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

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Abstract

This paper investigates the nature of contracting and the role of asymmetric price information between potato farmers and local trade intermediaries that buy their crop, in West Bengal, India. Farmers in randomly chosen villages were provided daily price information on prices in neighboring wholesale markets where the traders re-sell the potatoes. On average traders earn margins (net of transport costs) ranging from 55 to 100% of farmgate prices, depending on time of year. Information provision resulted in no change in average margins, but caused farm-gate prices and traded quantities to shrink (resp. expand) significantly in villages with low (resp. high) wholesale prices. The evidence is inconsistent with long term contracts between farmers and traders. They are consistent with a model of ex post bargaining, in which lack of direct access to wholesale markets depress outside options of farmers in bargaining with local traders and prevent informational interventions from benefitting farmers.

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1 Introduction

It is often argued that farmers in developing countries are unable to get a remunerative price for their produce. This lowers the profitability of agriculture and prevents diversification into cash crops and integration into the world economy. Large gaps between retail and producer prices for export goods have been documented: The average margin between consumer prices in the US and world prices for beef, coffee, oil, rice, sugar and wheat increased by 83 percent between 1975 and 1994 [Morisset, 1998]. These large gaps are also associated with limited pass-through of world price increases to the 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 et al. [2002] claim that no more than 40-50 percent of the increased cashew export prices in the 1990s went to farmers in Mozambique.

The evidence points to the important role of trade intermediaries, or middlemen, in agricultural marketing and trade. More specifically, middlemen margins might limit the pass-through of the benefits of trade liberalization to primary producers. Acknowledging their role may help us understand why globalization has been accompanied by increased inequality [Bardhan et al., 2010]. However, there is not much micro-level empirical evidence on the actual margins earned by these middlemen, and their determinants. What are the relationships between agricultural producers and the middlemen whom they sell to? How do these affect the prices that farmers receive, the returns to crop diversification, and the pass-through of price changes? The answers to these questions can help us understand the impact of different interventions, and in turn can inform public policy aimed at increasing producer prices, improving agricultural production and reducing rural poverty.

An important source of middlemen margins could be the asymmetry of price information between farmers and middlemen. If middlemen have more accurate information about the prevailing price in the market, they would have the incentive to understate this price when buying from farmers in order to lower the price they pay farmers. Removing this information asymmetry could then conceivably allow farmers to earn higher farm-gate prices. Alternatively, if farmers can sell directly in wholesale markets, improved information about prevailing prices could help them arbitrage across different markets or selling times so as to earn higher prices. If so, there is low-hanging fruit for public policy makers: disseminating price information to farmers using cellphones or other low-cost IT-based interventions may increase farm-gate prices which in turn could boost agricultural productivity.

A number of recent papers have examined the effect of introduction of improved price information via cell phones. Many of these pertain to contexts where farmers sell directly to wholesale or retail markets rather than to local intermediaries. In South Indian fishing markets, Jensen [2007] finds that the introduction of cellphone technology allowed fishermen to find out 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.

By contrast, in more recent work, Fafchamps and Minten [forthcoming] examine a context in Western India where farmers do sell to itinerant traders. They find that providing farmers with free subscriptions to a daily SMS service that delivered (among other things) price information for important crops had no impact on the average prices they received, though it did increase the likelihood that farmers sold at a wholesale market instead of selling to a trader. In discussing their findings, the authors speculate that the contracting relationship between farmers and traders, and the traders' comparative advantage at transporting produce may be the factor driving their results. If markets are not truly anonymous and trust between farmer and trader is important (say, due to trade credit or quality concerns), then farmers could be locked into relationships with specific traders that prevent competition. In such a situation more accurate price information may not improve farmers' outcomes.

The conflicting empirical evidence suggests that the effect of price information on farmer outcomes may be context-specific. In markets where intermediaries play a relatively unimportant role, increased access to information may have relatively straightforward effects. In markets where intermediaries exist due to market imperfections (e.g. credit constraints, quality control or branding) the effects can be quite different. Much again might depend on the nature of contracting between farmer and trader. This paper attempts to shed light on these aspects in the context of potato marketing in West Bengal.

In this paper we report on a field experiment conducted in 72 villages in two districts of West

Bengal in 2008, in which we provided potato farmers in randomly selected villages with daily price information from neighboring wholesale markets. The information was provided in two alternate ways: in 24 villages it was posted in public places and available to all persons to read (or have read to them). In another 24 villages, we delivered the information to four randomly selected farmers through private phone calls. We find significant middlemen margins on average, constituting between 25-30 percent of the wholesale market price, while farmgate prices are approximately 55 percent of this price (the rest being accounted by transport, handling and storage costs).[1] Neither information intervention had a significant average impact on these margins, consistent with the findings of Fafchamps and Minten [forthcoming].

We however find significant heterogeneous treatment effects. In villages located in market areas with low wholesale prices, traded quantities as well as farm-gate prices fell significantly as a result of the information interventions. There was a tendency for these to rise in areas with high wholesale prices. This indicates the possibility that providing information to farmers may end up hurting them in some situations.

To interpret the empirical results, we develop and test alternative models of bilateral contracts between farmers and traders. The results turn out to be inconsistent with predictions of long term (ex ante) contracting models. Such models predict that quantities traded will unambiguously increase with a reduction in asymmetric information, due to a reduction in screening distortions. This contrasts with the finding that quantities traded fell significantly as a result of the interventions when wholesale prices were low.

Instead, the empirical results are consistent with a model of ex post bargaining, in which 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 take their produce to a local market and sell to a different trader who will also resell it in the wholesale market. This mirrors anecdotal evidence we gathered through detailed conversations in the field. Farmers describe a potato sale as a process where they receive an ex post price offer from a local intermediary they have customary dealings with. They are free to either sell or not, and can decide upon the quantity to sell. Their outside option is to carry their produce to a local

[1] Our findings echo the conclusions of previous work: In his 1998-99 study of 136 potato farmers in 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.

market, and try to sell to other local intermediary they know at the market who is willing to buy from them. Farmers are unable to sell directly in the wholesale market. Wholesale buyers have concerns about product quality and prefer to buy in bulk from local trade intermediaries they know personally and have a long term relationship with; they do not want to negotiate small volume trades with a large number of farmers.

The ex post bargaining model helps explain why price information interventions may not have significant average effects, while causing farm-gate prices and quantities to go down significantly in some locations and go up in others. This is essentially a model of signaling (rather than screening), whereby traders in the village may potentially reveal their information about the wholesale price through the farmgate price they offer the farmer. We show that this model has a continuum of partially separating equilibria, characterized by intervals of wholesale prices with pooling of the offered price. The range over which pooling takes place depends on the extent of prior informational symmetry between farmer and traders. Providing better information to farmers can cause the ranges over which pooling takes place to shrink, as the equilibrium moves closer to a perfectly separating equilibrium. This can result in an increase in farm-gate price in some instances, and a decrease in others. Trader price offers leave farmers indifferent between accepting and not, both before and after the intervention. As the intervention leaves their outside option unaffected, the average treatment effect is zero.

We show that other predictions of the ex post bargaining model are also consistent with the facts: farmers obtain a higher price (gross of transport costs) if they reject the local traders offer, and sell to a different intermediary in the local market. The likelihood of this happening is higher when the wholesale market is higher, and in locations with higher transport costs.

The main implication of these findings is that high middlemen margins in West Bengal potato result from a combination of weak formal and informal institutions in marketing arrangements. There do not exist any formal centralized wholesale markets for potatoes in West Bengal where farmers can sell directly. Problems of trust arising from quality uncertainty and trade credit imply that trades are heavily reliant on reciprocal buyer-seller relationships. This is true at the bottom of the marketing chain where farmers sell to local intermediaries, and at the next rung where the latter sell to wholesale buyers. The relation between farmers and local intermediaries is characterized by ex post bargaining rather than long term ex ante contracting. In such an environment farmers do not gain from interventions that reduce the asymmetry in access to information.

The paper is organized as follows. The next section describes the context of potato production and trades in West Bengal. This is followed by a description of the informational interventions we implemented, and of the survey data collected. We then explain the predictions of ex ante contract models, and thereafter test them. This is followed by an exposition of the ex post bargaining model, and a description of the concordance between its predictions and the facts. We conclude with a summary of the results and principal implications.

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 crop in the two districts in our study: Hugli and West Medinipur. The large majority of farmers sell their potatoes to local intermediaries (known as *phorias*) who re-sell them in neighbouring wholesale markets (*mandis*) to wholesale buyers. The latter in turn sell them to retailers in nearby urban locations (such as Kolkata), or neighboring states such as Assam, Orissa and Andhra Pradesh.

Potatoes are a winter crop; they are planted between October and December, and harvested between January and March. Farmers have the option of selling at harvest time, or placing potatoes in home stores (from where they would have to be sold within two or three months) or in cold stores, where they can survive until October, when the new planting season begins. In our data from 2008, 42 percent of the quantity produced by sample farmers was sold immediately upon harvest. Some was allocated to home consumption, some was saved for seed, and some was lost to spoilage. Of the amount still remaining, about 37 percent was put into home stores, and the remaining 63 percent was put into cold stores.

