummies and interactions between them, applied to data from 2007, 2008, 2011 and 2012.[24] This filters out *mandi* specific components of the price that are fixed over time, besides correcting for seasonal fluctuations. The resulting weekly *mandi*-year effect for 2008 is then averaged over all weeks in which the concerned farmer made a sale.

Column 5 goes one step further, and computes deviation of the actual 2008 *mandi* price for any given week from an expected price for that *mandi*-week-variety combination. This is then averaged over weeks in which the farmer in question made a sale of that variety. The expected price is estimated from a regression of weekly *mandi* prices in that *mandi* in 2007, 2011 and 2012, after removing the year effect. Hence it represents the price that would "normally" be expected to prevail in the *mandi* for the specific variety, based on observations from years excluding 2008. The deviation of the actual price in 2008 from this expected price is an estimate of how much the actual 2008 *mandi* price deviated from what farmers in the catchment area of that *mandi* would have expected. Note that the price variable now is a deviation from the expected value, so the intercept term needs to be interpreted differently. It measures the effect of the information treatment for farmers selling in states where the expected *mandi* price equals the actual (rather

[23]These farmers are identified as follows. In our 2010 survey of this same sample, for each potato sale reported, we asked the farmer how long he had been selling to this buyer for. Farmers who report selling to this buyer for longer than 5 years in 2010 would have been selling to this buyer for longer than 3 years in 2008 (assuming the buyers are the same).

[24]Ideally we would have used data from 2007 and prior years. However we only have baseline data for the *mandis* in our sample for the second half of 2007, and not for earlier years. The Agmark dataset mentioned previously provides data for a wider sample of West Bengal *mandis*, but there is very little overlap between those *mandis* and ours. However, these data show that price patterns for 2011 and 2012 were similar to those in the years 2005-2007. For this reason we use our 2011-12 price data for our sample *mandis* as a proxy for pre-2007 data.

than at a hypothetical price of zero, as in the previous specifications). The interpretation of the slope coefficient remains the same. We see in column 5 that the intercept term is now positive and significant. The slope coefficient is also significant and reassuringly of the same order of magnitude as in the other columns. Panel A of Table 9 however shows the implied quantity effects at the 10th and 90th percentiles are now large and statistically significant: negative at the 10th percentile and positive at the 90th percentile (with the exception only for the public information treatment at the 90th percentile).[25]

Panel B of Table 8 provides corresponding estimates of treatment effects on net farmgate prices. With the exception of column 11 based on the *mandi* price deviation, the intercept and slope effects of the interventions have the same signs as those in the quantity regressions. In other words, the treatments caused farmgate prices to fall (resp. rise) for farmers facing low (resp. high) *mandi* prices. However these are statistically significant only for the private information treatment in the first column. Panel B of Table 9 shows a fall in the farmgate price at the 10th percentile in the first and the last columns, which is quantitatively large (greater than 10% of the mean price) and significant at 10%. However the rest of the price effects are not statistically significant.

6 An Alternative Hypothesis: Ex Post Bargaining

The results in the previous section are inconsistent with the single robust prediction of the *ex ante* contract theory. In this section we therefore seek an alternative explanation of the empirical findings.

As mentioned previously, field interviews are consistent with the view of *ex post* bargaining. Almost universally, when asked about how they negotiate with traders, farmers say that they react to price offers made by traders, and decide whether and how much to supply. They assert the absence of any explicit *ex ante* contractual arrangements with the traders, and say that while they may have implicit understandings that they will be approached by particular traders, they make no forward commitment to sell any predetermined quantity. *Phorias* are also unwilling to commit to a price offer in advance: they like to wait to see what v is and then make an offer. Farmers respond with a decision of how much to sell at this price.

[25] Since Columns 4-5 in Panel A and Columns 11-12 in Panel B of Tables 8 and 9 use explanatory variables that are themselves derived from estimates from other regressions, we report cluster-bootstrap standard errors, where the *mandis* are defined as the clusters.

This introduces a key difference from the screening model of *ex ante* contracts. We now have a signaling game, as the privately informed party makes the first move with a price offer. In theory, this price offer could reveal his information about v to the farmer. This signaling effect will be incorporated into the model.

What can the farmer do if he does not sell to the trader who made the price offer? This depends on the extent of competition: whether he can solicit competing offers from other traders. This complicates the model considerably. In the data we see multiple village traders co-existing, but farmers tend to sell to the same trader repeatedly. This could be due to credit and quality reputation issues which were mentioned in the introduction, although we have abstracted from them in the theory. There could also be tacit collusion among village traders, or market segmentation which restricts intra-village competition.

However, the farmer has the outside option of taking his crop to a local market or the mandi and selling it there. We find that in 2008, 8 percent of transactions were of this nature, accounting for 5% of all potatoes sold. We have seen before that when farmers sell in a local market they receive a substantially lower price than what the village traders receive at the mandi from wholesalers. The mandi is not a centralized market. Wholesalers tend to buy from village traders, not from farmers directly. Again this relates to problems with trust concerning quality and credit.

Informal field interviews with farmers who sell in the market indicate that they sell to other traders in the local market that they know, who are different from their regular village trader. They also mention the problem that they have to incur the cost of transporting their crop to the market. They mention their susceptibility to hold-up: the trader buying in the market knows that in the case of disagreement the farmer will have to incur the cost of taking the crop back to the village. This lowers the bargaining power of the farmer.

Despite this, the option of selling in a local market to a different trader there improves the bargaining power of a farmer vis-a-vis his regular village trader. It creates a form of sequential competition between the village trader and the market trader. The market brings together traders from other villages in the neighboring area; it is difficult for traders located in different villages to collude.

This motivates the following model of ex post bargaining, with three players: VT (trader in the village), MT (trader in the market) and F (farmer). In the interests of simplicity we identify the local market (*haat*) with the mandi, i.e., assume that a farmer who decides to sell at a market also goes to the same location as the village trader would have.

Stage 0: VT and MT learn the realization of v, F has beliefs over v represented by distribution function G, and has a given quantity $\bar{q}$ available to divide between sales and consumption (or stock).

Stage 1: VT offers F price p

Stage 2: F responds with either no, or yes and a quantity $q_1 \leq \bar{q}$ for sale to VT at the offered price. In this case F consumes $\bar{q} - q_1$ and the game ends. If F rejects, the game continues.

Stage 3: F takes $q_2 \leq \bar{q}$ to the mandi, and approaches MT (who observes q_2).

Stage 4: MT offers price m.

Stage 5: F decides on $q \leq q_2$ to sell to MT at the offered price, carries back the rest to the village and consumes $\bar{q} - q$.[26]

In this section we simplify by assuming that the farmer's supply elasticity is constant i.e., $q^*(p) = Kp^\epsilon$ for some $K, \epsilon > 0$. To avoid technical difficulties, we assume there is no upper bound to v, i.e., $\bar{v} = \infty$.

We will focus on two kinds of equilibria of this model: a perfectly revealing (separating) equilibrium, and a set of partially revealing (pooling) equilibria in a neighborhood of the separating equilibrium. Our interest will be in the pooling equilibria, but in order to explain them it helps to first describe the separating equilibrium and then relate it to the pooling equilibria.

In the separating equilibrium, the initial price offer by VT will reveal the realization of v to the farmer. From that point onwards, there will be no asymmetric information between the traders and the farmer on the equilibrium path. Subsequently, if F were to reject VT's offer, he will take $q_2 = q^*(\frac{\epsilon}{1+\epsilon}(v+t+w))$ to the mandi, following which MT will offer a price $m(v)$ defined by

$$m(v) = \frac{\epsilon}{1+\epsilon}v - \frac{t+w}{1+\epsilon}. \tag{8}$$

[26] If F were to transport the potatoes to the market, he would incur a cost of $t + w$, which is therefore t higher than the cost incurred by VT.

Anticipating this, the following price $p(v)$ if offered by VT would make the farmer indifferent between accepting it and rejecting it and then going to the mandi, assuming that the farmer knows the actual realization of v. It is defined by the solution to the following equation:

$$\Pi(p(v)) = [m(v) - t - w]q^*(\frac{\epsilon}{1+\epsilon}v + \frac{\epsilon(t+w)}{1+\epsilon}) + u(\bar{q} - q^*(\frac{\epsilon}{1+\epsilon}(v+t+w)). \tag{9}$$

In the separating equilibrium this price will be offered by VT, which will reveal v to the farmer because $p(v)$ is strictly increasing in v. The farmer will accept it with probability $\alpha(v)$, given by the solution to the following differential equation

$$\frac{\alpha'(v)}{\alpha(v)} = \frac{1}{v - w - p(v)} - \frac{q^{*\prime}(p(v))}{q^*(p(v))} \tag{10}$$

with endpoint condition $\alpha(\underline{v}) = \bar{\alpha}$ for arbitrary $\bar{\alpha} \in (0, 1)$.

The price $p(v)$ offered by the village trader will take advantage of the fact that if the farmer were to reject, he would have to incur costs of transporting his crop to the mandi. So it will be lower than $m(v)$, the price the farmer would receive in the mandi. And the price offer $m(v)$ in the mandi itself would take advantage of the costs the farmer would incur in transporting the crop back to the village if it were to be rejected. These transport costs therefore drive a wedge between the price the farmers get and what the traders get. The separating equilibrium is described below and illustrated in Figure 6.

