Buyers' response to third-party quality certification: Theory and evidence from Ethiopian wheat traders

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Abstract

When quality attributes of a product are not directly observable, third-party certification (TPC) enables buyers to distinguish between quality levels and reward sellers accordingly. We study the adoption of TPC by traders in smallholder-based agricultural value chains in low-income countries, where traders aggregate products from many small-scale producers before selling in bulk to downstream processors. In this context, the introduction of TPC services has oftentimes failed. We develop a theoretical model identifying how different market conditions affect traders' choice to purchase certified output from farmers. Next, using a novel lab-in-the-field experiment with Ethiopian wheat traders, we examine the model's predictions. Traders' willingness to specialize in certified output increases with the share of certified wheat in the market, and this effect is stronger in larger markets. However, we find that traders do not optimally respond to variation in the quality of uncertified wheat in the market. We also analyze conditions where traders deviate from optimal behavior and discuss implications for research and policy making to promote TPC in smallholder-based value-chains.

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When markets fail to reward non-observable quality attributes of products, a well-known market solution is to introduce third-party quality certification services (TPC) (Akerlof, 1970; Viscusi, 1978). TPC can increase market transparency, encourage investments and facilitate trade—raising welfare levels. While TPC can emerge endogenously this does not always happen. Producers or buyers may oppose the emergence of TPCs if they are concerned that increased transparency lowers their profit or if they do not trust TPC operators (Abate et al., 2021; Dranove and Jin, 2010). Another reason why TPC might not emerge spontaneously is expectations-driven coordination failure. Coordination problems might enter when the returns to using TPC services depend on whether other market parties use this service as well. In this paper we show that expectations about the behavior of others in the value chain affect the expected return to own investments in quality production, which may cause sub-optimal equilibria to emerge as a self-fulfilling prophecy. The context we have in mind is agricultural value chains in low-income countries, dominated by the supply of many smallholder farmers on rural markets where small-scale traders source and aggregate the product that they later sell to larger buyers downstream the value chain.

We study whether buyers ("traders") are willing to purchase quality-certified products when they are uncertain about the number of sellers ("farmers") willing to supply certified products. Our starting point is that traders must incur a fixed cost if they want to keep certified produce separate from uncertified produce. The reason is that traders who peddle third-party certified produce must abandon their "bulk and mix" mode of aggregation, and instead invest in physical capital goods to keep track of separate product flows. To recoup this fixed cost, a minimum quantity of certified produce should be supplied, which introduces the issue of trader expectations with respect to the certification choices of farmers.

In this paper, we develop a theoretical model to analyze how market parameters, including the size of the market and the share of uncertified crops that is of high quality, affect investment decisions of traders. We do not consider the full market system of expectations with respect to supply and demand, but concentrate on traders' expectations and choices—complementing earlier work concentrating on farmers decisions (e.g. Anissa et al., 2021; Bernard et al., 2017; Bold et al., 2017). Our theoretical model focuses on how traders' expectations with respect to the quantity of certified output supplied by farmers affect their willingness to incur the fixed cost to keep certified and uncertified crops separate, and pay a premium for certified output. The model shows that increasing the share of certified output supplied by producers (weakly) raises the probability that a trader incurs the fixed cost. This effect is mediated by market characteristics, such as the size of the market and the average quality of non-certified products.[1]

The model yields clear predictions, that could be tested across a large sample of markets across which one would find exogenous variation in crop quality and the share of farmers selling certified output, but we lack field data to do this. Instead, we design and implement a novel lab-in-the-field experiment with 178 traders operating in rural Ethiopian wheat markets, to probe model predictions. The experiment mimicked rural traders' daily activities where they seek to purchase a certain quantity of outputs from farmers who visit their shop in sequence. Before each round we provided traders with information regarding the share of farmers selling certified higher quality output and the share selling non-certified (i.e., non-observable) higher vs lower quality output in the market, along with the maximum number of farmers who will visit their shop that day (as a proxy for market size). Before starting their purchases, traders had to decide whether to incur a fixed cost enabling them to derive a larger price premium from the certified output that they would secure.

Our empirical results provide support for some of the theoretical predictions, but not all of them. Consistent with the theory, trader expectations about the share of certified crops that they can secure shapes their intermediation decisions. For example, fewer traders are willing to incur a fixed cost to keep certified output separate if the market-level share of certified output is small. This effect is more pronounced in larger markets where traders can choose their purchases from a large set of farmers offering their crop. However, while the theory predicts that, for a given share of certified output in the market, traders should be less likely to incur the fixed cost when the share of non-certified higher quality output increases, we find that this market parameter does not affect traders decisions. We also find that a significant share of traders, regardless of their investment decisions, fails to adopt a simple rule governing which units of output to accept and which ones to reject. The result, for some participating traders, is sub-optimal profit levels. We examine several alternative explanations—including risk aversion, limited salience of the optimal strategy, and cognitive biases—but find little supporting evidence for any of them. Perhaps the complexity of the game, with several moving parts, was too great for a subsample of our traders.

Our analysis is based on a generic description of rural food product markets where small-scale farmers sell most of their products to local traders who act as aggregators—purchasing products from small-scale producers before selling in bulk to downstream wholesalers or processors.[2] While farmers may be able to improve the quality of their crops by using affordable and readily available quality-improving technologies and practices they often choose not to incur the cost associated with producing high-quality output and produce low-quality output (Anissa et al., 2021; Bernard et al., 2017; Bold et al., 2022; Magnan et al., 2021; Treurniet, 2021).[3] Since farmers expect traders to "bulk and mix" the produce from multiple sources and pay the same price based on "average quality" to all farmers, a "market for lemons" outcome emerges. Traders may not offer price-premiums for high-quality products because they do not invest in capacity to keep uncertified and certified flows separate (think of investments in trucks or storage facilities). Such investments are only incurred if the flow of certified output is sufficiently large to recoup the investment cost.

This situation naturally lends itself to coordination issues regarding the use of TPC services. Two distinct but stable equilibria may exist: (i) a "low-quality equilibrium" where farmers offer uncertified outputs of the lowest quality because they expect traders to offer a price based on average quality, and traders pay low prices and make no effort to sort products based on certified quality because they expect farmers to offer uncertified outputs; and (ii) a "high-quality equilibrium" where farmers expect traders to reward high-quality outputs (so they invest in producing high quality and certify their crop) and traders expect farmers to offer certified outputs, so it is worthwhile to incur a fixed cost to keep flows of certified and uncertified outputs separate. Farmers' and traders' expectations about the behavior of others determine outcomes, and both equilibria can emerge as "self-fulfilling prophecies" where expectations are confirmed so that behavior is reproduced over time. The system might mover from a no-certification equilibrium to a certification if an intervention simultaneously alters the expectations of farmers and traders about the others' reliance on TPC services.