Cold stores are privately owned in these areas, and space is widely available. The person placing the potatoes in the cold store pays a fixed rental rate per bag, plus a handling fee. The rent is not dependent on the duration for which potatoes are stored, presumably because once potatoes are released from the cold store, there are no new potatoes that can be stored mid-way through the season in the space that becomes available, and so this space must remain un-utilized. The cold-storage gives a receipt for the potatoes that have been placed in the cold store; these receipts (called potato "bonds") are also traded. These bonds are also traded. To release potatoes, the holder of a bond must visit the cold store and request that the potatoes be removed from the cold store. They are then thawed and dried, before they can be sold later that day or the next.

Farmers typically sell their produce to local intermediaries: 72 percent of the potatoes sold by our sample farmers in 2007 were sold to small traders (*phorias*), another 11 percent to other larger traders, and 8 percent to moneylenders through bilateral transactions. *Phorias* aggregate potatoes and sell them up the chain to wholesale buyers (*arraddars*). *Phorias* might be entrepreneurs selling to wholesalers on a case-by-case basis, or might be their commissioned agents entrusted with the responsibility of sourcing potatoes. Most *phorias* have a network of farmers from whom they buy on a regular basis – farmers who have a track record of selling uniform quality potatoes and not cheating them by mixing potatoes of different grades into their sacks. Payment for potatoes is often delayed, and so farmers also prefer to sell to traders with whom they have a good record of trade credit repayment. However, anecdotal evidence suggests that farmers and traders are not bound to trade exclusively with each other: farmers are free to change the trader they sell to, at any point.

3 The Experiment

Our experiment was conducted in 72 villages drawn through stratified random sampling from two potato-growing districts of West Bengal, Hugli and West Medinipur. The villages were divided into three groups of 24 villages each. Villages were selected such that they were at a minimum distance of 8 kilometres from each other, so as to avoid information spillovers. In the control villages, we did no intervention of any kind. In the other two groups of villages, we delivered daily price information about the potato prices in up to two nearby local wholesale markets and the nearest metropolitan market. To collect this information, we hired an agent in each of these markets who surveyed leading buyers (wholesalers or retailers) to find out the price at which they had made purchases at the end of each trading day. The agent then called in these prices 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.[2] Price information was collected daily from June to November 2007 and from January to November 2008.

[2] The two most common varieties of potatoes grown are jyoti (accounting for 70 percent of potatoes produced) and chandramukhi (accounting for 20 percent). All our regressions are run on only these two varieties, with a variety dummy included.

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, we requested the service provider to block all 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.[3]

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 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.

Our tele-callers 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 did not know why this was being done or how farmers could use this information. The village vendors were also given the same instructions.

4 The Data

Our data come from surveys of 1599 households from a stratified random sample of potato farmers in the 72 villages in our study.[4] The sample consists of farmers who planted potatoes in 2007. In

[3]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.

[4]Although we collected a larger sample of 1726 farmers, we analyze here data only for producers of the jyoti and chandramukhi varieties of potatoes, which together account for about 90 percent of the potatoes grown by

2007, we did three types of surveys: In February-March, in addition to household demographics, assets, land ownership and credit, we asked them about the crops they had planted until the end of December 2006 and input use. We call this the production survey. In June we asked farmers about their harvest of potatoes and their sales after the harvest. From July to November, we did fortnightly surveys to ask them about subsequent sales, from home stores and cold stores (called trading surveys). In 2008, we did a production survey in January-February. This was followed by fortnightly harvest and trading surveys from March until November.

Price information was delivered from June to November 2007 and from January to November 2008. Unfortunately by the time we started delivering price information in June 2007, sample farmers had sold about 80% of the potato harvest already. In fact several households had no stocks of potatoes left. This greatly dampened the effectiveness of our intervention; farmers were unable to act on the information we provided. For this reason this paper only reports data from the 2008 round of the intervention and surveys. All villages and households were in the same treatment or control group in 2008 as they had been in 2007. However it should be borne in mind that the effects we report are the cumulative effect of the 2008 intervention and the 2007 one.

4.1 Price Information of Farmers

Wholesale transactions between the *phorias* and wholesalers being bilateral, prices in the wholesale market are not in the public domain. Small farmers therefore do not have the opportunity to learn directly about prices prevailing in the neighboring wholesale market. Their main source of information is the *phoria* they deal with directly: 62 percent of the farmers in our sample reported in 2007 that they learned about potato prices from the *phoria*. Note that telecommunication facilities are available: 51 percent of the villages in our sample had telephone booths, 23 percent of the households reported they had landline phones and 33 percent 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 local neighbouring market. When asked why they could not access information concerning prices at which *phorias* were selling in the wholesale market, they reported having no contacts in the wholesale market who could be willing to give them this information.

Consistent with this, when farmers were asked what the local market price has been recently,

the sample in 2008.

the prices they reported did not match prevailing wholesale market prices at which *phorias* were selling, but the price that they expected to receive if they were to make a sale in a local market. The average price they reported (Rupees 2.30 per kg) was much closer to the gross price they received in these markets (Rupees 2.19 per kg), and substantially below the average price received by *phorias* (Rupees 4.77 per kg).

There is also reason to believe that it is difficult to forecast wholesale (mandi) prices accurately on the basis of past trends. The graph in Figure 1 plots weekly averages of mandi price data for jyoti potatoes using the government's Agmark mandi price data set for West Bengal. The data clearly show that price paths over the course of the year can vary considerably: in particular, as a result of the unexpectedly large harvest of jyoti potatoes in 2008, prices fell in these mandis instead of rising as they did in the previous three years. Shocks to excess demand in distant destination markets or intervening transport bottlenecks can also cause large temporal variations in prices that cannot be predicted on the basis of local production information. Large year-to-year variations are apparent in Table 1, which shows an analysis of the variance in weekly mandi prices from the second half of 2007, all of 2008 and the first half of 2010. There is considerable variation in mandi prices across different mandis, and over time: both the mandi dummies and weekly dummies explain significant fractions of the total variation in mandi prices (see column 1). These two factors together explain 25 percent of the total variation in mandi prices. Allowing for mandi-specific weekly time variation (column 2) does not improve the fit much. Instead, as column 3 shows, year-to-year variation in mandi prices is substantial: once year dummies are included, 87 percent of the variation can be explained. It is clear that from year to year the mandi prices for potatoes can fluctuate quite substantially. The interactions of mandi location with year are also significant, indicating that some role is also played by time varying locality-specific supply shocks. Given this, it is hard for farmers to predict what price the *phorias* are receiving in the neighboring wholesale market in any given year, except for what they can infer from price reports or offers made by the *phoria*.

4.2 Descriptive Statistics

Summary statistics for our sample are presented in Table 9. Standard errors are not clustered. The mandis that we were providing price information for, were on average 8.5 kilometres away from the villages where our sample farmers resided. This distance was higher in Medinipur West (9.65

km) than in Hugli (7.26 km), as Medinipur West is more spread out and sparsely populated. The average farmer had a small landholding at just over 1 acre. Cultivated land in 2008 was slightly above this, due to crop rotation and leasing in. Thirty percent of the annual cultivated area was devoted to potatoes. Given that potatoes can only be planted in the fall season, this implies that a substantial fraction of the area cultivated in that season consisted of potatoes. As stated earlier, villages have telecommunication links: 51 percent of the villages in our sample had telephone booths where one could make a phonecall for a fee, 23 percent of the sample households had landline phones and 33 percent had cellphones. Connectivity is better in the district of West Medinipur than in Hugli. Despite this, 62 percent report that they rely on the *phoria* for price information, although 33 percent also collect price information from neighbouring markets. Another 14 percent state that their friends are the source of their information. As stated above, this reliance on the *phoria* for price information mirrors the fact that almost all farmers sell to intermediaries (mainly *phorias*, but also larger traders or moneylenders). Only 7 percent reported that they sold at least once in the market directly. These fractions change only slightly in 2008.

Table 2 shows how these descriptives vary by treatment groups for data collected before the intervention began in June 2007. This allows us to check that the sample was balanced across treatment groups. As can be seen, the differences across treatment groups before the intervention are mostly small and insignificant. Exceptions are that the control villages were more likely to have a public phone booth and that the control group farmers were more likely to report that they learned about potato prices from the *phoria*. Taken together these two features do not indicate a clear pattern that control group farmers should have had better information about market prices.

Table 3 show patterns in the mandi prices (that the *phorias* received) and prices received by control group farmers in 2008, depending on whom they sold to. As can be seen, on average farmers received (net of transport costs) only 43 percent of the mandi price. This proportion was lower in Medinipur (34 percent) than in Hugli (51 percent). The price varies slightly by whom they sell to: farmers selling to the market directly receive a slightly higher gross price than those who sell to the *phoria*. However this difference is reversed when transport costs are accounted for, since the farmer is more likely to have to incur transport costs when they sell to the market.

We also asked farmers if they tracked potato prices in local markets, and if so, what the price was when they last tracked it. Note that farmers' tracked prices were much closer to the prices they received than the actual mandi prices (i.e. the prices at which phorias sold to larger traders in the market). Our interpretation is that when asked to report the mandi price, most of them interpreted the question to mean the price they themselves were likely to get if they were to take their potatoes to a local market, rather than what the phorias were getting.