Proposition 2 *Consider arbitrary beliefs $G(v)$ held by F with support $[\underline{v}, \infty)$, conditional on the realization of the signal observed by F which is common knowledge between F, VT and MT. There exists a separating Bayesian perfect equilibrium in which TV offers $p(v)$ at stage 1, F accepts this at Stage 2 with probability $\alpha(v)$. If F rejects, he takes $q_2(v) = q^*(m(v) + \frac{t+w}{1+e})$ to the mandi, whereupon MT offers $m(v)$ and F sells $q_2(v)$ to MT at this price. A price offer of $p \geq p(\underline{v}))$ leads F to believe that $v = p^{-1}(p)$ with probability one, while any price offer below $p(\underline{v})$ leads him to believe $v = \underline{v}$ with probability one. The price offered by VT $p(v)$ is lower than $m(v)$ which is offered by MT. $\alpha(v)$ is strictly decreasing if*

$$\epsilon < 1 + \frac{t}{w} \tag{11}$$

This equilibrium does not depend on the specific beliefs G held by the farmer.

We now turn to the class of pooling equilibria. In these, village traders make price offers that locally do not vary with v, thereby concealing information about small variations in v from the farmer. However, the price offer can jump up by a discrete amount at some thresholds of v, so some information is revealed: that v lies in a specific range. See Figure 7 for an illustration.

Proposition 3 *Consider arbitrary beliefs G held by F over v, conditional on the realization of the signal observed by F which is common knowledge between F, VT and MT. There is a continuum of partially pooling Bayesian perfect equilibria with the following features. There is an interval partition ($\underline{v} = v_0 < v_1 < v_2 ...$) of the set of possible v values, and associated prices $r_1 < r_2 < r_3 < ..$ with VT offering r_i if $v \in (v_{i-1}, v_i)$ at stage 1. The price offer r_i is accepted by F with probability β_i, where*

$$\beta_i = \frac{(v_{i-1} - r_{i-1} - t)q(r_{i-1})}{(v_{i-1} - r_i - t)q(r_i)}\beta_{i-1} \tag{12}$$

and $\beta_1 > 0$ is arbitrarily chosen. If F rejects, he takes a quantity $q_{2i} \in (q_2(v_{i-1}), q_2(v_i))$ to the mandi, where MT offers him a price $M(v) = \min\{n(q_{2i}), m(v)\}$, F then sells $Q_2(v) = \min\{q_{2i}, q^*(M(v) + t + w)$, and carries back the rest to the village. Here $n(q)$ denotes the solution for p in $q^*(p + t + w) = q$. A price offer from VT of $p \in (r_{i-1}, r_i]$ for $i \geq 2$ leads F to update his beliefs on the event that $v \in [v_{i-1}, v_i]$, while any price offer below r_1 leads F to believe that $v = \underline{v}$ with probability one.

The thresholds v_i and offers r_i depend on G, the farmer's prior beliefs, as the farmer is indifferent between accepting and rejecting VT's offer (on the equilibrium path), conditional on the information communicated by the offer.

Note that the price offers $M(v)$ made by MT in the mandi equal $m(v)$ and are thus fully revealing if q_{2i} is not too large. The willingness of MT to make price offers is not affected by considerations of how much information will be contained in the offer, since there is no other trader the farmer can approach after MT. This pins down the farmers outside option in bargaining with the village trader. The price offers made by the latter in the pooling equilibrium is some kind of local average of the price offers in the separating equilibrium, since they are tied down by a similar indifference property between acceptance and rejection for the farmer. The average is rough, since the price offer made by VT conceals information about v from the farmer, which in turn affects what the farmer expects from going to the mandi. It consequently affects the amount of crop he takes there; he may end up taking less than what MT is actually prepared to buy at price $m(v)$. Or he may end up taking more, and has to cart back the excess to the village. The outside option payoff of F from rejecting VT's offer is therefore not the same as in the separating equilibrium, and is itself influenced by the offer.

There are many such pooling equilibria, varying with regard to the extent of information communicated by VT's price offer at Stage 1. For any given extent of asymmetric information and a given pooling equilibrium of this kind, there also exist other pooling equilibria which communicate more information to F through the price offers. Here the intervals of the induced information partition of F tend to be narrower, and the price offers are closer to those in the separating equilibrium.

The set of such pooling equilibria that exist is sensitive to how much asymmetric information there is to start with. Asymmetric information is necessary for the farmer to be indifferent between a pooled price offer and the price he expects to receive by rejecting it and going to the market: the farmer must be uncertain about the latter. In some states of the world he will end up doing better ex post by rejecting the offer and going to the mandi. In others he will be worse off. Indeed, the set of pooling equilibria converge to the separating equilibrium as the extent of asymmetric information tends to vanish. Since a formal statement and proof of this property involves some technical details, we avoid explaining the argument underlying this claim.

6.1 Testing the Predictions of the Ex Post Bargaining Model

What does this model predict? As long as F is not perfectly informed, there are multiple equilibria, including the separating equilibrium and a continuum of partially pooling equilibria. It should be noted that there are other equilibria outside these two kinds, so predictions are highly context-specific. We focus therefore on providing an equilibrium explanation of what we see in the data.

Suppose that to start with there is asymmetric information and we are in one of the pooling equilibria. The information treatment gives the farmer a more precise *ex ante* signal of the true value of v, which can cause the farmer's indifference property to not hold for some values of v. This equilibrium breaks down, and is replaced by another pooling equilibrium closer to the separating equilibrium. For the sake of illustration suppose that we actually move to the separating equilibrium. This means that the *ex post* effect on the price offered by the village trader will depend on the precise value of v within the interval that it happened to lie in the pooling equilibrium. If it was toward the lower (resp. higher) end of the interval, the farmer will receive a lower (resp.) price offer. Averaging over different realizations of v the resulting average treatment effect will be zero, as observed in our experiment. See Figure 8 for an illustration.

Moreover, the *ex post* price and quantity traded with the village trader will move in the same direction. This is exactly what we observed empirically.

The *ex post* bargaining model generates a number of implications which can be tested.

First, if we were in a pooling equilibrium to start with, which is vulnerable to an information treatment (in the sense that it ceases to exist thereafter), the treatment causes farmers in the village to become better informed about the price they would receive if they were to take their potatoes to the local market. In Table 10 we test this using our data. Using our data from half the sample where we asked farmers if they had tracked market prices recently and if so, to tell us the price when they had last tracked it, we used the date when they had tracked the price to match their reported price to the actual price in that market in that week. We define the normalized error as the difference between the tracked and the actual prices, as a ratio of the actual price. We find that the variance of these normalized errors was about 20% lower for farmers in villages receiving information treatments. The F-statistics show that the reduction is statistically significant at the 1 percent level.

Second, for either kind of equilibrium, at any v, the farmgate price should be lower than the price the farmer receives at the market. This is verified in Table 11: controlling for the prevailing mandi price, district and land ownership, farmers who sold in the market received a higher price than those who sold to the *phoria* or other traders/moneylenders.

Third, as v increases, the farmer tends to reject the village trader's offer and sell in the mandi more often.[27] To the extent that higher mandi prices are partly time-varying and thus unpredictable, higher values of mandi prices in the cross-section will be correlated with high-v realizations. So we expect to see a positive relationship between the mandi price and the likelihood of the farmer selling in the mandi rather than to the village *phoria*. This is verified in Table 12, which shows a higher likelihood of the farmer selling in the market when the mandi price is higher, after controlling for land ownership and a district dummy. This effect is statistically significant in Medinipur.

[27] This is true provided (11) holds, i.e., the farmer has a sufficiently high transport cost disadvantage relative to the village trader.

Fourth, if transport costs rise and everything else is unchanged, $m(v)$ shifts down, and the gap between $p(v)$ and $m(v)$ increases. If we are in a pooling equilibrium in a neighborhood of the separating equilibrium, middlemen margins will become higher. This is consistent with the difference in margins observed between Hugli and Medinipur. In Medinipur, which is less densely populated and where distances to the market are higher, farmers receive a smaller proportion of the mandi price than in Hugli.

Moreover, for given endpoint $\alpha(\underline{v})$, $\alpha(v)$ will fall for each $v > \underline{v}$. So F will accept the village trader's offer less and go to the mandi more frequently. This is indeed what we find: farmers in Medinipur were more likely to sell in the mandi than in Hugli.

7 Conclusion

We have reported results of a field experiment providing market price information to potato farmers in West Bengal. In our context, farmers are unable to sell to wholesale buyers directly, and are forced to sell to local trade intermediaries. This is in contrast to other settings studied in the previous literature where producers have direct access to markets and access to information increases farmers' arbitrage opportunities. In our context the effects of information provision are more subtle and complex, because they depend on the trading mechanism, e.g., whether farmers and local intermediaries enter *ex ante* contracts or not. Our surveys do suggest that both farmers and local traders care about each others' reputations and engage in repeat transactions, and yet our empirical results are not consistent with explicit or implicit *ex ante* contracts involving trade pre-commitments or risk sharing. Information treatments have heterogenous effects depending on market price realizations: for farmers facing low (high) prices, the treatments cause both quantities sold and farmgate prices to fall (rise). Thus the treatment increases the volatility of farmer revenues while leaving average revenues unaffected.[28]

Our findings are consistent with descriptions of the trading mechanism reported to us in interviews by farmers and traders. Farmers and traders do not enter into any trade pre-commitments with one another. Instead they bargain *ex post*, where the trader makes a price offer, and the farmer responds to this with a sale decision, with a limited outside option of taking the crop to the market and selling to another intermediary trader there. There is some competition between

[28] While the heterogeneity is across different *mandis*, we showed the results were robust (and actually sharper) when the *mandi* price variable was measured as a deviation from the expected price for each *mandi*.

traders, but it is limited by both the sequential and the spatial separation of the two trading options.

One caveat to our findings is that 2008 was an abnormal year for potatoes in West Bengal: instead of rising through the year as they usually do, potato prices remained low. It is conceivable that farmers and traders enter into contracts with partial insurance that break down in bad years. If so, then our findings do not extend to all years. Since we have resumed the information intervention in this same set of villages from 2010 onwards, we will be able to explore this hypothesis in future work.