This paper fits in a growing literature on food value chains in low-income countries, where markets often fail to reward quality attributes of food products that are unobservable to the naked eye. Examples of such unobservable attributes are the flour extraction rate, moisture levels, protein content, pesticides residues, and aflatoxin contamination. In these contexts, average quality levels of smallholder supply remain low, which has caused concerns among local processors who increasingly switch to certified imports to satisfy the demand for quality crops of a growing urban middle class.[4] This trend has adverse consequences for domestic food production systems, which are increasingly relegated to lowly-remunerative domestic value chains. Perhaps this trend could be reversed if local farmers were able to satisfy and credibly signal quality requirements, and were rewarded for their investments in quality-improving inputs and practices (Bai, 2024; Barrett et al., 2022; Cockx et al., 2018; Demont and Ndour, 2015; Treurniet, 2021).

Our work contributes to this literature in two ways. First, building on recent studies documenting how the introduction of TPC services affect farmers' production choices (e.g. Bai, 2024; Bernard et al., 2017; Deutschmann et al., 2024; Magnan et al., 2021), this study investigates how traders respond to the emergence of such services in the context of small-scale agriculture of low-income countries. The evidence in this paper supports the idea that coordination failure is a plausible explanation for the lack of TPC services and the resulting low-quality of products supplied in local crops value chains. From a policy perspective, our findings support the idea that a strong-enough initial intervention to support farmers' use of certification services will affect traders' decisions to purchase third-party certified output supplied by small-scale farmers—flipping the market outcome from one equilibrium to another and superior one. Therefore, initiating a process of modernization and integration of smallholders in remunerative value chains involves trust-building and institutional solutions––in addition to technical ones.

Second, this paper contributes to an emerging body of literature on the role of local market conditions in technology adoption. While existing works suggest that several constraints restrict farmers' ability to exploit market opportunities and adopt profitable technology (e.g., Bellemare et al., 2022; de Janvry and Sadoulet, 2020; Deutschmann et al., 2024; Karlan et al., 2014; Magruder, 2018; Suri and Udry, 2022), much less is known about constraints that traders may face. We show that coordination failures along the value-chain is an important constraint preventing technology adoption. Our contribution is to offer a case study of TPC services which supports coordination across actors of the value chains and foster value creation. Importantly, we document that such services are unlikely to emerge as market-mediated solutions under specific conditions (e.g., thin-markets) and that many traders are currently unable to respond optimally to opportunities provided by TPC services. This paper also speaks to a broad literature on the role of fixed costs in production (Banerjee et al., 2019; Bassi et al., 2022; Foster and Rosenzweig, 2022). Relying on a lab-in-the-field experiment allows us to document direct evidence that further encouraging technology adoption at scale may overcome fixed costs constraints that local traders are facing and to foster their engagement in new trading opportunities provided by TPC systems.

The paper is organized as follows. In section we sketch the context of Ethiopian wheat markets and value chains. In section , we discuss how expectations affect intermediation modalities and shape incentives to engage in the trading of quality-certified products. Section outlines the lab-in-the-field experiment, the data and the empirical strategy. The results follow in Section and the conclusion and discussion ensue.

Context: Ethiopian wheat value chain

Wheat is one of the most important crops in Ethiopia, where it is cultivated by more than 5 million small-scale farmers catering to a fast-increasing demand fueled by urban growth and changes in food habits (Minot et al., 2019; Shiferaw et al., 2014; Worku et al., 2017). Ethiopian producers have so far been unable to fully respond to this growing demand —particularly in terms of quality —and about one-third of national consumption depends on imports. Following recent disruptions and shortages in the global wheat value supply (e.g., the COVID-19 pandemic or the war in Ukraine), the Ethiopian government has intensified its efforts to reach wheat self-sufficiency.

In the Ethiopian wheat value-chain, many farmers do not appear to sell any of their wheat output, and only about 10% sell more than half of their yearly production (Minot et al., 2019). Most farmers who do engage in wheat trade sell in very small quantities (i.e., about 50kg per transaction), typically to local wheat traders on weekly local markets (Abate and Bernard, 2017). Local traders bulk and mix the output from several farmers, and supply mixed quality wheat onwards to larger traders, wholesalers, millers or retailers. Local trades typically aggregate and transport grain in a (at a minimum) 5 ton truck using own or rental truck. As it would not be profitable for traders to transport few bags of grain for a long distance trade, they may contract agreement with truck owner to ship their output to their buyer. All traders are facing the same constraint, they have a given volume available that they optimally fulfill. Supply of high-quality wheat is common and represents around 25% of the total supply (Do Nascimento Miguel, 2024), but local traders typically pay a nearly uniform market-day price, and only make slight adjustments based on easily observable attributes such as grain size, color, and impurity level. Importantly, returns to key unobservable quality parameters, such as the flour extraction rate (hectoliter mass) and protein content that are in high demand by downstream actors, are typically absent in local wheat markets, as these unobservable quality attributes correlate only weakly with observable ones (Anissa et al., 2021; Do

Nascimento Miguel, 2024). Downstream actors such as millers might use their own measurement tools to assess unobservable quality. They collect small wheat samples from the trader's bulk supply and measure its quality.[5] The lack of market institutions is a key impeding factor. In particular, TPC services have not been developed for local-level wheat markets, which increases the costs of transacting throughout the value chain (Gabre-Madhin and Goggin, 2005) and precludes a system of price premiums that incentivize quality production.

Yet, characteristics of local-level Ethiopian wheat markets offer a supportive context for the existence of TPC services. Abate et al. (2021) argue that four conditions must hold for successfully implementing a TPC system. First, downstream agents (e.g., millers) must be willing to pay a premium for improved quality. This condition holds in the Ethiopian wheat value chain, where millers appear willing to pay a significant price premium for high-quality wheat (Anissa et al., 2021). Second, farmers should be able to improve crop quality in response to certification. Ethiopian wheat farmers are quick to adopt practices that improve output quality if new market opportunities open up (Anissa et al., 2021; Zörb et al., 2018). Third, farmers must perceive TPC services as credible and be willing to pay a fee for their use. Abate and Bernard (2017) and Anissa et al. (2021) provide evidence of positive willingness to pay for TPC services by Ethiopian farmers. Fourth, farmers should be rewarded for quality production, which means that there should be sufficient competition between traders to pass part of the quality price premium obtained from downstream buyers through to farmers. Local Ethiopian wheat markets indeed appear fairly competitive (Bulte et al., 2024).