The graphs in Figure 1 allow us to see how mandi prices (in the mandis relevant to our sample) changed over the course of the year. We consider two potato varieties here: jyoti and chandramukhi. The former comprises approximately 70% of the overall crop, and the latter 20%. The year 2008 was a bad year for jyoti producers: a large harvest prevented prices from rising through the year. In contrast, the prices for Chandramukhi potatoes rose significantly. Turning to Figure 1 we see that the price path for chandramukhi potatoes is reflected in the graph for Medinipur, whereas in Hugli the mandi prices were essentially flat.[5] The yellow curve depicts tracked prices and we can once again see that they were substantially below mandi prices and much closer to the prices that farmers received. The prices that farmers received from *phorias* were substantially below the mandi price and fell even lower as the year progresses. Prices received from selling to the market followed a similar path, although they were higher on average. The pattern of farmer prices was similar in both Hugli and Medinipur, even though mandi prices rose in Medinipur instead of staying constant.

Figure 1 shows how farmer prices (net of transport costs) varied by treatment group. This provides a visual impression of the effect of reducing asymmetric information. There is no evident difference between the average prices received by control group farmers and either of the two intervention groups. The gap between the mandi price and the net farmer prices allows us to do a rough calculation of the middlemen margins (which were unaffected by the intervention).

As can be seen, the mandi prices were in the range of Rupees 4.5 to 5.5 during the entire period from week 12 (end of March) to week 50 (end of November). In contrast, net farmgate prices (the blue, green and maroon lines) were around Rupees 2 towards the beginning of the period, falling towards Rupees 1.5 towards the end. This gap of about Rupees 2.5 to 3 can be accounted for by transport, handling and storage costs, as well as middlemen margins as can be seen from the equation below:

$$\text{Mandi price} = \text{Net farmgate price} + \text{Transport, storage and handling costs} + \text{Middleman margin}$$

[5]There are very few price observations at the very beginning and end of the year since few potatoes are traded during those times.

Although we did not interview traders directly, we can estimate an upper bound for the transactions costs they might incur by using the cost data provided to us by farmers.[6] Based on farmer reports, transport costs were 24 paise per kilogram. Handling and other costs were 35 paise per kilogram while storage costs were 89 paise per kilogram on average. This allows us to estimate the middleman margin as

$$\text{Middleman margin} = \begin{cases} \text{Rs.}4.5 - 2.5 - 0.24 - 0.35 = \text{Rs.}1.41 & \text{per kg when sold from field or home stores,} \\ \text{Rs.}5.5 - 1.5 - 0.24 - 0.35 - 0.89 = \text{Rs.}1.52 & \text{per kg when sold from cold stores.} \end{cases}$$

This calculation suggests that net middlemen margins ranged from 27 to 30 percent of the wholesale market price, and 55 to 100 percent of the farm-gate price, depending on when in the year they sold the crop.

5 Theoretical Analysis: Ex ante contracts

Before examining the impact of our intervention, we organize our thinking by presenting a theoretical analysis of the bilateral contracting between farmer and trader in our context. The information intervention is modeled as moving a farmer from asymmetric information about the prevailing price in the market, to symmetric information. We consider first ex ante contracts, where the price and quantity are determined simultaneously.

A farmer F has an exogenous quantity $\bar{q}$ of potatoes to sell to a trader T, who can re-sell it 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. 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 is the existence of this differential cost that motivates the farmer to sell to the trader. It can represent differences in transport cost (owing to economies of scale) and in marketing connections at the mandi.

[6] The farmers' reports of these costs are likely to be an upper bound since traders are likely to take advantage of economies of scale in transport and handling.

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 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. For most part we shall assume that both parties are risk neutral. Later in this section we shall argue that the main predictions of the model continue to apply when they are risk-averse.

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 $\Pi(v - t)$.

We follow the approach of Myerson and Satterthwaite (1983) and analyze incentive efficient bilateral contracts. Let λ denote the welfare weight of the trader relative to the farmer. This represents the relative bargaining power of the trader. The case of a perfect monopsony corresponds to one where $\lambda = \infty$, i.e., where the farmer has no welfare weight at all. At the other extreme is perfect competition, where $\lambda = 0$. Whether λ is larger or smaller than one affects the nature of optimal contracts.

The timing of moves is as follows. The contract is designed at an ex ante stage, when neither trader or farmer have acquired any information about prices. It can be thought of as an implicit long-term contract, applicable to trading over many successive points of time. Whatever competition exists operates at this ex ante stage. So the ex ante contract is designed to maximize a weighted sum of ex ante expected payoffs of the trader and the farmer, with λ being the relative welfare weight of the trader. The Revelation Principle applies to this context, so without loss of generality attention can be confined to the following trading mechanism.

On any given date, the farmer receives a signal 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 a function of the farmers signal and the price report 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 participation constraints

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

and

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

5.0.1 Symmetric Information

We consider as a benchmark the case where the farmer's signal σ is the same v observed by the trader. Here the distribution G is degenerate, concentrated entirely at the true value v. The efficient contract with symmetric information then maximizes

$$\mathcal{U}(r(v) + u(\bar{q} - r(v))) + \lambda \mathcal{V}(vq(v) - r(v)) \tag{5}$$

subject to

$$vq(v) \geq r(v) \geq \Pi(v - t) - \mathcal{U}(\bar{q} - q(v)) \tag{6}$$

Lemma 1 *With symmetric information, 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* $\Pi(v) - \Pi(v - t) \geq s \geq 0$.

All proofs are provided in Appendix P. The logic is simple: the 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.

5.0.2 Asymmetric Information

Return to the problem with asymmetric information. 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:

$$r(v) = vq(v) - \int_{vl}^{v} q(\tilde{v})d\tilde{v} - \underline{V}, \quad \underline{V} \geq 0 \quad \text{and } q(v) \text{ nondecreasing.} \tag{7}$$

This is a convenient representation of the constraints imposed by asymmetric information. $\underline{V}$ 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

$$\int_{\underline{v}}^{\bar{v}} [\mathcal{U}(vq(v) + u(\bar{q} - q(v)) - \int_{\underline{v}}^{v} q(\tilde{v})d\tilde{v} - \underline{V}) + \lambda\mathcal{V}(\int_{\underline{v}}^{v} q(\tilde{v})d\tilde{v} + \underline{V})]dG(v|\sigma) \tag{8}$$

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 $q(v)$ will turn out not to bite owing to the assumption on the monotonicity of the inverse hazard rate. So we shall ignore it from now on. Hence the problem reduces essentially to selecting the quantities traded $q(v)$ to maximize (8) in an unconstrained fashion.

Proposition 2 *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*

$$q(v|\sigma) = q^*(v - \mu\frac{1 - G(v|\sigma)}{g(v|\sigma)}) \tag{9}$$

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

$$r(v|\sigma) = vq(v|\sigma) - \int_{\underline{v}}^{v} q(\tilde{v}|\sigma)d\tilde{v} - \underline{V} \tag{10}$$

The result states that asymmetric information causes quantities traded to shrink in general, relative to 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 compared with the case of symmetric information, a consequence of the trader's monopoly over information regarding v. The bargaining power of the two parties (i.e, welfare weight λ and t which defines the outside option of the farmer) affects this markup only through μ, the weight applied to the inverse hazard rate of G.

The main implication of the result is that asymmetric information causes an inefficient shrinkage of quantities traded, except in the case where the trader has greater bargaining power ($\lambda > 1$) and t is large, i.e., the farmer's outside option of going to the market directly is low enough. We shall refer to this as the *unconstrained monopsony* case, as 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 gets traded in each state ($q(v) = q^*(v)$), while the 'fixed fee' $\underline{V}$ is set equal to

$$\underline{V}^*(t) \equiv \int_{\underline{v}}^{\bar{v}} [\{v - \frac{1-G(v|\sigma)}{g(v|\sigma)}\}q^*(v) + u(\bar{q} - q^*(v)) - \Pi(v-t)]dG(v|\sigma) \tag{11}$$

so that the farmer is indifferent between participating or not (i.e., (4) is met with equality). As all the surplus goes to the trader, the incentive constraints do not bite as they do not generate any externalities. The threshold t^* is defined by the property that $\underline{V}^*(t^*) = 0$.

If $t < t^*$ this solution is no longer feasible: i.e., the farmer's outside option of selling in the market directly binds. In such cases, an inefficient contraction in trade volume must occur: $\mu > 0$ is chosen so that

$$\int_{\underline{v}}^{\bar{v}} [\{v - \frac{1-G(v|\sigma)}{g(v|\sigma)}\}q^*(v - \mu\frac{1-G(v|\sigma)}{g(v|\sigma)}) + u(\bar{q} - q^*(v - \mu\frac{1-G(v|\sigma)}{g(v|\sigma)})) - \Pi(v-t)]dG(v|\sigma) = 0 \tag{12}$$

while the fixed fee $\underline{V}$ is set at zero. We refer to this as the *constrained monopsony* case.

In the case where the farmer has greater bargaining power — the *competitive* case – with $\lambda < 1$, the fixed fee $\underline{V}$ is set at zero, and $\mu = 1 - \lambda$. Hence trade volumes are inefficiently low in either the competitive or constrained monopsony cases. This is in order to limit the tendency of the trader to understate v: if the trader claims that v is low then trade volumes shrink more than they would under symmetric information. The lower the v, the greater the shrinkage of traded volumes.