Our bargaining model assumed that any given farmer was locked into selling to a given trader within the village. However, multiple traders are observed to operate within each village. One way to reconcile these two observations would be to suppose that traders within the same village collude with one another.[29] Or else traders who have historically bought from a given set of farmers within the village could have exclusive access to information about their reliability and the quality of their potatoes. This can generate a segmented market structure, with different traders specializing in procuring from segments of farmers about whom they have an informational advantage. In such a context traders can earn large margins on average, despite a lack of collusion. A segmented monopoly model along these lines for related credit transactions has been successfully tested for the same sample of villages by Maitra et al (2012). Further work is needed to understand better the market structure for potato transactions between farmers and local traders.

This paper has ignored the effects of the information treatments on farmer decisions about storage and timing of sales. As is well known from the literature on durable goods monopoly, endogenous timing of transactions combined with a lack of price commitment by the monopolist can limit the effective monopoly power of a monopolist. In our context, a farmer can decide to delay sales if the monopsonistic trader makes him a low price offer. In the absence of an ability to pre-commit to future prices, the monopsonist effectively competes against his future selves. Delaying a sale in response to an unfavorable price offer is similar in some ways to taking one's potatoes to the local market to sell to some other trade intermediary with substantial market power. Whereas in the first case the farmer incurs storage costs, in the second case he incurs

[29] In the presence of tacit collusion, information provision to farmers may affect the extent of collusion, as it might encourage farmers to search for price offers from traders other than their customary buyer. However, in the data we found no systematic effect of the information treatments on trader concentration.

transport costs. The monopsonist will accordingly set prices at an early date to leave the farmer indifferent between selling now and delaying the sale. We therefore expect that if the *ex post* model is extended to accommodate endogenous timing of sales, similar results will obtain.[30] Nevertheless this remains an interesting extension to be pursued in future work.

With regard to policy implications, the paper shows that West Bengal potato farmers are unlikely to benefit from access to better information about prices in wholesale or retail markets, delivered via cell-phones or other means. The more fundamental problem is that there is limited competition for farmers' produce. This suggests that government regulation of wholesale markets that reduce entry barriers for farmers or new buyers can play an important role in improving the prices that farmers receive. Encouraging backward integration by retail chains via forms of contract farming is a possible way of increasing competition amongst buyers that will both help farmers realize a higher price and deliver higher output. These policy options are of course subject to other hazards: the possibilities of collusion among government regulators and buyers of produce in wholesale markets, and of predatory pricing by retail chains.

[30] In fact, we find the public information treatment did tend to induce greater storage and delayed sales by farmers.

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Appendix: Proofs

Proof of Proposition 1. Standard manipulations (e.g., using Mirrlees (1986)) show that the incentive and participation constraints (2, 3) for the trader are equivalent to the following constraint:

$$r(v) = vq(v) - \int_{v_l}^{v} q(\tilde{v})d\tilde{v} - \underline{V}, \quad \underline{V} \geq 0 \quad \text{and } q(v) \text{ nondecreasing.} \tag{13}$$

$\underline{V}$ can be interpreted as the ex post payoff which will be earned by the trader in state $\underline{v}$, and $\int_{vl}^{v} q(\tilde{v})d\tilde{v}$ is the additional rent earned by the trader in state v owing to asymmetric information. The interim participation constraint states that $\underline{V}$ must be non-negative. The monotonicity of q is a consequence of the single-crossing property, wherein an increase in q is more valuable to the trader when v is higher.

This enables us to substitute out the transfers and reduce the asymmetric information contract problem in terms of $q(v)$ and $\underline{V}$ alone, which must maximize

$$\int_{\underline{v}}^{\bar{v}} [\mathcal{U}(vq(v) + u(\bar{q} - q(v)) - \int_{\underline{v}}^{v} q(\tilde{v})d\tilde{v} - \underline{V}) + \lambda\mathcal{V}(\int_{\underline{v}}^{v} q(\tilde{v})d\tilde{v} + \underline{V})]dG(v|\sigma) \tag{14}$$

subject to $\underline{V} \geq 0$ and that $q(v)$ is non-decreasing. The trader's surplus $\underline{V}$ in state $\underline{v}$ is selected purely on distributive grounds; hence its optimal value will depend on λ. The monotonicity constraint on $q(v)$ does not bite owing to the assumption on the monotonicity of the inverse hazard rate. So this constraint can be ignored. The problem reduces to selecting the quantities traded $q(v)$ to maximize (14) in an unconstrained fashion.

Now the objective function (14) reduces to

$$\int_{\underline{v}}^{\bar{v}} [\{v + (\lambda - 1)\frac{1 - G(v|\sigma)}{g(v|\sigma)}\}q(v) + u(\bar{q} - q(v)) + (\lambda - 1)\underline{V}]dG(v|\sigma) \tag{15}$$

If $\lambda > 1$ it is optimal to set $\underline{V} = \underline{V}^*(t)$, while if $\lambda < 1$ it is optimal to set $\underline{V} = 0$.

In the former case, the objective function (15) reduces to

$$\lambda \int_{\underline{v}}^{\bar{v}} [vq(v) + u(\bar{q} - q(v))]dG(v|\sigma) - (\lambda - 1) \int_{\underline{v}}^{\bar{v}} \Pi(v - t)dG(v|\sigma) \tag{16}$$

so the problem is to maximize

$$\int_{\underline{v}}^{\bar{v}} [vq(v) + u(\bar{q} - q(v))]dG(v|\sigma) \tag{17}$$

subject to

$$\int_{\underline{v}}^{\bar{v}} [\{v - \frac{1 - G(v|\sigma)}{g(v|\sigma)}\}q(v) + u(\bar{q} - q(v)) - \Pi(v - t)\}dG(v|\sigma) \geq 0. \tag{18}$$

The unconstrained optimum involves $q(v) = q^*(v)$, which satisfies constraint (18) if and only if $t \geq t^*$. If $t < t^*$, the solution is as depicted in Proposition 1 with $\mu = \frac{\alpha}{1+\alpha}$, where α is the Lagrange multiplier on constraint (18).

If $\lambda < 1$, the result is immediate, as $\underline{V}$ is optimally set at zero then. ∎

Effects of Local Changes in Information of Farmers. Suppose that the noise in the farmer's signal σ is indexed by a parameter n, so a higher n corresponds to a less informative signal. Let the optimal quantity traded be denoted $q(v|\sigma, n)$ in the state where the trader observes v, the farmer observes a realization σ of his signal, which has noise n. We have seen above that

$$q(v|\sigma, n) = q^*(v - \mu\frac{1 - G(v|\sigma, n)}{g(v|\sigma, n)})) \tag{19}$$

The effect of a change in n on either q or q_v depends on where the effect is being evaluated, in particular the signal realization σ relative to the true state v since the effect of n on the inverse hazard rate depends on this.[31] For any given true state v, the realization of the signal will be random. One should perhaps be interested in the average effect, while averaging over different possible signal realizations. This generates an additional complication: a change in v is likely to change the realized values of the signal, if the signal is informative. The 'total' effect should incorporate this dependence.

However, we argue now using a specific example that the same prediction concerning the effect of asymmetric information on traded quantities continues to hold for local changes. Suppose that G is uniform on the support $\sigma - \frac{n}{2}, \sigma + \frac{n}{2}$ which is a subset of $[\underline{v}, \bar{v}]$, and $u(c) = \log c$. To guarantee interior solutions for quantity, assume that $\underline{v} > \frac{1}{\bar{q}}$. Then

$$q(v|\sigma, n) = \bar{q} - [(1 + \alpha)v - \alpha(\sigma + \frac{n}{2})]^{-1} \tag{20}$$

[31] An added complication is that in the case of a constrained monopsony, μ depends on a Lagrange multiplier whose value would depend on n.

Then $q_n(v|\sigma,n) < 0$ while $q_{vn}(v|\sigma,n) > 0$ for all v, σ, n, i.e., for any fixed signal realization σ an improvement in the farmer's information (lower n) will raise the quantity traded and lower the slope of q with respect to v. Moreover, the same is true if we incorporate the effect of changes in v on the signal realization itself, in the following sense. Let $Q(v|n) \equiv q(v|v,n)$, i.e., the quantity traded when the farmer observes a realization of the signal which is the true state v. Then $Q_n < 0$ while $Q_{vn} > 0$. In this example, the price is

$$p(v|\sigma,n) = v - \int_{\sigma-\frac{n}{2}}^{v} \frac{\bar{q} - [(1+\alpha)\tilde{v} - \alpha(\sigma+\frac{n}{2})]^{-1}}{\bar{q} - [(1+\alpha)v - \alpha(\sigma+\frac{n}{2})]^{-1}} d\tilde{v} \tag{21}$$

and we see that $p_n < 0$, while p_{vn} is difficult to sign. Improved information then raises the price.

Proof of Proposition 2. Working backwards from Stage 5, suppose F had taken q_2 to the mandi and received a price offer of m from TM. How much would he want to sell at this price? This corresponds to selecting $q \leq \bar{q}$ to maximize $mq - (t+w)(q_2 - q) + u(\bar{q} - q)$. The 'effective' price received by F is now $m+t+w$, since anything not sold here will have to be transported back at an additional cost of $t+w$. The solution to this is $q(q_2, m) = q^*(m+t+w)$ if $q_2 \geq q^*(m+t+w)$, and q_2 otherwise. Note here that the farmer's beliefs regarding v do not matter at Stage 5, since the only option he has at this stage is to either sell to TV at the offered price m or consume the rest.