Field observations however suggest that for TPC to benefit traders, the latter should adapt their current bulking and mixing of farmers' products, and keep high-quality certified crops separate from uncertified ones. Maintaining certified and non-certified crops separate however implies additional investments into physical capital such as trucks or storage facilities. Local trades typically aggregate and transport grain in a 5 ton truck, which is the unit volume used for transactions with wholesalers and millers downstream. Trucks are sometimes owned, but more often rented by traders for part or all of the wheat commercialization season. In short, all traders face the same 5 ton unit constraint for each of their sales to downstream buyers. In addition, shifting from bulk and mix to keeping output flows separate is gradual, and this transitory stage also involves extra costs for traders. In that phase, traders sell certified and uncertified crops to different buyers, yielding additional expenses at each step of the transaction process (e.g., testing, bagging) and raising transaction costs. Lastly, mental and cognitive costs are associated with keeping records of what traders should purchase. For instance, they have to work more carefully to preserve certified output labels, train their employees in new methods, and create and sustain relationships with different buyers and sellers. Thus, the price premium that most downstream value chain agents are willing to pay for quality-certified crops must be high enough to cover such costs and to reward all upstream agents.

Theory

In this section, we build on the Ethiopian wheat markets context described above to develop a theoretical framework showing that traders' expectations regarding the share of quality-certified output supplied on local markets determine their strategies to keep certified and uncertified output separately. In line with the context described above, we essentially think of unobservable quality as flour extraction rate which is not directly visible to the naked eye despite strong variations across otherwise similar grain samples. Flour extraction rate determines how much flour miller can process from a volume of grain. Importantly, it is not correlated with other more visible quality attributes (purity, size, color) of grain, from which one could have indirectly inferred the level.[6] In this model, traders have to decide whether or not to incur a fixed cost to keep certified and non-certified output separate, and (conditional on the earlier decision) which units of output to accept and which ones to reject.

A model of trader behavior

Traders aggregate the output of smallholder farmers, and transport it to the next node in the value chain —typically millers —who pay a premium for high-quality crops. To receive such a price premium, traders could source quality-certified wheat, and keep it physically separate from uncertified wheat. For uncertified wheat, millers measure the average quality of each batch of wheat and determine the level of a quality-related price premium. In what follows we assume that an intermediation strategy that involves keeping certified and uncertified wheat separate involves a fixed cost F for the trader.

During a market day, traders meet up to S farmers who are willing to sell a unit quantity of their crop. We interpret S as a measure of market size. Traders can accept a maximum of $Z \leq S$ offers to fill up their truck, with Z being the size of their truck. We assume that there are two qualities of wheat: high and low. Individual farmers can choose to grade and certify their high quality crop at some cost. Parameter $\pi \in [0;1]$ represents the share of certified wheat in the market, parameter $\theta \in [0;1]$ the share of high-quality in the uncertified wheat. The share $(1-\pi)\theta + \pi$ of wheat is thus of high quality.[7] Consistent with the situation on actual wheat markets in Ethiopia we assume that key dimensions of wheat quality are unobservable to the trader (notably the flour extraction rate). Traders struggle to distinguish between low- and high-quality crops if that crop is not certified, and therefore pay the same price for uncertified wheat, regardless of its quality. They subsequently bulk and mix the uncertified wheat.

We assume that local markets are fairly competitive (Bulte et al., 2024; Casaburi and Reed, 2022; Dillon and Dambro, 2017), hence traders take prices as given. Let p^u (p^c) be the price paid for uncertified (certified) wheat by the trader to the farmer (with $p^c > p^u$). The next node in the value chain are millers, who are able to verify the quality of the crop supplied to them. Millers are willing to pay a premium for high-quality wheat in general, including for certified wheat. Let P^C be the price paid for certified wheat by the miller to the trader (where $P^C > p^c$), and P^U the price paid for uncertified wheat (with $P^U > p^u$). P^U is increasing in average quality of the batch supplied by the trader. Define $P^U = a + bh$, where a is the price traders receive for uncertified low-quality output, b is the quality premium, and h is the share of high-quality output (certified or uncertified) in this mix. Hence, the price per unit a trader expects to receive is $E(P^u) = a + b\theta$ if she only buys and sells uncertified wheat, where E is the expectations operator.[8]

We make three additional assumptions. First, $(P^C - p^c) > a + b\theta - p^u$, after paying the (sunk) fixed cost, traders prefer to trade certified wheat rather than uncertified wheat. Observe that if this assumption would not hold, no trader would ever incur the fixed cost F.[9] Second, we assume that $(p^c - p^u) > b(1-\theta)$, meaning that traders who did not pay the fixed cost F and cannot keep certified and uncertified flows separate prefer to purchase uncertified crop over certified one. Third, we assume that traders who did not pay the fixed cost F can still buy certified wheat to mix in with their other crop and "fill their truck" if there is no uncertified wheat for them to buy: $(P^U - p^c) > 0$, for all values of θ.

The trader's problem involves two steps: (i) whether or not to incur the fixed cost F to maintain a separate flow of certified output, and (ii) which units of crop supply to accept and which ones to reject on a trading day. This problem is solved through backward induction. Using an optimal accept-reject strategy, a trader computes the expected profits with and without separate flows. Given these outcomes, she decides to incur the fixed cost or not. If expected profits with separate flows are greater than expected profits of a bulking and mixing strategy, then the trader pays F.