Having thus characterized the optimal contract, we now examine the comparative static effect of varying the information of the farmer. The simplest way to do this is to compare the optimal contracts with asymmetric and symmetric information respectively.

In the unconstrained monopsony case, the quantity traded is unaffected by asymmetric information, and so are transfers. In the other two cases, quantities traded are uniformly lower, except when $v = \bar{v}$. Moreover q co-moves more with v under asymmetric information — owing to the strategic reduction in trades when the trader reports low v. Conversely, *going from asymmetric to symmetric information either has no effect at all (in the case of an unconstrained monopsony), otherwise it raises the level of traded quantities, while reducing the extent to which they co-move with v.*

What happens to prices? Suppose we are in the competitive case. Under symmetric information $p^F(v) = v$, but with asymmetric information

$$p(v) = v - \frac{1}{q(v)} \int_{\underline{v}}^{v} q(\tilde{v}) d\tilde{v} \tag{13}$$

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, despite farmers having 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.[7] Hence in the competitive case we only get a general result concerning the level of prices, but not the extent to which they co-move (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 constrained 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 traders ability to extract monopsony rents from the farmer.

[7] 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.

Hence the more robust prediction of the ex ante contract model is the effect on quantities traded, in which levels rise and co-movement falls as a result of better information. Indeed, this same result holds also in the case of risk-aversion (see [Hart, 1983]). The same logic applies: traded volumes shrink relative to the first-best when traders report a low mandi price in order to discourage them from under-reporting. Efficient trade volumes are determined by the tradeoff between ex post efficient trade and the need to limit information rents accruing to traders.

To what extent do these results concerning the effects of reduced informational asymmetry hold locally, i.e., when we have a slight reduction in the asymmetry? This is a more complex question, compared with the 'global' comparison above. 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

$$q(v|\sigma, n) = q^*(v - \mu \frac{1 - G(v|\sigma, n)}{g(v|\sigma, n)}) \tag{14}$$

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.[8] 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

$$q(v|\sigma, n) = \bar{q} - [(1 + \alpha)v - \alpha(\sigma + \frac{n}{2})]^{-1} \tag{15}$$

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

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

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

$$p(v|\sigma,n) = v - \int_{\sigma-\frac{n}{2}}^{v} \frac{\bar{q} - [(1+\alpha)\tilde{v} - \alpha(\sigma+\frac{n}{2})]^{-1}}{\bar{q} - [(1+\alpha)v - \alpha(\sigma+\frac{n}{2})]^{-1}} d\tilde{v} \tag{16}$$

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

6 Empirical Analysis

We now turn to the data to examine the effects of the information intervention. The empirical analysis will be presented as follows. First, we show that our intervention changed farmers' information sources and information set, thus confirming that our intervention did take place as planned. Next, we analyze the impact of the intervention on the farmers' quantities sold and price received. Finally, we examine the effects on area planted, quantity harvested, and the allocation of quantities into storage. Given that the intervention began in 2007 and farmers knew that it was going to continue throughout 2008, farmers could have changed their planting, input and sales decisions in anticipation of the effects of the information they would have. We will then take these results together and interpret them with reference to the ex ante contracting theory described above.

6.0.3 Effect 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.

Table 4 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 wholesale price tracking: farmers were more likely to report that they tracked prices in villages where we posted daily price information in public locations. With private information the positive significant effect is smaller and only seen on farmers who received phonecalls from us. Column 2 shows that there were similar effects on phonecall receipients and non-recipients in the private information treatment, and the average farmer in the public information treatment: they reduce 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 either. 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 of a long list of categories available we interpret their report as indicating the price information intervention. There is thus evidence that the intervention did work as planned: farmers who received the intervention were more likely to track market prices, were more likely to have tracked the prices recently, and were more likely to report that they received the information from a category other than traders, friends, neighbours, relatives, caste members, government officials, cooperative members or NGO employees.

7 Testing Predictions of the Ex Ante Contracting Model

7.0.4 Effect on quantity sold and price received by farmers

Next, we examine the effect of the interventions on the farmers' sales and prices received. We have detailed data about potato sales transactions collected through fortnightly surveys. However, to analyse the data at the weekly level we must model the dynamics of farmer decisions of whether and when to sell, and the non-stationarity across different times of the year because their stocks and the time horizon over which they are optimizing changes week-by-week. In addition, we would have to account for seasonal changes of the market price and the role of future price expectations. Putting this aside for future work, in this paper we focus on aggregate sales and average price received within the year. All potatoes must be sold within the year (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) Aggregating over all transactions within the year for each farmer[9], we avoid modeling the dynamics and the endogeneity of the sales decision.[10]

The effects on the annual quantity sold and the average price received (net of transactions costs paid by the farmer) are shown in Tables 5. The unit of observation is a farmer-variety-quality combination. We include variety and quality dummies, as well as a district dummy for Medinipur. In addition we 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:

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

where $y_i t$ is the dependent variable: price received, quantity sold or the tracked price reported for farmer i, variety j and quality q. Private information and Public information are dummy variables to indicate which treatment group the farmer was in. Private information farmers could also be phone recipients in which case they would also receive a value 1 for the Phone recipient dummy (this dummy is included in column 2). In that case private information should then be interpreted as the effect on farmers whose village received the private information treatment but who did not personally receive phonecalls. Instead any effect on their outcomes would occur through the spread of information from the phonecall recipients through to them. In Table 5 we see in column (1) that although the sign of the coefficient is positive for all intervention dummies, the coefficients are not significantly different from zero. In column (2) we include mandi fixed effects into the regressions. This way we are now comparing the effect of the intervention across different treatment groups within the catchment area of the same mandi. This reverses the sign of the coefficients, but they remain non-significant. Also, in contrast to the prediction of the ex ante contract theory, the point estimate of the treatment effects on quantity is negative. Columns (3) and (4) show that analogous to the findings of Fafchamps and Minten [forthcoming], there is also no impact of the intervention on the average net price. Note however that the theory does

[9]In fact, for each farmer we know each variety that he produced and the amount of his harvest of each variety that was of high or low quality. Our data are thus at the level of farmer-variety-quality.

[10]Another way to avoid the dynamics and endogeneity issues is to focus on weekly sales occurring late in the year, when farmers must sell most of their remaining stocks and so the issue of future price expectations is not so important. We can then examine the effects of weekly variations in prices. However even with this there will be selection effects: farmers' price expectations in the past will have determined whether they still have unsold stocks at the end of the year.

not deliver clear predictions about the average impact on prices.

Next we examine possible heterogeneity of treatment impacts with respect to the local mandi price. As the analysis of mandi price variance earlier showed, about three quarter of the cross-mandi variations are fixed over time, and the remaining quarter is time-varying. Hence most of these variations reflect locational characteristics that do not vary over time. The regression in column (1) now takes the following form:

$$y_{it} = \beta_0+\beta_1 p_{imt}+\beta_2\text{Private information}_i+\beta_3\text{Public information}_i+\beta_4\text{Private}_i\times p_{imt}+\beta_5\text{Public}_i\times p_{imt}+X_{it}+\epsilon_{imt}$$

These results are presented in Table 6. The intervention dummies now indicate how the intercept of price and quantity changed as a result of the intervention (in other words, when the mandi price was a hypothetical value of zero), whereas the interaction terms indicate the variation of the dependent variable with the mandi price.

As column (1) shows, there are significant heterogenous treatment effects. The intercept fell (although the coefficient is not significant) and the interaction effect is significantly positive. This result becomes sharper when we focus on the effect on phone non-recipients, and becomes even stronger when we include mandi fixed effects in column (3) and (4). Using this to estimate the impact in areas with low mandi prices (at the 10th percentile of the mandi price distribution), we see a statistically significant negative impact on quantity traded with both information treatments (in the specification with mandi fixed effects). The quantities shrink by a factor of one-third. Effects on mandis with high prices are positive on the other hand, though statistically insignificant (excepting the case of the private information treatment in the specification without mandi fixed effects).

These results are inconsistent with the ex ante contract model, where information interventions are predicted to always raise the quantity traded. Instead we see the quantity traded shrinking in some locations and rising in others, with a zero average effect.

Consider next columns (5) – (8) which use the net price received as the dependent variable. The sign patterns of the treatment effects and their interaction with the mandi price are similar to those for quantity traded: in mandis with low (resp.) prices the treatment effects were negative (resp. positive). These are statistically significant only for the private information treatment (and in the case of the mandi fixed effect specification). The magnitude of the effect ranged between Rs 0.33 − 0.44, against an average farmer net price of a little over Rs 2. Hence the price effects were also large, and tended to be in the same direction as the quantity effects.

Finally, turn to treatment effects on farmer decisions to plant, quantities they produced, sales and storage decisions. Since the interventions commenced in 2007 before they planted the 2008 crop, they may have affected farmer expectations of returns from potato cultivation and the benefits of selling late in the year when prices traditionally rise. Tables 7 and 8 show that the area planted with potatoes did not increase, and the increase in quantity harvested was not significant. But the private information intervention was associated with a significant rise in yield of the order of 12%. The percent of harvest sold did not increase. The public information treatment induced a 11% shift of output to sales in the last period of the year when prices traditionally rise. In 2008 prices failed to rise at the end of the year, implying that those holding out for late sales did not benefit. These results indicate that the information treatments did cause changes in farmers' expectations of returns from potato, that were left unrealized.