Now move to Stage 4, where TV is approached by F with stock q_2. Let $n(q_2)$ be defined by the solution to m in $q^*(m+t+w) = q_2$. Any price m bigger than $n(q_2)$ is dominated by the price $n(q_2)$ since it would result in the same traded volume q_2 but at a higher price. Any price m lower than $n(q_2)$ will result in traded volume of $q^*(m+t+w)$ at price m. Hence TV selects a price $m \leq n(q_2)$ to maximize $(v-m)q^*(m+t+w)$.

Given the constant elasticity form that q^* takes, the solution to this problem is as follows:

$$m(v, q_2) = \frac{\epsilon v - t - w}{1+\epsilon} \tag{22}$$

provided $q_2 \geq q^*(\frac{\epsilon v - t - w}{1+\epsilon} + (t+w)) = q^*(\frac{\epsilon}{1+\epsilon}(v+t+w))$, and $n(q_2)$ otherwise. Note again that this decision doesn't depend on beliefs held by F.

We move back to Stage 3, and suppose that F has decided to reject TV's offer. What decision should he make regarding q_2? Here his beliefs regarding v matter, since they affect what he expects TM to offer at Stage 4. Suppose that F believes that the realization of v is $\tilde{v}$ with probability one. A choice of $q_2 \leq q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w))$ will result in a sale of q_2 to TM at a price of $n(q_2)$, and an expected payoff of

$$\mathcal{P}(q_2,\tilde{v}) \equiv n(q_2)q_2 + u(\bar{q}-q_2) - (t+w)q_2. \tag{23}$$

Given the definition of the function $n(.)$, it follows that

$$\mathcal{P}(q_2,\tilde{v}) = \Pi(n(q_2)-t-w) - x$$

which is (locally) strictly increasing in q_2. Hence any $q_2 < q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w))$ is strictly dominated by $q_2 = q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w))$.

Now consider any $q_2 > q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w))$. This will lead to a sale of $q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w))$ to TM at a price of $m(\frac{\epsilon}{1+\epsilon}\tilde{v}-t-w)$, with the excess transported back to the village. Hence it is optimal for F to select $q_2 = q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w))$ if he decides to go to the mandi. And going to the mandi results in an expected payoff of

$$[m(\tilde{v})-t-w]q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w)) + u(\bar{q}-q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w)) \tag{24}$$

At Stage 2, then, if TV offers a price $p(\tilde{v})$ where $\tilde{v} \geq \underline{v}$, the farmer believes the realization of v is $\tilde{v}$ with probability one and expects a payoff equal to (24) from going to the mandi. The farmer is indifferent between accepting and rejecting the offer, by construction of the function $p(\tilde{v})$. Hence it is optimal for the farmer to randomize between accepting and rejecting the offer, and in the event of accepting F will sell $q^*(p(\tilde{v}))$ to TV. And offering any price less than $p(\underline{v})$ leads the farmer to believe that $\tilde{v} = \underline{v}$ with probability one, so such an offer will surely be rejected.

Finally consider TV's problem of deciding what price to offer at Stage 1. Any offer below $p(\underline{v})$ will surely be rejected, while any offer $p(\tilde{v}), \tilde{v} \geq \underline{v}$ will be accepted with probability $\alpha(\tilde{v})$ and will result in a trade of $q^*(p(\tilde{v}))$ at price $p(\tilde{v})$. Hence TV's problem is similar to making a price report of $\tilde{v} \geq \underline{v}$ in a revelation mechanism which results in a trade of $q^*(p(\tilde{v}))$ at price $p(\tilde{v})$, resulting in a payoff of

$$\mathcal{W}(\tilde{v}|v) = \alpha(\tilde{v})[v-w-p(\tilde{v})]q^*(p(\tilde{v})) \tag{25}$$

It remains to check that it is optimal for TV to report truthfully in this revelation mechanism. Now $\mathcal{W}_v(\tilde{v}|v) = \alpha(\tilde{v})q^*(\tilde{v})$, so if we define $X(v) = \mathcal{W}(v|v)$ we see that $X'(v) = \alpha(v)q^*(p(v))$, so

$$X(v) = X(\underline{v}) + \int_{\underline{v}}^{v} \alpha(\tilde{v})q^*(p(\tilde{v}))d\tilde{v} \tag{26}$$

which implies that

$$\alpha(v)[v - w - p(v)]q^*(p(v)) = \alpha(\underline{v})[v - w - p(\underline{v})]q^*(p(\underline{v})) + \int_{\underline{v}}^{v} \alpha(\tilde{v})q^*(p(\tilde{v}))d\tilde{v} \tag{27}$$

Differentiating with respect to v, this local incentive compatibility condition reduces to the differential equation (10).

A sufficient condition for global incentive compatibility (see Mirrlees (1986)) is that $\mathcal{W}_v(\tilde{v}|v) = \alpha(\tilde{v})q^*(p(\tilde{v}))$ is non-decreasing in $\tilde{v}$. This is equivalent to $\alpha'(v)q^*(p(v)) + \alpha(v)q^{*'}(p(v))p'(v) > 0$ for all v. Condition (10) implies $\alpha'(\tilde{v})q^*(p(\tilde{v})) + \alpha(v)q^{*'}(p(v))p'(v) = \frac{\alpha(v)p'(v)q^*(p(\tilde{v}))}{v-p(v)}$ which is strictly positive.

That $p(v) < m(v)$ is obvious from the definition of $p(v)$. The unconstrained monopsony price p for TV (which maximizes $(v-w-p)q^*(p)$) equals $\frac{\epsilon}{1+\epsilon}(v-w)$, which exceeds $m(v)$ if (11) holds. Hence if this condition holds, the monopsony price exceeds $p(v)$, implying that $\frac{q^{*'}(p(v))}{q^*(p(v))} > \frac{1}{v-p(v)}$, so $\alpha(v)$ is strictly decreasing. ∎

Proof of Proposition 3. Note first that nothing changes from the separating equilibrium above at Stages 4 and 5, since the farmer's beliefs do not matter at these stages.

At Stage 3, the farmer's beliefs do affect his decision on the stock q_2 to take to the mandi upon rejecting TV's offer. Suppose that the farmer's updated beliefs at Stage 3 are obtained by conditioning G on the event that $v \in [v^*, v^* + x]$ where $v^* \geq \underline{v}$ and $x > 0$. F will then not be able to exactly forecast the price that TM will offer him at Stage 4. He knows that if he takes q_2, and the state happens to be v, TM will offer him a price $M(v, q_2) = \min\{n(q_2), m(v)\}$, and F will then sell him $Q_2(v, q_2) = \min\{q_2, q^*(M(v) + t + w)\}$, and carry back the rest to the village. Since $m(v)$ is increasing in v, his ex post payoff will be increasing in v for any given q_2. Moreover, given any v^*, an increase in x will induce him to select a higher optimal q_2 and earn a strictly higher expected payoff from going to the mandi. Denote this payoff by $Y(v^*, x)$, which is thereby strictly increasing in x. It is evident that $Y(v^*, 0)$ is the expected payoff when he is certain the state is v^*, as in the separating equilibrium in state v^*. Hence $Y(v^*, 0) = \Pi(p(v^*))$, the payoff attained by F in the separating equilibrium in state v^*.

Construct the endpoints $\{v_i\}$ of the partition and the prices $\{r_i\}$ iteratively as follows. Define the function $\tilde{p}(v^*, x)$ by the property that $\Pi(\tilde{p}(v^*, x)) = Y(v^*, x)$, the price which if offered by TV would make F indifferent between accepting and rejecting, conditional on knowing that

$v \in [v^*, v^* + x]$. By definition, then, $\tilde{p}(v^*, 0) = p(v^*)$. Select $v_0 = \underline{v}$. Given v_{i-1}, select $r_i \in (p(v_{i-1}), \tilde{p}(v_{i-1}, \infty))$. Select $v_i = v_{i-1} + x_i$ where x_i is defined by the property that $\tilde{p}(v_i, x_i) = r_i$. By construction, F is indifferent between accepting and rejecting a price offer of r_i from TV, conditional on the information that $v \in [v_{i-1}, v_i]$.

The rest of the argument is straightforward. With β_i's following (12), TV in state v_{i-1} is indifferent between offering prices r_{i-1} and r_i. This implies that any type $v \in [v_{i-2}, v_{i-1})$ prefers to offer r_{i-1} rather than r_i. Moreover, the single-crossing property of TV's payoffs with respect to the state v implies that each type is selecting offers optimally in the set $\{r_i\}_{i=1,2,..}$. And offering a price between r_{i-1} and r_i is dominated by the price r_i, since it corresponds to the same probability β_i of acceptance by F, and a lower profit for TV conditional on acceptance. ∎