Purchasing crops after paying the fixed cost

Consider first the case when the trader has paid the fixed cost that allows her to keep certified and uncertified wheat separate. The decision rule applied by the trader follows immediately from the assumption that the marginal return from buying certified wheat is higher than uncertified wheat. Traders should thus accept all certified wheat and reject all uncertified wheat, until they encounter farmer number N. Farmer N is the farmer after which the number of remaining encounters $(S-N)$ with farmers on that day is equal to the remaining space available on the truck. From farmer N onwards, the trader should buy all wheat offered (but keep the certified and uncertified separate). Observe that after N encounters, the trader expects to have obtained πN units of certified output, leaving $Z-\pi N$ slots to fill on the truck while there are $S-N$ encounters left. Critical farmer N is thus defined by $S-N=Z-\pi N$, or:

(1) $$N=\frac{S-Z}{1-\pi}$$

Define $E(C)$ as the expected number of certified units that a trader can obtain and $E(U)=Z-E(C)$ as the expected number of uncertified ones. If the share of certified output offered on the market is sufficiently high, $\pi > \frac{Z}{S}$, then the trader expects to only accept certified units, so that $E(C)=Z$ and $E(U)=0$. Trader profits amount to:

(2) $$\Pi^{fc}=Z(P^C-p^c)-F$$

Instead, if $\pi < \frac{Z}{S}$, then the trader expects to buy both certified and uncertified units (which are to be sold separately):

(3a) $$E(C)=\pi N+(S-N)\pi=\pi S$$

(3b) $$E(U)=(S-N)(1-\pi)=Z-\pi S$$

For traders managing two flows of output, with different quality levels, expected profits are:

(4) $$\Pi^{fc} = \pi S(P^c - p^c) + (Z - \pi S)(a + b\theta - p^u) - F$$

Purchasing crops without paying the fixed cost

Consider now the case when the trader has not paid the fixed cost. Since the extra cost of purchasing certified wheat is greater than the benefit brought by its contribution to increasing the quality of mixed wheat ($(p^c - p^u) > b(1-\theta)$), traders who did not pay the fixed cost (and must mix the crops they buy) should accept all uncertified wheat, and reject all certified wheat until they encounter farmer M. Farmer M is the farmer after which the number of remaining encounters, $S - M$, equals the number of remaining empty units on the truck. After farmer M, the trader should buy all crops offered by the farmers that they meet that trading day, since $(P^U - p^c) > 0$. After M encounters, the number of remaining slots on the truck is equal to $Z - M(1-\pi)$ and the remaining number of encounters equals $S - M$. Equating these two expressions yields an expression for critical farmer M:

(5) $$M = \frac{S - Z}{\pi}$$

If $\pi \leq 1 - \frac{Z}{S}$ then the trader expects to purchase only uncertified wheat: $E(C) = 0$ and $E(U) = Z$. Trader profits are

(6) $$\Pi^{nfc} = Z(a + b\theta - p^u)$$

If $\pi > 1 - \frac{Z}{S}$, the trader expects to buy both certified and uncertified wheat, and mix them, with certified wheat increasing the quality of the mix:

(7a) $$E(U) = S(1-\pi)$$

(7b) $$E(C) = (S - M)\pi = Z - (1-\pi)S$$

Expected profits are then:

(8) $$\Pi^{nfc} = S(1-\pi)(a + b\theta - p^u) + \{Z - (1-\pi)S\}(a + b - p^c)$$

Paying the fixed cost, or not?

To decide whether it is profitable to pay the fixed cost and keep certified and uncertified crops separate, the trader compares expected profits Π^{fc} and Π^{nfc} of the two trading strategies, as defined above. This comparison gives rise to four cases, depending on the size of the local market (whether S is larger or smaller than $2Z$) and the share of the certified wheat π relative to $\frac{Z}{S}$ and $1-\frac{Z}{S}$.

First consider large local markets, where $S > 2Z$, i.e., $\frac{Z}{S} < 1-\frac{Z}{S}$. The comparison of Π^{fc} and Π^{nfc} define three cases depending on the value of π. The solution is represented in Figure 1.[10] To ease notation, we define $\Delta = P^C - p^c - (a + b\theta - p^u)$, which is the differential marginal return from buying and selling certified rather than uncertified wheat. This margin Δ is decreasing in θ, the proportion of high-quality wheat among non-certified crops offered by farmers.

Case 1. $\pi < \dfrac{Z}{S}$.

Traders' expected profits are given by equation (4) if they pay the fixed cost and by equation (6) if they don't. Subtracting these two equations yields the following differential profit from buying and selling certified wheat:

$$\Delta^{fc} = \Pi^{fc} - \Pi^{nfc} = \pi S \Delta - F \tag{9}$$

This net profit is increasing in π and decreasing in θ. Incurring the fixed cost F and keeping certified and uncertified crop separate is a profitable strategy for traders, $\Delta^{fc} > 0$, if $\theta < \theta^* = \frac{1}{b}(P^c - p^c - a + p^u - \frac{F}{\pi S})$. The function $\theta^*(\pi)$ is the segment AB on Figure 1.

Case 2. $\dfrac{Z}{S} < \pi < 1-\dfrac{Z}{S}$.

Traders expected profits are given by equations (2) and (6). Subtracting these yields:

$$\Delta^{fc} = \Pi^{fc} - \Pi^{nfc} = Z\Delta - F \tag{10}$$

Hence $\Delta^{fc} > 0$ if $\theta < \theta^* = \frac{1}{b}(P^c - p^c - a + p^u - \frac{F}{Z})$. This term is independent of π and represented by the horizontal segment BC on Figure 1. This net profit is decreasing in

θ.

Case 3. $\pi > 1 - \dfrac{Z}{S}$.

Traders expected profits are given by equations (2) and (8). Subtracting these yields:

$$(11) \qquad \Delta^{fc} = \Pi^{fc} - \Pi^{nfc} = Z(P^c - (a+b)) - (1-\pi)S(p^c - p^u - b(1-\theta)) - F$$

Hence $\Delta^{fc} > 0$, if $\theta < \theta^* = 1 + \frac{Z(P^C - a - b) - F}{b(1-\pi)S} - \frac{p^c - p^u}{b}$. This is the segment CD in Figure 1. This net profit is increasing in π and decreasing in θ.

Taking these cases together shows that the net benefit from keeping certified and non certified wheat separately is (weakly) increasing in the share of certified supply, π, and decreasing in the share of high-quality in uncertified supply, θ. The net profit is positive and traders will incur the fixed cost for values of θ and π that are below and to the right of the line $\theta^*(\pi)$ on Figure 1. The net profit is negative and traders do not incur the fixed costs for values above and to the left of the line.

Recall that once traders have decided to pay the fixed cost, their objective is to maximize the quantity of certified crops purchased. In the case where the share of certified output offered on the market is sufficiently high, $\pi > \frac{Z}{S}$, we can thus expect them to never reach farmer N of section and fully specialize in certified crops (area below and to the right of EBCD in Figure 1). In contrast, if $\pi < \frac{Z}{S}$ they are expected to have to buy both certified and non certified crops to fill in their load, albeit keeping them separate (area ABE). Symmetrically, when traders have not payed the fixed cost (in the area above the $\theta^*(\pi)$ line in figure 1, their objective is to maximize the quantity of uncertified crops purchased. Traders are expected to specialize in non-certified crops where the share of certified output offered on the market is sufficiently low, $\pi < 1 - \frac{Z}{S}$ (area to the right and above ABCG), but they would buy both certified and uncertified if the share π is very high (area GCD).