8 An Alternative Hypothesis: Ex Post Bargaining

In this section we provide an alternative explanation of the main findings above, viz. the decrease in quantity traded in some mandis accompanied by increase in other mandis. Recall also that effects on traded quantities and prices were in the same direction, suggesting that farmers were always on their supply curve, i.e. they had the option to select q ex post after observing the trader's offers of p. This suggests trades might have been based on ex post bargaining.

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 to respond and how much to supply. They assert the absence of any ex ante contractual arrangements with the traders, and that 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.

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 do find about 10% of transactions 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 buy from village traders, not from farmers directly. Again this relates to problems with trust concerning quality and credit. Village traders are referred to as 'aggregators'. Wholesalers say it is not worth their time to enter into small transactions with large number of individual farmers they don't know personally: they prefer to delegate the sourcing of potatoes to the intermediate aggregators.

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. There is potential here for hold-up: the trader buying in the market knows that in the case of disagreement the farmer will have to take 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: TV (trader in the village), TM (trader in the market) and F (farmer). In the interests of simplicity we identify the local market with the mandi, i.e., assume that the village trader transports potatoes to the same location as the farmer in order to sell them outside the village.

Stage 0: TV and TM 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: TV offers F price p

Stage 2: F responds with either no, or yes and a quantity $q_1 \leq \bar{q}$ for sale to TV 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 TM (who observes q_2).

Stage 4: TM offers price m.

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

If TV buys from F, the former incurs a cost of w in transporting each unit from the village to mandi: so he gets net $v - w$ after selling in the mandi. F incurs a unit transport cost which is higher by t, i.e. is $t + w$.

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 some 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 TV 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 TV's offer, he will take $q_2 = q^*(\frac{\epsilon}{1+\epsilon}(v+t+w))$ to the mandi, following which TM will offer a price $m(v)$ defined by

$$m(v) = \frac{\epsilon}{1+\epsilon}v - \frac{t+w}{1+\epsilon}. \tag{17}$$

Anticipating this, the following price $p(v)$ if offered by TV 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:

$$\Pi(p(v)) = [m(v) - t - w]q^*(\frac{\epsilon}{1+\epsilon}v + \frac{\epsilon(t+w)}{1+\epsilon}) + u(\bar{q} - q^*(\frac{\epsilon}{1+\epsilon}(v+t+w)). \tag{18}$$

In the separating equilibrium this price will be offered by TV, 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

$$\frac{\alpha'(v)}{\alpha(v)} = \frac{1}{v - w - p(v)} - \frac{q^{*\prime}(p(v))}{q^*(p(v))} \tag{19}$$

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

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.

Proposition 3 *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, TV and TM. 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 TM offers $m(v)$ and F sells $q_2(v)$ to TM 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 TV $p(v)$ is lower than $m(v)$ which is offered by TM. $\alpha(v)$ is strictly decreasing if*

$$\epsilon < 1 + \frac{t}{w} \tag{20}$$

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.

Proposition 4 *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, TV and TM. 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 TV 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*

$$\beta_i = \frac{(v_{i-1} - r_{i-1} - t)q(r_{i-1})}{(v_{i-1} - r_i - t)q(r_i)}\beta_{i-1} \tag{21}$$

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 TM 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 TV 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 TV's offer (on the equilibrium path), conditional on the information communicated by the offer.

Note that the price offers $M(v)$ made by TM in the mandi equal $m(v)$ and are thus fully revealing if q_{2i} is not too large. The willingness of TM 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 TM. 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 TV 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 TM 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 TV'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 TV'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 are 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.

8.1 Evidence for 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 treatment effect will be zero.

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 other implications which can be tested.

First, for either kind of equilibrium, the farmgate price is lower than the farmer mandi price for any v. We saw this pattern in the graph in Figure 1, where throughout the year, farmers who sold in the market received higher prices than farmers who sold to *phorias*. This is verified more rigorously in Table 9, where controlling for mandi price, district and land ownership, farmers who sell at the market receive a higher price than those who sell to the *phoria* or other traders/moneylenders.

And the farmer tends to reject the village trader's offer more often and sell in the mandi as v becomes higher (provided (20) holds, i.e., the farmer has a sufficiently high transport cost disadvantage relative to the village trader). 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 10, which shows a linear probability regression of the event that the farmer sold in the market on the mandi price, after controlling for land ownership and a district dummy.

Third, 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. In Table 9 we found that farmers in Medinipur were more likely to sell in the mandi than in Hugli.

9 Conclusion

We have reported results of a field experiment providing market price information to potato farmers in West Bengal. In contrast to previous work showing that increased access to information has straightforward positive average effects on producer prices and reduced price dispersion across markets, we find that the effects of price information are conditional on the nature of the contracts written between farmer and trader, and conditional on the prevailing market price. Our analysis suggests that instead of looking merely at the average impact of the intervention, it is instructive to examine heterogenity of treatment effects with respect to the mandi price. For certain ranges of low mandi prices we found a significant negative effect on traded quantities and prices received by farmers, which is inconsistent with an ex ante contractual mechanism. These negative effects are accompanied by positive effects for a range of higher mandi prices, resulting in an insignificant average impact.

This is consistent with what was reported to us in interviews with farmers and traders. Farmers do not appear to pre-commit to selling to particular traders, and traders do not appear to be pre-committing to a price. Instead there is ex post bargaining between farmer and trader. This can explain the pattern of heterogenous treatment effects. If mandi prices are ex post lower than expected, an informational intervention makes the low realization of these prices known to the farmer, which lowers their expected outside option. This motivates the local trader to offer a lower price, which has a reasonable chance of being accepted by the farmer. Being offered a lower price, the farmer wants to sell less, leading to lower quantities traded. The converse is true when ex post mandi prices are higher than expected by the farmer: the farmers outside option rises, inducing the trader to offer a higher price and the farmer to sell more.

Here there is some competition between traders: the farmer is not compelled to sell to any given trader. Yet the farmer's outside options are limited in the bargaining between any given local trader-farmer pair: the farmer can reject a price offered by the local trader and take his potatoes to the mandi where he sells to a different trader. The competition is limited both by the sequential and spatially separated form of the two trading options, requiring the farmer to carry his potatoes to the market and then subject to whatever price is offered there. Anticipating these limited outside options, the village trader offers a price to the farmer that makes the farmer indifferent between accepting and rejecting.

The underlying cause of ineffectiveness of price information provision to farmers is the weakness of both formal and informal marketing institutions. Farmers do not have the option of taking their potatoes to the mandi and selling there to wholesalers on par with other traders. This owes to the fact that the wholesale potato markets in West Bengal are not centralized, where anyone can bring their goods for sale and receive the same market-clearing price as any other supplier (controlling for variety and quality). Many other parts of India do involve centralized wholesale markets for agricultural commodities: for example in Maharashtra or Madhya Pradesh where government agents placed in these markets evaluate the quality of produce brought by farmers and then supervise auctions in which the produce is sold at market clearing prices. Mandis in West Bengal still feature decentralized trades between large buyers and local traders engaged in bilateral long term personalized relationships. This creates entry barriers for farmers or other newcomers who intend to sell in these markets.

Consequently farmers are forced to sell to local traders, also on a bilateral personalized basis. These informal trading relationships however involve ex post bargaining rather than long term commitment to trading rules. Despite the multiplicity of traders within any village or market, farmers are locked into selling to particular traders at any given location owing to the importance of reputations on either side for trustworthy behavior. Some limited competition arises between traders in different locations, allowing them to earn large margins that grow disproportionately when wholesale prices rise. These informal relationships do not allow any risk-sharing or trade commitments. Reducing the extent of informational symmetry regarding wholesale prices then has no significant impact on farmgate prices on average, and expose farmers to greater volatility.

With regard to policy implications, the analysis of this paper highlights the importance of the role of government in organizing wholesale markets that reduce entry barriers for farmers or newcomers. Encouraging entry into marketing by retail chains integrating backwards via forms of contract farming is another way of trying to increase forces of competition that will both help farmers realize a higher price and deliver higher outputs. Any of these policy options are subject to other hazards: possibility of collusion among government regulators and buyers of produce in wholesale markets in the former case, and possibilities of predatory pricing by retail chains.

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Appendix P: Proofs

Proof of Lemma 1. 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 $vq(v)+u(\bar{q}-q(v)-\Pi(v-t) \geq s(v) \geq 0$. The result now follows. ∎

Proof of Proposition 2. With risk neutrality, the objective function (8) reduces to

$$\int_{\underline{v}}^{\bar{v}} [\{v + (\lambda - 1)\frac{1 - G(v|\sigma)}{g(v|\sigma)}\}q(v) + u(\bar{q} - q(v)) + (\lambda - 1)\underline{V}]dG(v|\sigma) \tag{22}$$

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 (22) reduces to

$$\lambda \int_{\underline{v}}^{\bar{v}} [vq(v) + u(\bar{q} - q(v))]dG(v|\sigma) - (\lambda - 1) \int_{\underline{v}}^{\bar{v}} \Pi(v - t)dG(v|\sigma) \tag{23}$$

so the problem is to maximize

$$\int_{\underline{v}}^{\bar{v}} [vq(v) + u(\bar{q} - q(v))]dG(v|\sigma) \tag{24}$$

subject to

$$\int_{\underline{v}}^{\bar{v}} [\{v - \frac{1 - G(v|\sigma)}{g(v|\sigma)}\}q(v) + u(\bar{q} - q(v)) - \Pi(v - t)\}dG(v|\sigma) \geq 0. \tag{25}$$

The unconstrained optimum involves $q(v) = q^*(v)$, which satisfies constraint (25) if and only if $t \geq t^*$. If $t < t^*$, the solution is as depicted in Proposition 2 with $\mu = \frac{\alpha}{1+\alpha}$, where α is the Lagrange multiplier on constraint (25).