Figures

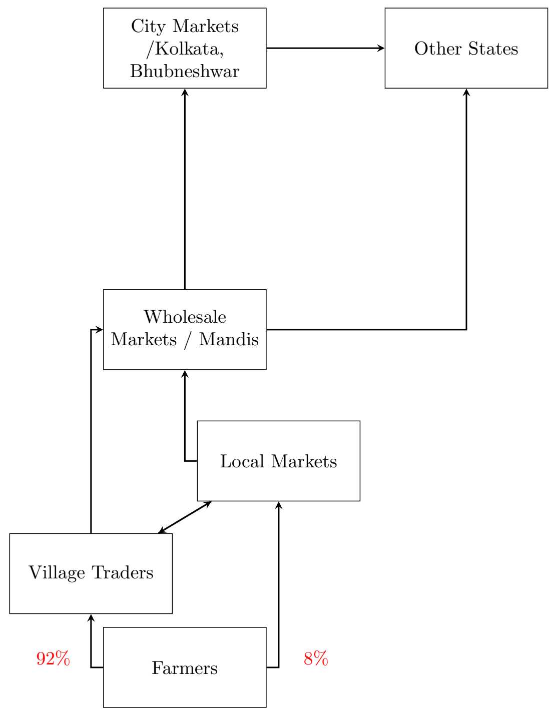

Figure 1: Potato Supply Chain

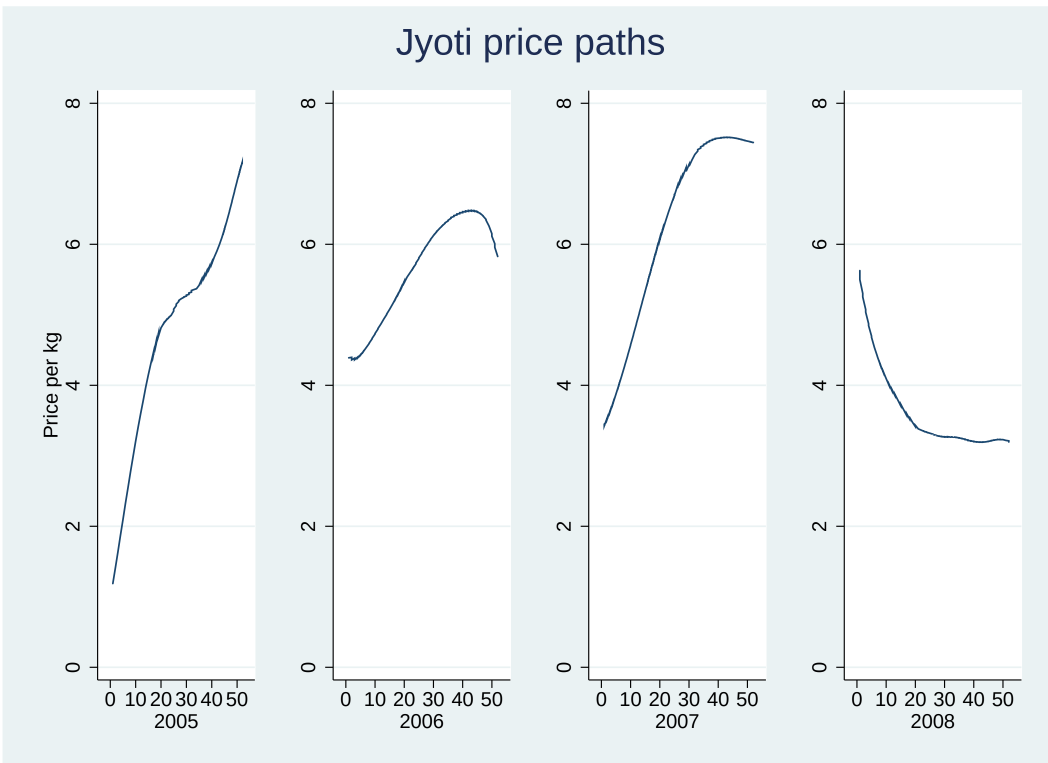

Figure 2: Mandi Prices by variety, 2008

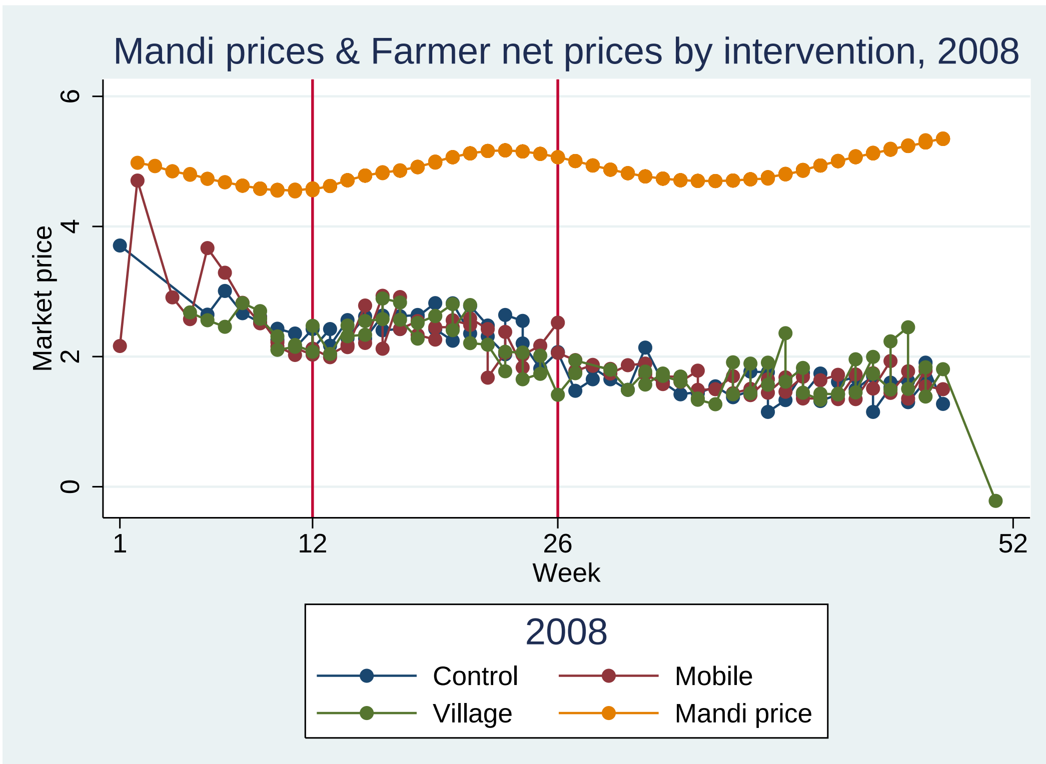

Figure 3: Intervention Impacts

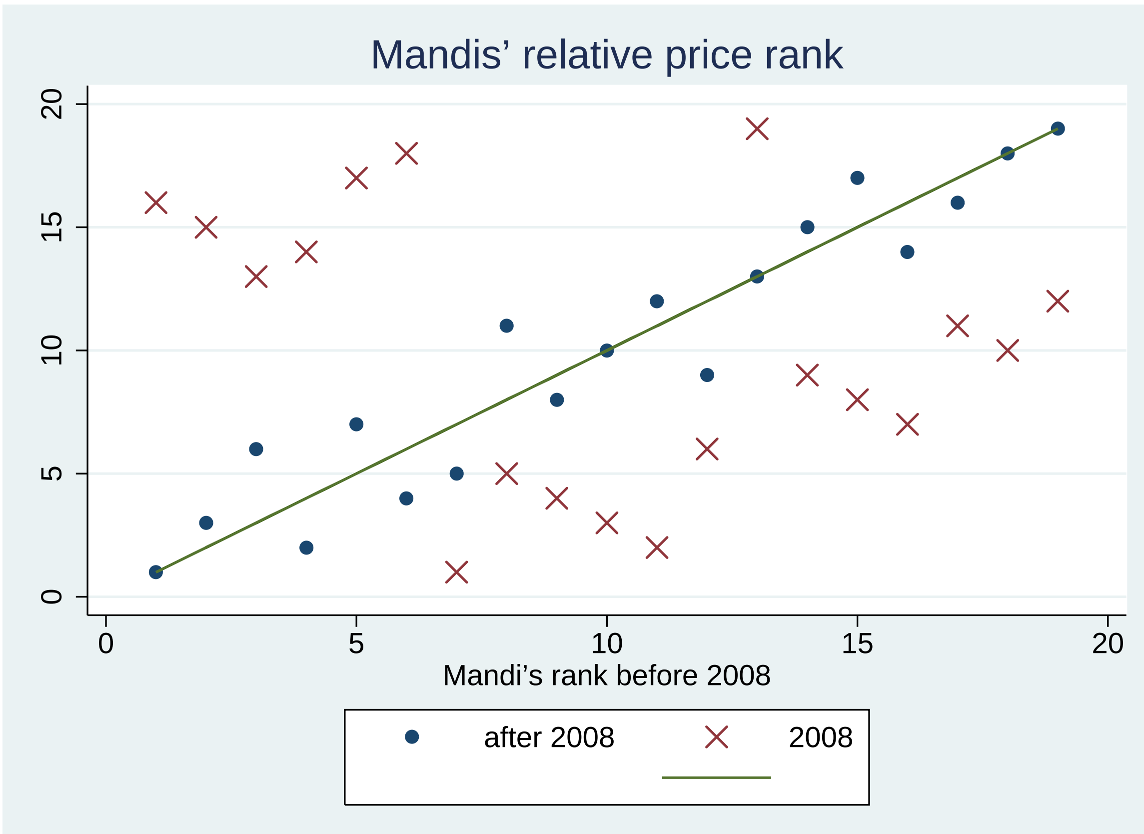

Figure 4: Relative Rankings of Mandis by Prices, 2008 versus other years

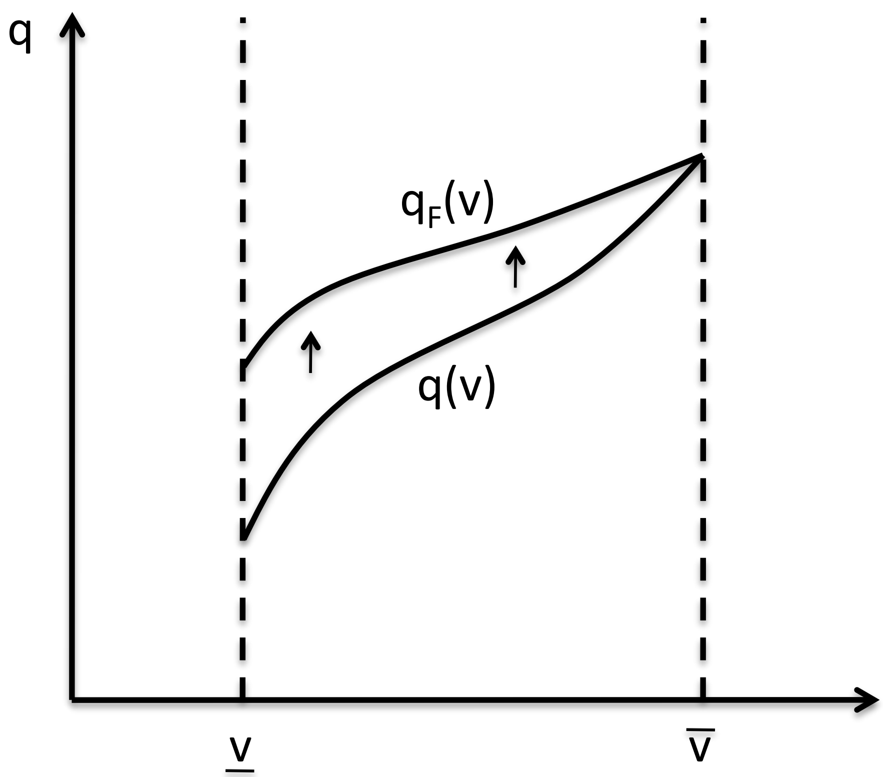

Figure 5: Prediction of the *Ex ante* Contracting Model

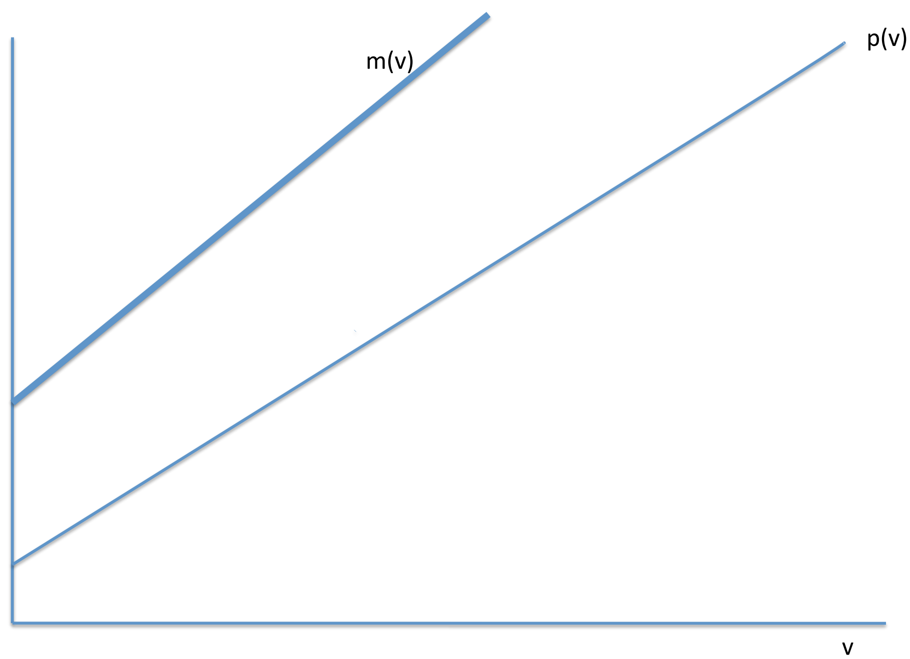

Figure 6: Separating Equilibrium

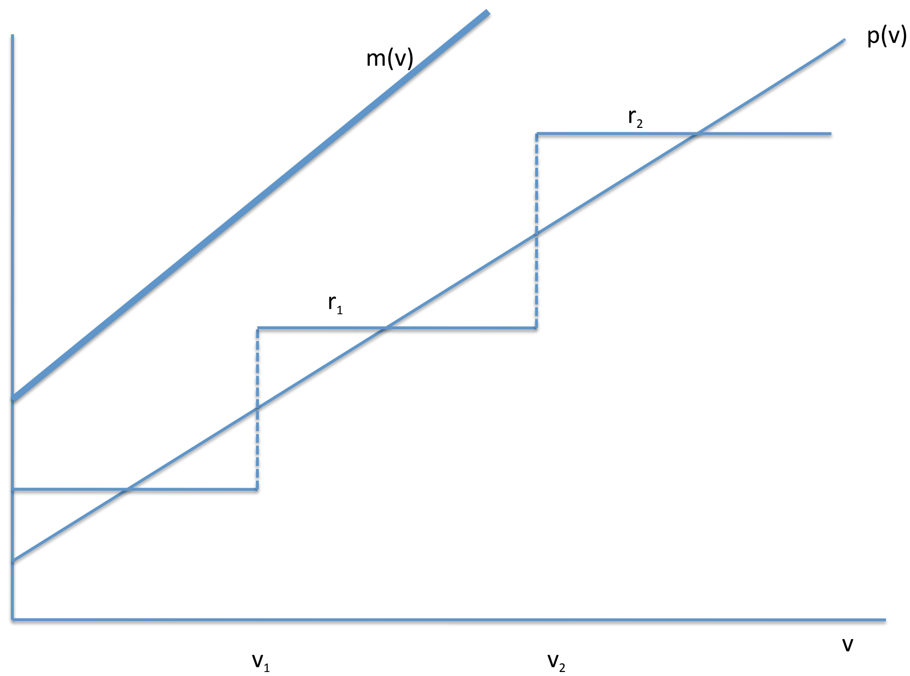

Figure 7: Partially Pooling Equilibrium

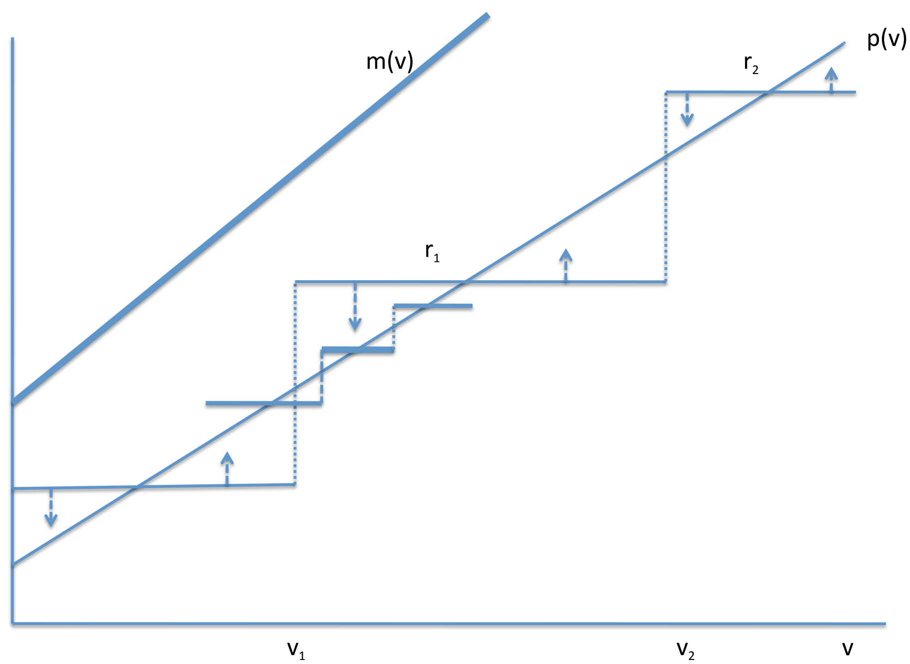

Figure 8: Effect of Information Treatment

Tables

Table 1: Pooled Regression of annual average mandi price on city price and local characteristics

	Before/After 2008	2008
	(1)	(2)
City price	1.12***	-1.74
	(3.38)	(-0.41)
Distance (km)	-0.02	-0.08
	(-0.49)	(-0.62)
Distance x City price	0.00	0.01
	(0.52)	(0.65)
Local yield	0.00	-0.00
	(1.33)	(-0.40)
% households with landline	4.57	-0.91
	(0.66)	(-0.14)
% villages with metalled road	1.26	0.98
	(0.87)	(0.68)
% villages with factory/mill	-1.72	-0.72
	(-1.50)	(-0.79)
Constant	-4.85	15.49
	(-1.49)	(0.74)
R-squared	*0.59*	*0.61*
Observations	*57*	*22*