The larger the market the further apart are $\frac{Z}{S}$ and $1 - \frac{Z}{S}$. Hence the areas of specialized intermediation in a unique type of output increase. The intuition is that in large markets traders can expect to interact with many farmers, so they can more easily decide *not* to trade with specific farmers (to save space in their truck for more profitable output).

Next, we turn to the case of a "small market" where $S < 2Z$, i.e., $1 - \frac{Z}{S} < \frac{Z}{S}$. The comparisons of Π^{fc} and Π^{nfc} similarly leads to three cases, with the solution represented in Figure 2. Solutions for $\pi < 1-\frac{Z}{S}$ and $\pi > \frac{Z}{S}$ are the same as under case 1 and case 3 above. We encounter a new situation for $1-\frac{Z}{S} < \pi < \frac{Z}{S}$.

Case 4. $\quad 1-\dfrac{Z}{S} < \pi < \dfrac{Z}{S}$

Traders expected profits are given by equations (4) and (8). Subtracting these yields:

$$\Delta^{fc} = \Pi^{fc} - \Pi^{nfc} = \pi S \Delta + (Z-(1-\pi)S)(p^c - p^u - b(1-\theta)) - F \tag{12}$$

Hence $\Delta^{fc} > 0$, if $\theta < \theta^*(\pi) = 1 + \frac{\pi S(P^C - a - b) - F}{b(S-Z)} - \frac{p^c - p^u}{b}$, an increasing function of π.

This is the segment AB in Figure 2. This net profit is increasing in π and decreasing in θ.

Like in the large market, the traders will incur the fixed cost for values of θ and π below the line $\theta^*(\pi)$, and won't incur the fixed costs for values above and to the left of the line. A major difference between case 4 of the small market and case 2 of the large market is that traders can't expect to be specializing in that middle range values of π. As their purchase objective Z is larger than either the expected quantity of certified crop (πS) and of non-certified crop ($(1-\pi)S$) they will encounter, traders have to accept both certified and non certified crops to fill their truck, keeping them separate if $\theta < \theta^*(\pi)$, and mixing them if $\theta > \theta^*(\pi)$.

In conclusion, and as reported in Figures 1 and 2, both cases of large and small markets lead to the definition of a frontier between incurring or not the fixed cost as the function $\theta^*(\pi)$. Note that this function is monotonic and hence one can just as well define it as $\pi^*(\theta)$. This gives a fairly intuitive proposition that summarizes the results of the model as follows.

Proposition 1. Traders should invest in intermediation modalities that keep certified and uncertified output separate if $\pi > \pi^*(\theta)$, but not if $\pi < \pi^*(\theta)$.

The intuition is simple: to re-coup their fixed costs, traders need a minimum supply of certified output. Since they earn an extra margin per unit of certified crop bought and sold (compared to trading high quality output), traders will keep certified and uncertified output separate if they expect to encounter a sufficiently large number of farmers supplying certified output.

Corollary 1. In production areas where a sufficient number of farmers produce high-quality crop output, $\theta > \theta^*(\pi)$, traders should <u>not</u> invest in intermediation modalities that keep certified and uncertified output separate —they should bulk and mix output to maximize their profits.

Next, we examine how traders' decisions very with the market size (see Appendix for a detailed demonstration). Consider two markets of size S^L and S^S, with $S^L > S^S$. If both are 'large' markets, as defined above, $2Z < S^S < S^L$, using equations 9-11, one can show that Δ^{fc} is weakly larger in the larger market for $\pi < 1 - \frac{Z}{S^S}$, but lower beyond that value. If both are small markets, the comparison shows that if $\Delta > (a + b\theta - p^u) - (a + b - p^c)$, meaning that the marginal benefit of specializing in the trading of only certified output exceeds that of specializing in the trading of only uncertified output, Δ^{fc} increases with market size for all $\pi \leq 0.5$. Finally, if $S^S < 2Z < S^L$, corresponding to one small and one large market, one can show that Δ^{fc} is larger in the larger market for $\pi < \max(\frac{Z}{S^L}, 1 - \frac{Z}{S^S})$, but not beyond $\max(\frac{Z}{S^S}, 1 - \frac{Z}{S^L})$. Taken together these results can be summarized as follows:

Proposition 2. Returns to investing in intermediation modalities that keep certified and uncertified output separate increase with market size as long as the share of certified output $\pi \leq 0.5$, and $\Delta > (a + b\theta - p^u) - (a + b - p^c)$.

The intuition is as follows: When the supply of certified output is low, it is easier for traders to re-coup their fixed cost in larger markets.

The model generates three important predictions that we empirically test using a lab-in-the-field experiment with Ethiopian wheat traders:

1. All else equal, increasing the share of certified output (weakly) increases the probability that a trader incurs a fixed cost to keep certified and uncertified output separate.

2. All else equal, increasing the share of high-quality crop in uncertified output increases the probability that a trader bulks and mix uncertified and certified output

3. Under conditions that the marginal benefit of trading certified rather than uncertified crop is greater than the loss that would be incurred by having to sell certified rather than uncertified crop as uncertified, the probability that a trader incurs a

fixed cost to keep certified and uncertified output separate increases with market size for $\pi \leq 0.5$.

An experimental test of trader behavior

Sample of traders

We implemented an experiment to test the model's predictions with wheat traders in Ethiopia's main wheat-producing areas: Amhara, Oromia, and Southern Nation Nationalities and Peoples' Region. During the 2018-2019 marketing season we did a census of all wheat markets in these regions to collect market-level information (e.g., number of farmers and traders, volume traded, market facilities).[11] We selected 25 high-potential wheat *woreda*s (i.e., districts) and the main wheat market in each *woreda*. We randomly selected 15 markets from this list and obtained a list of active traders from the *woreda* trade office. Using this list, we randomly selected a sample of 12 traders per *woreda*. If a trader was unable to participate, we randomly selected another one. We conducted the survey in April 2022, and collected information from 12 traders per market, except in Misha woreda where fewer traders were present during our visit. Our final experimental sample consists of 178 traders.