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

Proof of Proposition 3. 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:

$$m(v, q_2) = \frac{\epsilon v - t - w}{1+\epsilon} \tag{26}$$

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

$$\mathcal{P}(q_2, \tilde{v}) \equiv n(q_2)q_2 + u(\bar{q} - q_2) - (t+w)q_2. \tag{27}$$

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

$$[m(\tilde{v}) - t - w]q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w)) + u(\bar{q} - q^*(\frac{\epsilon}{1+\epsilon}(\tilde{v}+t+w)) \tag{28}$$

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 (28) 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

$$\mathcal{W}(\tilde{v}|v) = \alpha(\tilde{v})[v - w - p(\tilde{v})]q^*(p(\tilde{v})) \tag{29}$$

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

$$X(v) = X(\underline{v}) + \int_{\underline{v}}^{v} \alpha(\tilde{v})q^*(p(\tilde{v}))d\tilde{v} \tag{30}$$

which implies that

$$\alpha(v)[v - w - p(v)]q^*(p(v)) = \alpha(\underline{v})[v - w - p(\underline{v})]q^*(p(\underline{v})) + \int_{\underline{v}}^{v} \alpha(\tilde{v})q^*(p(\tilde{v}))d\tilde{v} \tag{31}$$

Differentiating with respect to v, this local incentive compatibility condition reduces to the differential equation (19).

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 (19) 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 (20) 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 4. 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 (21), 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. ∎

Table 1: Descriptive Statistics, by district

	Hugli	Medinipur West	Overall
Distance to mandi (km)	7.26	9.65	8.52
	(1.08)	(0.89)	(0.70)
Village has a PCO box (2007)	0.26	0.74	0.51
	(0.08)	(0.07)	(0.06)
Owned land (2008) (acres)	0.83	1.37	1.12
	(0.03)	(0.04)	(0.03)
Cultivated land (2008) (acres)	0.98	1.47	1.25
	(0.03)	(0.04)	(0.03)
Fraction of area planted with potatoes (2008)	0.35	0.23	0.29
	(0.01)	(0.01)	(0.01)
Households with landline phones (2007)	0.16	0.28	0.23
	(0.01)	(0.01)	(0.01)
Households with cell phones (2007)	0.28	0.37	0.33
	(0.02)	(0.02)	(0.01)
Source of information			
Phoria	0.58	0.66	0.62
	(0.02)	(0.02)	(0.01)
Market	0.32	0.34	0.33
	(0.02)	(0.02)	(0.02)
Friends	0.07	0.19	0.14
	(0.01)	(0.01)	(0.01)
Sold atleast once to phoria/ML/OT (2007)	0.98	0.94	0.96
	(0.00)	(0.01)	(0.00)
Sold atleast once to market (2007)	0.03	0.10	0.07
	(0.01)	(0.01)	(0.01)
Sold atleast once to phoria/ML/OT (2008)	0.98	0.90	0.94
	(0.01)	(0.01)	(0.01)
Sold atleast once to market (2008)	0.06	0.20	0.13
	(0.01)	(0.01)	(0.01)
Fraction of sold potatoes sold to (2007)			
phoria/ML/OT	0.98	0.93	0.95
	(0.01)	(0.01)	(0.00)
Market	0.02	0.07	0.05
	(0.01)	(0.01)	(0.00)
Fraction of sold potatoes sold to (2008)			
phoria/ML/OT	0.96	0.88	0.92
	(0.01)	(0.01)	(0.01)
Market	0.03	0.12	0.08
	(0.01)	(0.01)	(0.01)

Notes: Numbers in parentheses are standard errors. ML = moneylender. OT=outside trader.

begintable[tbp]

Descriptive Statistics, by District

Table: Analysis of variance of mandi prices

Source	MSE	F	MSE	F	MSE	F	MSE	F
	(1)		(2)		(3)		(4)	
Mandi dummies	68.25	9.76 ***	56.46	7.97 ***	61.40	51.21 ***	58.47	64.91 ***
Period dummies	935.46	133.72 ***	963.61	135.97 ***	210.64	175.70 ***	183.77	204.00 ***
Mandi dummies x Period dummies			3.14	0.44	1.61	1.35 *	1.25	1.38 *
Year dummies					4368.39	3643.70 ***	3112.38	3454.99 ***
Mandi x Year dummies					32.92	27.46 ***	36.44	40.45 ***
Year dummies x Period dummies							258.57	287.03 ***
Observations	*1837*		*1837*		*1837*		*1837*	
R-squared	*0.21*		*0.22*		*0.87*		*0.90*	

Notes: Price data were collected through "vendors" we identified in wholesale potato markets neighbouring our sample villages. Vendors were paid a daily 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 use weekly averages of these prices for the months June-November in 2007, January - November in 2008 and January - June in 2010. 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).

Table 1: Analysis of Variance of Mandi Prices

Table : Descriptive Statistics, by intervention group

	Public Info	Private Info	Control	Differences between groups		
	(1)	(2)	(3)	(3)-(1)	(3)-(2)	(2)-(1)
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)
Village 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)
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)
Cultivated land (2008) (acres)	1.29	1.25	1.21	-0.08	-0.04	-0.04
	(0.05)	(0.05)	(0.05)	(0.07)	(0.07)	(0.07)
Households with landline phones (2007)	0.24	0.23	0.25	0.01	0.01	-0.01
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Households with cell phones (2007)	0.34	0.31	0.34	-0.01	0.02	-0.03
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Source of information (2007) (asked in production survey: Jan-March 2007)						
Phoria	0.63	0.65	0.74	0.11 ***	0.09 ***	0.02
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Market	0.35	0.34	0.38	0.02	0.04	-0.02
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Friends	0.13	0.16	0.16	0.03	0.00	0.03
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)

Table 2: Descriptive Statistics, by Intervention Group

Table : Price data, by district

	Hugli	Medinipur West	Overall
	(1)	(2)	(3)
Big mandi prices 2008 (prices received by phoria)	4.23	6.00	4.77
	(0.04)	(0.06)	(0.04)
Gross Prices received by farmer 2008 (control group)	2.26	2.09	2.15
	(0.07)	(0.03)	(0.03)
when sold to phoria	2.25	2.07	2.14
	(0.07)	(0.04)	(0.04)
when sold in market	2.46	2.15	2.19
	(0.50)	(0.07)	(0.08)
Net prices received by farmer 2008 (control group)	2.16	2.01	2.06
	(0.07)	(0.03)	(0.03)
when sold to phoria	2.17	2.01	2.07
	(0.07)	(0.04)	(0.04)
when sold in market	2.43	1.94	1.99
	(0.51)	(0.07)	(0.09)
Tracked prices 2008 (control group)	2.72	2.11	2.30
	(0.10)	(0.05)	(0.05)

Notes: Big mandi prices are the price data we collected on a daily basis through "vendors" stationed at the mandis. Prices received by the farmer were reported in the fortnightly surveys as the price received when farmers sold potatoes. Farmers reported the date on which the sale occurred. Gross prices are the revenue received/quantity sold. Net prices are (revenue - all handling costs paid by the farmer)/quantity sold. Tracked prices were farmers' responses to the question "what was the market price for potatoes when you last tracked it?" Prices are averaged over the year. All prices reported are Rupees/kilogram for two varieties: jyoti and chandramukhi.

Table 3: Potato Prices: Mandi Prices, Prices Received by Farmers, and Prices Tracked by Farmers

Table: Effect of interventions on price tracking behavior

	Probability that farmer tracks wholesale prices	How long ago did you last track prices? (minimum) (days)	What was your source of information?		
			Friends/Neighbours	Trader	Other
	(1)	(2)	(3)	(4)	(5)
Private info	0.80 -0.47	0.71 -2.88 ***	1.12 0.19	0.50 -1.05	1.82 0.79
Phone recipient	1.71 1.65 *	0.86 -2.78 ***	1.43 0.82	2.31 1.47	20.33 4.42 ***
Public info	8.00 3.03 ***	0.80 -2.20 **	1.03 0.04	0.49 -1.10	30.19 4.72 ***
Land	1.55 3.37 ***	0.99 -1.03	0.95 -0.51	1.21 1.97 **	1.01 0.10
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 4: Effect of Intervention on Farmers' Price Information, 2008

Table: 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	0.88	28.83	0.05	-0.07	-0.55	0.01	0.12
Phone	524.55	1.18	454.95	1.00	0.10	1.05	0.08	0.98
Public info	229.40	0.44	-253.16	-0.50	-0.10	-0.82	-0.06	-0.51
Land	2252.24	12.89 ***	2210.30	12.39 ***	-0.09	-5.03 ***	-0.07	-4.78 ***
Constant	2844.90	5.16 ***	3015.58	6.69 ***	2.20	18.26 ***	2.37	26.37 ***
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; therefore the constant refers to high-quality jyoti potatoes in Hugli district. For each regression we report coefficients and t-statistics. Standard errors are clustered at the village level.