Notes: The unit of observation is *mandi* -year. A *mandi* is defined as a market-variety combination. City price is the Kolkata price for *mandis* in Hugli district and Bhubaneswar price for *mandis* in Medinipur district. Distance is distance from the *mandi* to the relevant city. Local yield is the average potato yield (kg/acre) for jyoti and chandramukhi potatoes of all sample farmers in villages that fall in the catchment area of the *mandi* , in the relevant year. t-statistics are in parentheses.

Table 2: Pass-through of Weekly City Prices to Mandi Prices, Panel Regression

	Mandi price		Farmgate price
	(1)	(2)	(3)
City price	1.00***	0.90***	0.06
	(79.97)	(36.52)	(1.07)
Local yield	0.00	0.00	0.00
	(1.11)	(-1.41)	(0.43)
2008	1.29***		
	(8.09)		
2011	1.81***	3.04***	
	(8.40)	(8.41)	
2012	2.55***	4.49***	
	(12.74)	(13.13)	
Constant	-4.97***	-4.59***	-0.77
	(-11.98)	(-6.95)	(-0.11)
R-squared	*0.95*	*0.93*	*0.50*
Observations	*2,563*	*1,614*	*689*

Notes: The unit of observation is *mandi*-week. A *mandi* is defined as a market-variety combination. City price is the Kolkata price for mandis in Hugli district and Bhubaneswar price for mandis in Medinipur district. Distance is distance from the *mandi* to the relevant city. Local yield is the average potato yield (kg/acre) for jyoti and chandramukhi potatoes of all sample farmers in villages that fall in the catchment area of the *mandi*, in the relevant year. All regressions also include week dummies and *mandi* dummies. t-statistics are in parentheses.