Table 1 reports summary statistics of traders and their trading behavior. Almost all traders are men with some formal education, and half of them are members of a traders association. Few traders own much physical capital to support their wheat trading activities (e.g., trucks and grain storage facilities). 12% can rely on their own truck for at least part of their operations, while the remaining must fully rely on rented ones. Overall, transport cost and storage rental costs represent almost half of their total trading costs. Panel C shows how traders deal with wheat quality. Many traders pay a quality premium to their sellers, although this premium is small in magnitude: less than 1 birr per kilogram. While most traders assess observable quality attributes (i.e., color, impurity, kernel size), a minority also report checking the flour extraction rate although proper testing of this attributes requires specific and costly equipment that very few (if any) traders use. Almost three quarters of the traders reportedly make an effort to separate quality levels, but again sorting is rough and only based on observable quality attributes.

Protocol

Each trader received a participation fee of 300 Birr (6 USD in 2022). We used a survey to collect information on traders' background characteristics, marketing activities, attitudes, and behaviors characteristics. After the survey, traders were invited to participate in a lab-in-the-field marketing experiment, where they would be asked to invest some of the money they had earned from showing up and answering our survey. While these investments could yield positive returns, traders were informed that they could also lose (part of) what they had just earned. Traders were free to leave without playing, although all decided to participate. We visited all traders at their warehouses and played a single-person decision game in full privacy. We explained the game orally with support materials. The game started after the traders fully understood the rules of the game. Details of the protocols and support materials are in Appendix .

The experiment involved traders buying and selling units of output ("wheat"). To this end, they could draw chips from a non-transparent urn containing 36 chips, one after another, without replacement. They were asked to purchase a 12 chips (Z) representing only one full truckload (filling less than a load would yield lower profits). After drawing each chip traders had to decide whether to buy or reject it. Chips were either blue or red—each representing a unit of wheat. Blue chips represented certified (high-quality) wheat, and red chips represented uncertified wheat, of either high or low quality. Participants could not observe the quality of red chips. Traders had to pay more to acquire blue chips (p^c=220 Birr) than red chips (p^u= 200 Birr). Importantly, traders had the option to keep certified and uncertified output separate, but for this they had to pay a fixed cost (F=330 Birr) before starting to draw chips. Traders offering certified wheat (blue chips) kept separately received a price P^C of 280 Birr per chip. Traders who did not incur the fixed cost had to mix and bulk their chips, and received a price based on the average quality of their acquired stock of chips, as determined by the experimenter after the round: a red chip was classified as high-quality wheat if a mark is drawn under an opaque adhesive tape that the experimenter removes after at the end of the round. The selling price for these chips P^U ranged from 220 to 240 Birr. A price of 220 Birr (240 Birr) corresponded with the extreme case of selling only low-quality (high-quality) wheat.[12]

Each trader in our experiment participated in multiple rounds of play. First, we varied the market size (S) to distinguish between "large market sessions" (S^L) and "small market sessions" (S^S).[13] Traders could draw 30 chips in large market sessions and only 16 chips in the small market ones. A key difference between these two types of session is a potentially greater deviation between expected values of the share of higher quality or certified wheat and traders' actual draws in smaller market ones. Second, across different market sizes we varied the share of certified wheat, π, and the share of uncertified wheat that is of high-quality, θ.[14] We selected three values for π (10%, 30%, and 50%) and two values for θ (30% and 80%) to construct 4 different treatments (i.e., not a factorial design) representing the 4 theoretical cases outlined in section .[15]

The choice of the three parameters and their combination was informed by prior field work and related studies of rural wheat markets in Ethiopia (e.g. Abate and Bernard, 2017; Anissa et al., 2021; Do Nascimento Miguel, 2024). Given their strong interplay, omission of any one of them would have led to partial and possibly biased estimates of traders' response to the introduction of TPC in these context. The objective was to compare traders' behavior (i) across the four treatments within a session; and (ii) between sessions for a given treatment. After the experiment, we randomly selected the earnings of one of the rounds to determine payouts for traders.[16]

The four treatment variations T^1, T^2, T^3, T^4 are as follows, with traders exposed twice to each of them: implemented twice, under small ($S^S = 16$) and large ($S^L = 30$) market conditions: $T^1(\pi = 0.1; \theta = 0.3)$; $T^2(\pi = 0.3; \theta = 0.3)$; $T^3(\pi = 0.5; \theta = 0.3)$; and $T^4(\pi = 0.5; \theta = 0.8)$. We summarize our treatment games in Figure B.1 and map them onto their corresponding theoretical case and expected traders' optimal decisions in Figures 1 and 2 representing the case of large and small markets, respectively.

In Figure 3 we present Monte-Carlo simulations of traders' earnings in each round (see details of simulation in appendix), depending on their investment in the fixed-cost or not. Separating certified and uncertified flows allows traders to earn high profits in some conditions, but causes near-zero profits or even a loss in others. Investing to keep high and low-quality output flows separate can therefore be profitable, but this depends on market conditions and the accept-reject strategy adopted by traders. The vast majority of players made a sizable profit from participating in the experiment (being paid on one randomly drawn round after completing the eights round), and none made loss greater than half of the show-up fee (see Figure C.1 in Appendix).

Excluding two test trials per trader, our within-subject design yields data from 1,424 games played by traders (178 traders × 8 rounds per trader: 4 treatments × two market sizes).[17] Charness et al. (2013) discuss potential issues arising from within-subject designs. Participating in multiple treatments can introduce biases (e.g., anchoring, demand and order effects). Treatment order is a concern, so we randomly varied the order of treatments presented to each trader. We find no substantial correlation between treatment order and trader decisions (i.e., decisions whether to buy a cup), which suggests that order effects are unimportant.[18] Communication spillovers are another threat to the internal validity of experiments (Coutts, 2022). Communication spillovers may occur when participants talk about the game with future participants—affecting behavior of the latter group. We minimize within-market spillovers by conducting all sessions on the same day. We are also not concerned about between-markets spillovers because the average distance between markets is large. Last, we sought to avoid windfall effects by engaging traders to play with their own money: the money that had effectively earned from showing up to answer our survey.