Table 5: Average Effect of Intervention on Total Quantity Sold and Net Price Received by Farmers, 2008

Table: Panel A: Heterogeneous Effects of Intervention on Total Quantity Sold and Net Price Received

	Total Quantity sold (kg)				Net Price Received (Rs/kg)			
	(1)		(2)		(3)		(4)	
Average mandi price	-517.08	-2.91 ***			0.18	2.38 **		
Private info	-3083.74	-1.68 *	-3124.54	-2.57 **	-0.76	-2.16 **	-0.99	-4.31 ***
Private info x Avg mandi price	796.05	1.85 *	711.31	2.54 **	0.15	2.02 **	0.23	4.50 ***
Phone	1334.19	1.03	1889.66	1.36	0.09	0.29	0.07	0.22
Phone x Avg mandi price	-186.52	-0.58	-335.14	-1.00	0.00	-0.01	0.00	-0.01
Public info	-2075.32	-1.30	-3019.02	-2.79 ***	-0.21	-0.63	-0.38	-1.84 *
Public info x Avg mandi price	499.16	1.34	623.06	2.55 **	0.02	0.29	0.07	1.60
Land	353.64	0.72	2176.18	11.91 ***	-0.26	-1.93 *	-0.07	-5.34 ***
Constant	5195.77	5.36 ***	3128.35	7.23 ***	1.73	5.66 ***	2.38	27.65 ***
Mandi fixed effects	No		Yes		No		Yes	
R-squared	0.36		0.39		0.41		0.45	
Observations	*2299*		*2299*		*2299*		*2299*	

Table: Panel B: Total Effects of the Intervention at Different Levels of the Mandi Price

	(1)		(2)		(3)		(4)	
Private Info, no phone								
at 10% mandi price	-799.23	-1.09	-1083.23	-1.85 *	-0.33	-2.00 **	-0.33	-2.83 ***
at 90% mandi price	1832.83	1.80 *	1268.64	1.59	0.17	1.00	0.42	2.83 ***
Private Info, with phone								
at 10% mandi price	-0.31	0.00	-155.35	-0.19	-0.24	-1.25	-0.27	-1.55
at 90% mandi price	2015.05	1.71 *	1088.43	1.11	0.25	1.07	0.48	2.17 **
Public info								
at 10% mandi price	-642.83	-1.00	-1230.96	-2.25 **	-0.15	-0.98	-0.17	-1.47
at 90% mandi price	1007.59	1.11	829.14	1.16	-0.08	-0.42	0.08	0.51

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; therefore the constant refers to high-quality jyoti potatoes in Hugli district. For each regression we report coefficients and t-statistics. Standard errors are clustered at the village level. .

Table 6: Heterogeneous Effects of Intervention on Total Quantity Sold and Net Price Received by Farmers, 2008

Table: Effect of Intervention on Farmers' Cropping and Production of Potatoes

	Total area planted (acres)				Total quantity harvested (kg)				Yield (kg/acre)			
	(1)		(2)		(3)		(4)		(5)		(6)	
Private info	0.02	0.63	0.01	0.44	447.77	1.19	404.79	1.06	1313.16	2.96 ***	1180.54	2.93 ***
Phone			0.04	1.31			267.89	0.85			826.51	1.22
Public info	0.03	0.73	0.03	0.73	201.56	0.51	201.53	0.51	-86.90	-0.23	-86.96	-0.23
Land	0.17	13.38 ***	0.17	13.42 ***	1672.17	11.89 ***	1673.09	11.92 ***	94.11	1.19	96.95	1.25
Medinipur dummy	0.01	0.32	0.01	0.31	79.46	0.27	77.50	0.26	-331.87	-0.98	-337.89	-0.99
Constant	0.39	10.44 ***	0.39	10.45 ***	3739.78	9.07 ***	3740.42	9.07 ***	9570.63	26.97 ***	9572.59	26.92 ***
R-squared	0.44		0.44		0.42		0.42		0.04		0.04	
Observations	*3386*		*3386*		*3386*		*3386*		*3386*		*3386*	

Notes: The unit of observation is farmer-variety-quality. Variety and quality dummies are included. Standard errors are clustered at the village level. Numbers in the second column are t-statistics. *** p <0.01, ** p<0.05, * p<0.1.

Table 7: Effect of Intervention on Farmers' Cropping and Production of Potatoes, 2008

Table: Effect of Intervention on Quantity and Timing of Sale of Potato Harvest

	Percent of harvest sold		Percent sold at harvest		Percent sold middle		Percent sold late	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Private info	-0.01	-0.01	-0.05	-0.05	0.02	0.01	0.04	0.03
	(0.32)	(0.15)	(0.85)	(0.69)	(0.22)	(0.16)	(1.09)	(0.91)
Phone		-0.04 *		-0.06		0.03		0.03
		(1.95)		(1.60)		0.53		0.82
Public info	0.00	0.00	-0.05	-0.05	-0.05	-0.05	0.11 ***	0.11 ***
	(0.03)	(0.03)	(0.75)	(0.75)	(0.80)	(0.81)	2.92	2.92
Land	0.03 ***	0.03 ***	-0.03 ***	-0.03 ***	-0.03 ***	-0.03 ***	0.06 ***	0.06 ***
	4.34	4.35	(2.71)	(2.74)	(2.95)	(2.93)	6.55	6.60
Medinipur dummy	-0.08 **	-0.08 **	0.15 **	0.15 **	0.02	0.02	-0.16 ***	-0.16 ***
	(2.55)	(2.54)	2.51	2.52	0.29	0.29	(5.28)	(5.30)
Constant	0.96 ***	0.96 ***	0.53 ***	0.53 ***	0.24 ***	0.24 ***	0.23 ***	0.23 ***
	31.46	31.51	8.42	8.42	3.72	3.72	6.80	6.80
R-squared	0.53	0.53	0.07	0.07	0.03	0.03	0.12	0.12
Observations	*3386*	*3386*	*2318*	*2318*	*2318*	*2318*	*2318*	*2318*

Notes: "At harvest" is defined as weeks 1-12 of the year. "Middle" is weeks 13 to 26, and "Late" is weeks 26 to 52. The unit of observation is farmer-variety-quality. Variety and quality dummies are included. Standard errors are clustered at the village level. Numbers in the second row are t-statistics. *** p <0.01, ** p<0.05, * p<0.1.

Table 8: Effect of Intervention on the Timing of Farmers' Potato Sales, 2008

Table: Total price received by farmer as a function of whether he sold at the market

	Overall		Hugli		Medinipur	
	(1)		(2)		(3)	
Sold to market	0.36	2.78 ***	0.56	2.99 ***	0.36	1.99 *
Mandi price	0.23	5.07 ***	0.47	6.92 ***	0.19	4.65 ***
Land	-0.06	-4.01 ***	-0.07	-2.21 **	-0.05	-3.53 ***
Constant	1.44	9.06 ***	0.73	3.11 ***	1.30	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. 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. The numbers in the second column at t-statistics. Standard errors are clustered at the village level.

Table 9: Gross Price Received by Point of Sale, 2008

Table: Probability that farmer sells in the market, 2008

	Overall		Hugli		Medinipur West	
	(1)		(2)		(3)	
Mandi price	1.61	3.55 ***	0.85	-0.45	1.68	3.37 ***
Land owned	0.93	-1.10	0.86	-0.76	0.96	-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. A variety dummy for chandramukhi potatoes and a dummy for low-quality potatoes are included. Standard errors are clustered at the village level.