Table 3: Analysis of variance of *mandi* prices

Source	MSE	F
Year	6382.05	2980.75 ***
Period	1756.82	820.53 ***
Year x Period	731.69	341.74 ***
Mandi	165.92	77.49 ***
Mandi x Year	54.61	25.50 ***
Observations	*2717*	
R-squared	*0.87*	

Notes: Price data were collected through "vendors" we identified in wholesale potato markets neighbouring our sample villages. Vendors were paid a monthly fee for calling our information centre in Kolkata each evening to report the average price at which potatoes were transacted, separately for each variety sold in that market. The analysis above uses weekly averages of these prices for the months June-November in 2007, January - November in 2008 and 2011, and January-April in 2012. Periods refer to three "seasons" when potato sales occur: harvest (weeks 1-12), post-harvest early (weeks 13-26) and post-harvest late (weeks 27-52). A *mandi* is defined as a variety-year combination.

Table 4: Descriptive statistics, by intervention group

	Public Info	Private Info	Control	Differences		
	(1)	(2)	(3)	(3)-(1)	(3)-(2)	(2)-(1)
Village-level						
Distance to mandi (km)	8.07	8.56	8.93	0.86	0.37	0.49
	(1.01)	(1.65)	(0.88)	(1.34)	(1.87)	(1.94)
Has a PCO box (2007)	0.46	0.42	0.67	0.21	0.25*	-0.04
	(0.10)	(0.10)	(0.09)	(0.14)	(0.14)	(0.15)
Household-level						
Owned land (2008) (acres)	1.19	1.09	1.09	-0.09	0.00	-0.10
	(0.05)	(0.05)	(0.05)	(0.07)	(0.07)	(0.07)
Has at least one cultivator	0.66	0.64	0.66	0.00	0.03	-0.02
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Cultivator's age (years)	48.05	48.92	49.50	1.45	0.58	0.87
	(0.74)	(0.68)	(0.68)	(1.00)	(0.96)	(1.00)
Cultivator's years of schooling	7.40	7.01	6.60	-0.80	-0.41	-0.39
	(0.19)	(0.20)	(0.20)	(0.28)	(0.29)	(0.28)
Planted potatoes (2007)	1.00	1.00	0.99	-0.01**	-0.01*	-0.00
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)
Fraction land planted with potatoes (2007)	0.51	0.51	0.53	-0.02	0.03*	-0.02
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Planted variety jyoti (2007)	0.90	0.95	0.95	0.05**	-0.00	0.05***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
Planted variety chandramukhi (2007)	0.13	0.11	0.05	-0.08***	-0.06***	-0.02
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Has a landline phone (2007)	0.25	0.23	0.23	-0.02	0.00	-0.02
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)
Has a cell phone (2007)	0.36	0.32	0.32	-0.04	0.01	-0.04
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Test of joint significance ($\chi 2$) for household-level variables				12.34	15.14	3.68

Notes: Village-level data were collected through village surveys administered in 2007. Household-level data were collected in the baseline household survey conducted in 2007. Cultivator is defined as a household member whose main occupation is reported as cultivation.

Table 5: Effect of Interventions on Farmers' Price Information

	Probability of tracking	Days since tracked	Information source		
			Friends/Nbrs	Trader	Other
	(1)	(2)	(3)	(4)	(5)
Private info	0.80	0.71***	1.12	0.50	1.82
	(0.47)	(2.88)	(0.19)	(1.05)	(0.79)
Phone recipient	1.71*	0.86***	1.43	2.31	20.33***
	(1.65)	(2.78)	(0.82)	(1.47)	(4.42)
Public info	8.00***	0.80**	1.03	0.49	30.19***
	(3.03)	(2.20)	(0.04)	(1.10)	(4.72)
Observations	*10771*	*10771*	*9302*		
Prob > χ^2	*0.00*	*0.00*	*0.00*		

Notes: In the fortnightly trading surveys (March — December 2008) a randomly selected 50% sample (stratified by village) was asked if they kept track of retail or wholesale potato prices, and if they answered yes, were asked to list up to 3 markets (2 varieties per market) where they tracked prices, how long ago they last tracked the price, the price when they last tracked it and the source of their information. Each observation is a household-variety-market combination. Column (1) reports odds ratios from a logit regression. Column (2) reports incidence-rate ratios from a Poisson regression. Columns (3), (4) and (5) report relative-risk ratios from a single multinomial logit regression. Dummies for month, variety and district are included.

Table 6: Tests of differences in trader concentration in information and control villages in 2011-12

	Control	Information	Difference
	(1)	(2)	(3) *p-value*
Panel A: Kolmogorov-Smirnov tests of equality of distributions			
Villages that stayed in the same treatment arm throughout			*0.25*
All villages, using 2011-12 treatment assignment			*0.30*
Panel B: Mean Herfindahl index			
Villages that stayed in the same treatment arm throughout	0.24	0.22	*0.70*
All villages, using 2011-12 treatment assignment	0.21	0.20	*0.57*

Note: Panel A, Column (3) reports p-values from Kolmogorov-Smirnov tests of equality of distributions of within-village market shares of buyers, between the control villages and information villages. Panel B columns (1) and (2) report mean Herfindahl indices in each set of villages, and column (3) reports the p-value of the t-test of differences. Villages are included in the sample according to two different criteria: The first row of each panel considers only those 45 villages that remained within the same treatment arm in 2011-12 as they were in 2007-08, and classifies them accordingly into control (22 villages) or (public) information (23 villages). The second row of each panel considers all 72 villages that existed in the study in 2011-12 and classifies them according to their 2011-12 treatment assignment into control (36 villages) and (public) information (36 villages). All market shares are computed using 2011-12 sales data.

Table 7: Average Effects of Intervention on Total Quantity Sold and Net Price Received

	Total Quantity Sold (kg)		Net Price Received (Rs/kg)	
	(1)	(2)	(3)	(4)
Private info	484.65	16.09	-0.07	0.02
	(0.88)	(0.03)	(-0.55)	(0.15)
Phone	524.55	454.09	0.10	0.08
	(1.18)	(0.99)	(1.05)	(0.98)
Public info	229.40	-275.17	-0.10	-0.05
	(0.44)	(0.54)	(-0.82)	(0.47)
Land	2252.24***	2218.82***	-0.09***	-0.07***
	(12.89)	(12.42)	(-5.03)	(4.82)
Constant	2844.90***	3022.93***	2.21***	2.37***
	(5.16)	(6.69)	(18.28)	(26.40)
Mandi fixed effects	*No*	*Yes*	*No*	*Yes*
R-squared	*0.35*	*0.39*	*0.37*	*0.44*
Observations	*2318*	*2318*	*2318*	*2318*

Notes: The unit of observation is a farmer-variety-quality. A *mandi* is defined as a market-variety combination. In columns (1) and (3) a variety dummy for chandramukhi potatoes, a dummy for low-quality potatoes and a dummy for Medinipur district are included. All columns control for the farmer's landholding. Columns (1) and (3) include controls for variety and quality of potatoes, and a dummy for Medinipur district. Columns (2) and (4) include *mandi* dummies. t-statistics are in parentheses. Standard errors are clustered at the village level.

Table 8: Heterogenous Treatment Effect Regressions
Panel A: Effects on Quantity sold (kg)

	farmer-sp avg (1)	mandi-weights (2)	district-weights (3)	price shock (4)	deviation from expected price (5)	only harvest sales (6)	farmers with long-term relationships (7)
Mandi price	65.40	n.a.	n.a.	n.a.	-567.92 ***	-115.14	-816.23 *
	(0.27)				(3.18)	(0.71)	(1.72)
Private info	-3066.96 **	-3538.18 **	-3794.00 **	-3601.18 *	2170.03 **	-1499.32	-5528.67 *
	(2.22)	(2.16)	(2.16)	(1.85)	(2.32)	(1.39)	(1.75)
Private info x Mandi price	695.64 **	825.67 **	900.28 **	774.17 *	638.50 ***	405.09 *	1372.80 *
	(2.15)	(2.12)	(2.13)	(1.81)	(3.29)	(1.73)	(1.68)
Phone	1715.92	-5.54	86.40	125.66	921.85	265.99	3223.37
	(1.23)	(0.004)	(0.06)	(0.11)	(1.23)	(0.12)	(0.80)
Phone x Mandi price	-293.64	100.95	81.42	66.27	73.21	116.09	-704.69
	(0.87)	(0.25)	(0.19)	(0.28)	(0.55)	(0.19)	(0.67)
Public info	-2845.59 **	-2823.83 *	-3085.43 *	-2558.54	1069.87	-1696.39	-6647.99 ***
	(2.26)	(1.73)	(1.77)	(1.12)	(1.25)	(1.26)	(2.71)
Public info x Mandi price	581.60 **	577.90	647.66	472.26	440.38 ***	334.70	1615.19 ***
	(2.04)	(1.54)	(1.60)	(1.03)	(2.71)	(1.01)	(2.85)
Land	2184.05 ***	2201.96 ***	2201.19 ***	2203.17 ***	2107.66 ***	1375.52 ***	2435.57 ***
	(11.96)	(12.35)	(12.34)	(9.76)	(11.05)	(9.36)	(6.00)
Constant	2837.50 **	3075.25 ***	3075.59 ***	3089.03 ***	872.86	3154.56 ***	6273.49 ***
	(2.63)	(7.28)	(7.30)	(7.18)	(1.16)	(3.86)	(3.07)
Mandi fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
R-squared	*0.39*	*0.39*	*0.39*	*0.39*	*0.40*	*0.40*	*0.50*
Observations	*2299*	*2317*	*2317*	*2318*	*2282*	*1370*	*443*