Empirical Strategy

Traders' choice to pay the fixed cost present substantial heterogeneity. As shown in Figures C.3 in the Appendix, 5% of the traders never purchased the cup, 17% purchased it all all rounds, and the remaining traders are somewhat evenly distributed (between 8 and 16%) across the remaining values (2 to 7). We leverage this heterogeneity to explore the model's predictions through the following estimation, where our key choice variable is the trader decision to incur a fixed cost:

$$F_{ij} = \beta_2 T_{ij}^2 + \beta_3 T_{ij}^3 + \beta_4 T_{ij}^4 + \sum_{t=1}^{4} \delta^t (\mathrm{T}_{ij}^t \times S_{ij}^L) + \alpha_i + \lambda_j + \epsilon_{ij} \tag{13}$$

where the dependent variable F_{ij} is a dummy equal to one when trader i pays the fixed cost in round j, T^k are dummy variables equal to one when trader i was exposed to treatment arm $k = \{1, 2, 3, 4\}$ in round j, and S_{ij}^L identifies whether the round was played in large market condition or not. The excluded category consists of treatment 1 ($\pi = 0.1, \theta = 0.3$) in small markets. We also include round order fixed effects λ_j and trader fixed effects α_i to control for carryover effects and traders' unobservable characteristics. We use robust standard errors.

Equation 13 enables us to test the three main predictions of the model as follows:

Prediction 1. All else equal, the share of traders incurring a fixed cost (weakly) increases with the share of certified output (π) available for their purchase in the market. Recalling that the share of high-quality in uncertified supply (θ) equals 0.3 across T^1, T^2, and T^3, parameters β^2 and β^3 only capture variations in π in small markets, while δ^1, δ^2 and δ^3 capture variations in π in large markets. The model therefore predicts that $\beta^3 \geq \beta^2 \geq 0$ (in small markets), and $\beta^3 + \delta^3 \geq \beta^2 + \delta^2 \geq \delta^1$ (in large markets).

Prediction 2. All else equal, trader decisions to incur a fixed cost decreases with the share of uncertified wheat that is of "high-quality". We rely here on the variation of θ between $T^3(\theta = 0.3)$ and $T^4(\theta = 0.8)$, where the share of certified product is constant at $\pi = 0.5$. The model therefore predicts $\beta^4 \leq \beta^3$ in small markets and $\beta^4 + \delta^4 \leq \beta^3 + \delta^3$ in large markets. Note however that given the game parameters we used, the model predicts that in small markets traders should neither incur the fixed cost in T^4 nor in T^3, despite the differential in net profit (Figure 2). In contrast, in larger markets traders are expected to incur the fixed cost (and specialize in the trade of certified output) in T^3 and to not incur the fixed cost (and specialize in uncertified output) in T^4. So while the relative profitability of incurring a fixed cost is higher in T^3 than in T^4 in both cases, the contrast in the optimal purchase decision is weaker in a small market.

Prediction 3. All else equal, the probability that a trader incurs a fixed cost to keep certified and uncertified output separate increases with market size for $\pi \leq 0.5$. The prediction thus implies a steeper slope in large markets for the first three treatment conditions: $\delta^1 \geq 0, \delta^2 \geq 0, \delta^3 \geq 0$.

Next, we leverage within-round data regarding traders' acceptance or rejection of chip drawn from the urn to assess their degree of alignment with the optimal purchase strategy. Our model produces simple predictions with respect to the types of chips that should be accepted and rejected. If the trader keeps certified and uncertified chips separate, she should accept only certified chips until encountering threshold chip N. After that she should accept every chip. Conversely, traders who mix and bulk should accept only uncertified chips until encountering threshold chip M, after which she should accept every chip. We visually examine the patterns in the time series of purchasing decisions to probe whether traders indeed behave optimally, and empirically investigate potential drivers of their deviation from the predicted optimal behaviors.

Empirical results

Traders' behavior (1) – Optimal fixed cost investment

Test of the model's main predictions

We summarize regression results from the estimation of Equation 13 explaining variation in fixed costs investments to keep certified and uncertified output (blue and red chips) separate in Figure 4 (the corresponding value of each parameter estimate are provided in Appendix Table C.1). For each Treatment arm (T^1, T^2, T^3, T^4) we separately report the coefficients for small and large markets where the former correspond to the β parameters in Equation 13, and the latter to the sum of the corresponding β and δ parameters. The estimation further controls for individual trader (α_i) and round order (λ_j) fixed effects (not reported).

The results support some of the model's main predictions. To begin with, we find that several traders (i.e., 34% regardless of market size) incurred the fixed cost in situations where the share of certified output is low ($\pi = 0.1$), despite its unambiguously lower expected profit than the strategy of not paying the fixed cost.

Next, and in line with the first prediction, we find a positive gradient in the probability that traders do incur the fixed cost, as we move from a lower share of certified output in the market (T^1: $\pi = 0.1$) to a medium (T^2: $\pi = 0.3$) and a higher one (T^3: $\pi = 0.5$). Focusing on the large markets only (reported in orange), an increase from 10% to 30% and from 30% to 50% in the share of certified output (π) increases the probability of paying the fixed cost by 25 and 16 percentage points, respectively.

We also find support for the third prediction according to which traders' response to an increase in the share of certified output is somewhat steeper in larger market conditions (reported in orange) than in smaller ones (reported in blue). While a similar proportion of traders incur the fixed cost when the share of certified output is low (T^1: $\pi = 0.1$), we find a five percentage points higher (albeit non-significant; p=0.30) proportion in large markets when the share of certified output is increased to $\pi = 0.3$ (T^2), and a significant (p=0.03) 11 percentage points difference when the share is increased to $\pi = 0.5$ (T^3).

However, our results do not support the model's second prediction. Accordingly, and specifically for large markets, the larger the share of high-quality uncertified products available in the market, the lower the probability that traders should incur the fixed cost. Our results suggest that traders in large markets are unresponsive to a large increase in the share of uncertified higher quality output (from $\theta = 0.3$ to $\theta = 0.8$).[19] Lastly, and at odds with the model's prediction, traders in smaller markets respond positively to the higher share in uncertified higher quality output, with a 13 percentage point increase in the probability to invest in the fixed cost (p=0.00).

We investigate whether that (part of) our results are reflective of participants' limited understanding of the rules of the game, which may limit traders' capacity to choose the optimal strategy. We first assess if traders likelihood of investing in the cup varied with the round order, which would be indicative of increased familiarity (or reversely increase cognitive fatigue) as traders played more rounds of the game. We report the results in Figure C.2 where we find no clear evidence of such effects. Next, we test for the existence of a relationship between traders' choice to invest in the cup and the number of times the enumerators had to (re)explain the game before its effective start.[20] In Figure C.4 we find no evidence of correlation between the two. Taken together, these results suggest that traders' comprehension of the game is not the main driver of the suboptimal behavior observed in some of them. Beyond the functioning of the game, it remains possible that its complexity, with several moving parts, was too great for a subsample of our traders to systematically identify the optimal strategy. We cannot fully rule it out, but as an additional robustness we can check whether our main results hold when we estimate our model on the sub-sample of traders traders who did choose the optimal decision in the first round that they played. Results are reported in Figure C.5 showing that, if anything, our results are somewhat stronger in this subsample.