Table 10: Probability of Farmers Selling in a Market, 2008

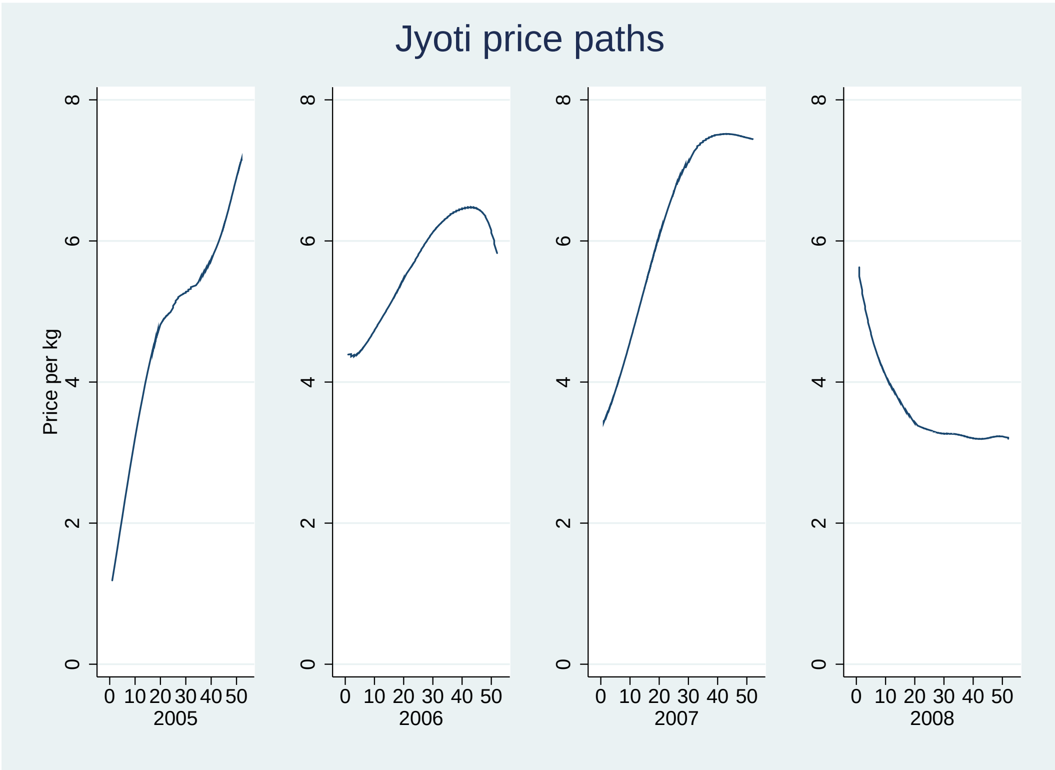

Figure 1: Mandi Prices by variety, 2008

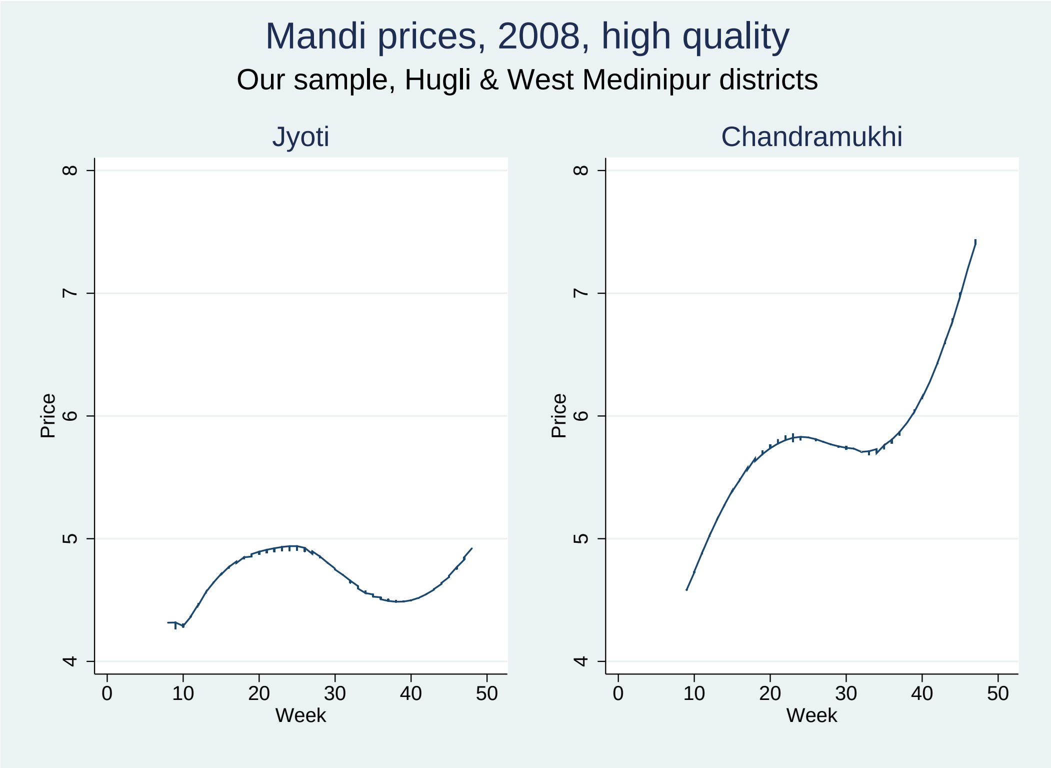

Figure 2: Mandi Prices by variety, 2008

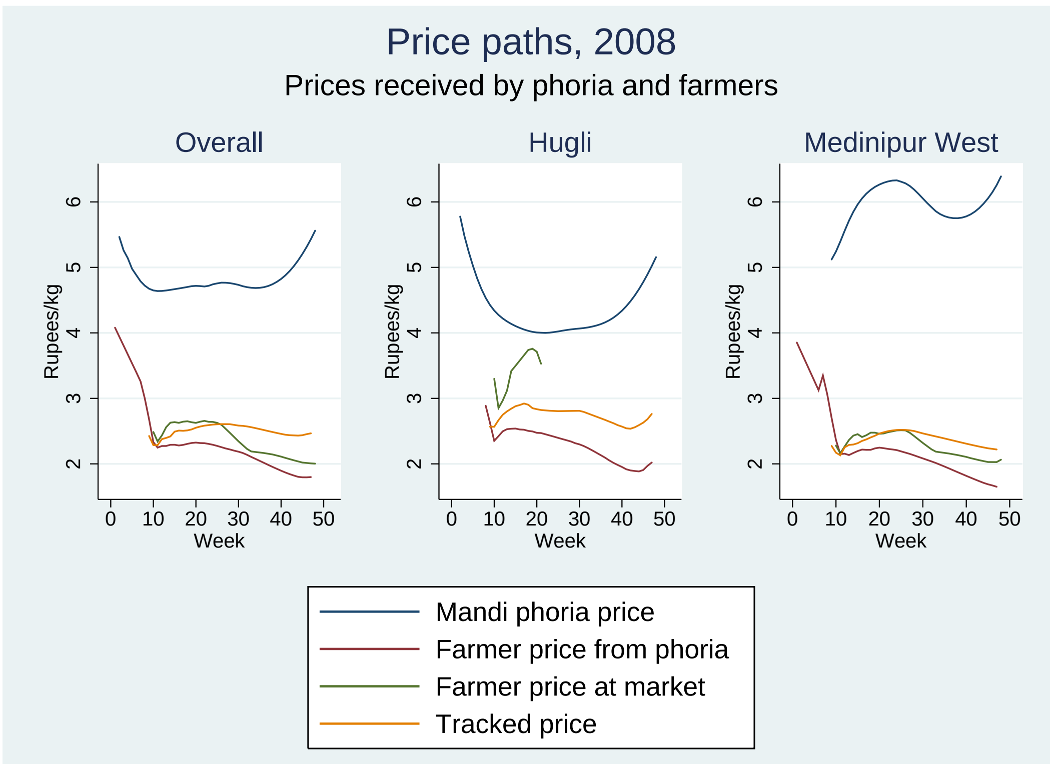

Figure 3: Mandi prices, farmer prices and tracked prices, by district, 2008

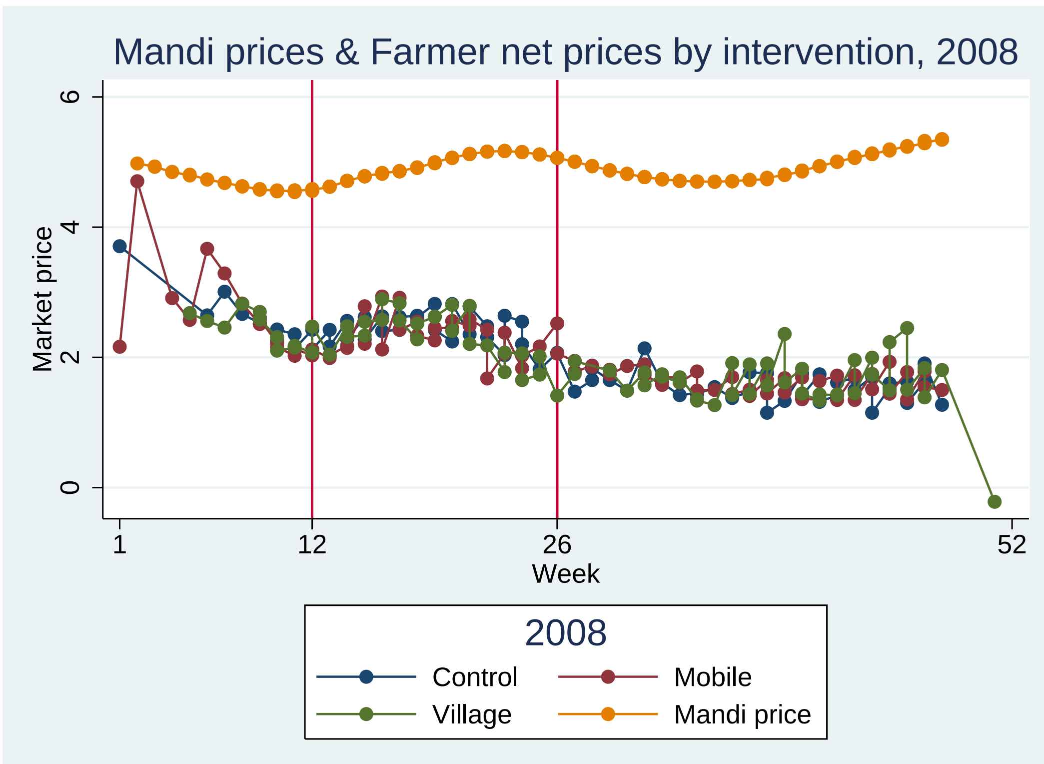

Figure 4: Middlemen Margins and Average Intervention Impacts, Jyoti and Chandramukhi potatoes, 2008