Notes: Unit of observation: farmer-variety-quality; *mandi* defined as market-variety combination. Controls include quality, variety and district dummies. Columns differ in calculation of average mandi price. Columns 1,8: average price in the relevant mandi for every farmer-variety-quality, averaged over the weeks in which the farmer made a potato sale. Columns 2,3,9,10: average price in the relevant mandi, with weeks weighted by aggregate volume of potatoes sold in that week by sample farmers in the catchment area of that mandi by sample farmers in that district. Columns 4,11: estimated mandi x year effect for 2008 from a regression of weekly mandi prices on mandi dummies, period dummies, and year dummies and their interaction for 2007, 2008, 2011 and 2012 price data. Columns 5,12: average deviation of 2008 mandi price from expected price in that mandi in that week for every farmer-variety-quality, averaged over the weeks in which the farmer made a potato sale. The expected price is computed as the estimated weekly price in that mandi based on 2007, 2011 and 2012 price data, after removing the year effect. Columns 6,13 restrict observations to sales made directly from the field at the time of harvest. Columns 7, 14 restrict observations to sales made by farmers who told us that in 2010 they sold some fraction of their potatoes to a buyer whom they had been selling to for longer than 5 years. t-statistics in parentheses; standard errors are clustered at the village level. However in columns 4, 5, 11, 12 we report cluster-bootstrap standard errors, with 400 replications; clusters are the *mandis* .

Table 8: Heterogenous Treatment Effect Regressions
Panel B: Effects on Net price received (Rs/kg)

	farmer-sp avg (8)	mandi-weights (9)	district-weights (10)	price shock (11)	deviation from expected price (12)	only harvest sales (13)	farmers with long-term relationships (14)
Mandi price	0.18 **	n.a.	n.a.	n.a.	0.08 **	0.27 ***	0.25
	(2.60)				(2.23)	(3.95)	(1.22)
Private info	-0.61 **	-0.73 **	-0.73 *	-0.56 *	0.11	-0.41	0.35
	(2.03)	(2.09)	(1.98)	(1.68)	(0.92)	(1.41)	(0.50)
Private info x Mandi price	0.14 **	0.18 **	0.18 *	0.13 *	0.03	0.06	-0.07
	(2.02)	(2.07)	(1.97)	(1.75)	(1.12)	(0.85)	(0.41)
Phone	0.05	0.14	0.14	0.06	0.09	0.12	1.12
	(0.18)	(0.61)	(0.57)	(0.29)	(0.82)	(0.30)	(1.46)
Phone x Mandi price	0.00	-0.02	-0.02	0.00	0.00	-0.01	-0.29
	(0.05)	(0.26)	(0.23)	(0.07)	(0.09)	(0.16)	(1.33)
Public info	0.02	-0.26	-0.23	-0.04	0.07	-0.03	0.77
	(0.08)	(0.79)	(0.65)	(0.11)	(0.52)	(0.09)	(1.14)
Public info x Mandi price	-0.01	0.05	0.04	0.00	0.02	-0.01	-0.18
	(0.17)	(0.61)	(0.49)	(0.02)	(0.82)	(0.09)	(1.15)
Land	-0.07 ***	-0.07 ***	-0.07 ***	-0.07 ***	-0.05 ***	0.00	-0.08 **
	(5.55)	(4.98)	(4.96)	(5.47)	(5.19)	(0.07)	(2.12)
Constant	1.58 ***	2.37 ***	2.37 ***	2.37 ***	2.72 ***	1.31 ***	1.31
	(5.34)	(27.62)	(27.59)	(27.74)	(12.88)	(4.76)	(1.48)
Mandi fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
R-squared	*0.46*	*0.44*	*0.44*	*0.44*	*0.47*	*0.50*	*0.54*
Observations	*2299*	*2317*	*2317*	*2318*	*2282*	*1370*	*443*

Notes: see notes under Panel A.

Table 9: Total Effects of the Intervention at 10th, 90th Percentile of Distribution

Panel A: Quantity sold (kg)

	farmer-sp avg	mandi-weights	district-weights	price shock	deviation from expected price	only harvest sales	farmers with long-term relationships
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Private information, no phone							
10th percentile	-1038.01 *	-412.45	-514.43	-1054.75	-2955.29 ***	-347.71	-1593.30
	(1.70)	(0.82)	(1.00)	(1.50)	(3.28)	(0.66)	(1.40)
90th percentile	1170.48	1110.32	1472.61	1017.32	2123.19 **	931.21	2217.86
	(1.37)	(1.39)	(1.59)	(1.20)	(2.30)	(1.60)	(1.23)
Private information, with phone							
10th percentile	-178.55	-35.82	-131.41	-711.11	-2621.14 ***	248.30	-390.04
	(0.21)	(0.06)	(0.20)	(0.82)	(2.96)	(0.31)	(0.24)
90th percentile	1097.70	1673.12	2035.34	1538.34 **	3039.67 ***	1893.74	1464.76
	(1.04)	(1.52)	(1.59)	(2.29)	(3.87)	(1.20)	(1.32)
Public information							
10th percentile	-1149.27 *	-636.06	-726.10	-1005.17	-2465.10 ***	-744.89	-2017.79 **
	(1.97)	(1.28)	(1.41)	(1.12)	(2.89)	(1.33)	(2.06)
90th percentile	697.16	429.75	703.38	258.83	1037.57	311.79	2466.27 **
	(0.94)	(0.59)	(0.84)	(0.34)	(1.22)	(0.37)	(2.37)
Mandi fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Total effects are computed at the 10th percentile and 90th percentile of the relevant explanatory variable using results from the heteregenous effects regressions reported in Table 7 Panels A and B. e.g. in columns 1 & 8 the effects are computed at 10th and 90th percentiles of the farmer-specific *mandi* price average.

Table 9: Total Effects of the Intervention at 10th, 90th Percentile of Distribution
Panel B: Net price received (Rs/kg)

	farmer-sp avg	mandi-weights	district-weights	price shock	deviation from expected price	only harvest sales	farmers with long-term relationships
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Private information, no phone							
10th percentile	-0.20	-0.07	-0.08	-0.15	-0.09	-0.23 **	0.15
	(1.57)	(0.65)	(0.76)	(1.08)	(0.53)	(2.01)	(0.62)
90th percentile	0.25	0.26	0.31	0.19	0.11	-0.04	-0.03
	(1.46)	(1.46)	(1.53)	(1.12)	(0.73)	(0.25)	(0.11)
Private information, with phone							
10th percentile	-0.13	0.02	0.00	-0.07	0.01	-0.15	0.44
	(0.77)	(0.13)	(0.04)	(0.44)	(0.05)	(0.77)	(1.63)
90th percentile	0.33	0.31 *	0.37 *	0.27	0.20	-0.01	-0.55
	(1.47)	(1.78)	(1.79)	(1.61)	(1.13)	(0.03)	(1.17)
Public information							
10th percentile	-0.01	-0.08	-0.08	-0.05	-0.09	-0.04	0.25
	(0.08)	(0.74)	(0.72)	(0.38)	(0.58)	(0.37)	(1.01)
90th percentile	-0.04	0.01	0.02	-0.05	0.07	-0.06	-0.25
	(0.26)	(0.07)	(0.08)	(0.34)	(0.42)	(0.34)	(0.97)
Mandi fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: See notes under Panel A.

Table 10: Effect of intervention on variance of normalized error in tracked price relative to actual market price

	Public info	Private info	Control	Variance-comparison test F-statistic		
	(1)	(2)	(3)	(3)/(1)	(3)/(2)	(2)/(3)
Standard deviation of normalized error	0.33	0.32	0.40	1.541***	1.418***	0.920*
Observations	*2957*	*1335*	*1802*			

Note: Half the farmers in the sample were asked each fornight if they tracked the wholesale prices in any market, and if so which market, and what the price was when they last checked. The date when they checked was matched to the actual average price in that market in that fortnight. The normalized error is defined as (tracked price - actual market price)/actual market price.

Table 11: Farmers' net price difference between within-village and local market sales

	Overall	Hugli	Medinipur
	(1)	(2)	(3)
Sold to market	0.36***	0.56***	0.36*
	(2.78)	(2.99)	(1.99)
Mandi price	0.23***	0.47***	0.19***
	(5.07)	(6.92)	(4.65)
Constant	1.44***	0.73***	1.30***
	(9.06)	(3.11)	(5.78)
R-squared	*0.37*	*0.48*	*0.29*
Observations	*3919*	*2002*	*1917*

Notes: The unit of observation is a farmer-quality-variety-week when a transaction occurred. Landholding, a variety dummy for chandramukhi potatoes, a quality dummy for low quality potatoes and a district dummy for Medinipur are included; therefore the constant term is the coefficient on high-quality jyoti potatoes in Hugli. t-statistics are in parentheses. Standard errors are clustered at the village level.

Table 12: Likelihood of market sales regressed on *mandi* price

	Overall	Hugli	Medinipur West
	(1)	(2)	(3)
Mandi price	1.61***	0.85	1.68***
	(3.55)	(0.45)	(3.37)
Land owned	0.93	0.86	0.96
	(1.10)	(0.76)	(0.58)
Medinipur dummy	4.72**		
	(2.41)		
Prob > χ^2	0.00	0.58	0.00
Observations	*3919*	*2002*	*1917*

Notes: The unit of observation is a farmer-variety-quality combination in a week when a positive quantity is sold. The results show odds-ratios and z-statistics for logit regressions. Landholding, a variety dummy for chandramukhi potatoes and a dummy for low-quality potatoes are included. Standard errors are clustered at the village level.