Role of risk and confusion in deviation from optimal investment strategy

Building on the above results, we investigate traders' deviations from the optimal behavior defined as per our model. In particular, while the model assumes that traders only seek to maximize their expected earnings, their strategy may also account for other features of the experiment. We use Monte Carlo simulations of traders' earnings across games to propose a series of tests assessing whether parameters other than expected earnings can explain traders' investment decisions.[21] We consider three plausible parameters other than expected earnings. First, the spread of the earnings difference after paying or not the fixed cost, which captures the earnings risk. Second, the overlap in earning distribution with and without paying the fixed cost, which may capture trader's confusion: more overlap makes identification of the optimal choice more difficult. Last, the earnings salience, capturing nonlinear responses along the earnings difference spectrum: weak (or no) response for small differences and large response after a certain threshold.[22] With all these parameters included, the model is given by Equation 14 below:

$$F_{ij} = \alpha_i + \beta_1 \mathbb{E}[\mathrm{E}_1 - \mathrm{E}_0]_j + \beta_2 SD[\mathrm{E}_1 - \mathrm{E}_0]_j + \beta_3 \text{overlap}_j + \beta_4 \text{salience}_j + \lambda_j + \epsilon_{ij} \tag{14}$$

where F_{ij} is a dummy equal to one when trader i pays the fixed cost in round j, $\mathbb{E}[\mathrm{E}_1 - \mathrm{E}_0]_j$ is returns to incur the fixed cost, the standard deviation of this return $SD[\mathrm{E}_1 - \mathrm{E}_0]_j$, overlap_j is the overlap in earnings after incurring the fixed cost or not, and salience_j is the tangent of the returns to incur the fixed cost. We also include round order fixed effects λ_j and trader fixed effects α_i to control for carryover effects and traders' unobservable characteristics. We start with a model containing only the expected earnings parameter, and gradually add the three other parameters to assess how the model's explanatory power varies when moving from one model to the next.

As reported in Figure C.6, we find no evidence that risk, confusion or salience substantially increase the share of the variation in traders' behavior that can be explained, compared to the standard expected earnings framework. Accordingly, traders maximizing their expected earnings from the choice they make in the experiment remains the most credible assumption.

Traders' behavior (2) – Optimal accept/reject strategy

Traders' alignment with optimal behavior

We use traders' accept/reject decision of each chip drawn to evaluate if they follow an optimal strategy to maximize their expected profits—conditional on whether they invested in the fixed cost. We start with a descriptive analysis where, for every treatment, we compute the theoretical threshold level of draws *before* which the trader should specialize and only buy her preferred output: the certified wheat (blue chip) until draw N for traders who invested in the separating technology, and the uncertified wheat (red chip) until draw M for traders who did not. After this (N or M) threshold, the trader should purchase all outputs because purchasing any unit of output remains profitable, so failing to trade at full capacity reduces profits.

We report traders' alignment with this optimal strategy in Figure 5 where we separate the analysis between small and large markets. Here also, we find mixed support for the theory. It is encouraging that, across markets, the majority of traders who invested in the separating technology only purchased certified wheat in conditions where the share of certified wheat is high (the specialization rate is between 62%–74% for π=0.5). When the share of certified wheat is at a medium level (π=0.3), approximately half the traders adopted the correct purchase strategy, showing that not all traders behave optimally. The sub-optimal behavior of some traders is also evident from the acquisition strategies adopted by those who chose to mix and bulk (i.e. not investing in the separating technology). A small share of 1 to 11% only accept uncertified wheat before farmer M. In fact between 1% and 12% of these traders accepted only certified wheat—exactly the wrong behavior, as these traders should reject all certified wheat and accept only uncertified wheat.

Deviation from optimal behavior: switching too soon

We further unpack traders' deviation form the optimal accept/reject strategy, leveraging traders' decision to accept or reject the chip that they've obtained at each draw. As long as one has not reached the threshold draw (N or M) —whereby the remaining number of draws is equal to the remaining number of chips that must be purchased to fill the truck – traders should stick with the optimal accept/reject strategy. Instead of their theoretical values, we now rely on the actual values of N and M, which capture one's "luck" at drawing chips that are optimal given one's (non)investment in the fixed cost. This value is in part endogenous as it also depends on one's accept/reject decisions in previous draws – every chip that is rejected brings one closer to the threshold after which the trader must accept all the chips drawn. In small markets for instance, one can reject at most 4 chips since one has to accept 12 chips out of a maximum of 16 draws.

For each trader and at each draw we compute the number of remaining choices to accept/reject chips before reaching the threshold draw (N or M), given his choices to accept/reject the chips drawn until now. In Figure 6, we plot "how soon" traders in small markets start to deviate from the optimal strategy of rejecting all non-optimal chips until the threshold draw when number of possible rejections left is null. Results indicate that the majority of traders start making sub-optimal accept/reject decisions several draws before they have reached the threshold draw (similar patterns are found in large markets, see Figure C.7 in Appendix).

Why would traders not systematically follow the accept/reject strategy that is most optimal given their choice to (not) invest in the fixed cost? As discussed above, it is possible that the complexity of our experiment blurred traders' capacity to precisely identify the threshold draw and build their accept/reject strategy accordingly. However, this explanation is at most incomplete as sub-optimal decisions occur even when traders are still four rejections away from their threshold, and while this sub-optimal behavior is more frequent among those traders that have not invested in the fixed-cost, it is also quite common among those who did.

Alternatively, traders' early switch to sub-optimal accept/reject decisions may come from their aversion to post-threshold situations when they no longer have capacities to seize upcoming favorable opportunities. Accordingly, one may seek to stay "active" in the market for as long as possible, even it comes with a cost (in this case accepting chips that are not the most rewarding given one's investment choice). Another possibility is that traders are subject to standard cognitive biases when it comes to random draws. In particular, the more one feels "lucky", the more one may be willing to keep-up with the optimal accept/reject strategy, and not otherwise. We find some support to this explanation in Figure 7 showing that trader's likelihood to follow the optimal accept/reject strategy is positively affected by whether she drew a favorable chip in the previous draw. Both of these explanations are at odd with the optimal accept/reject behavior in the framework of the games that traders were asked to play (and all the more so since chips were drawn without replacement such that any unfavorable chip drawn increases the probability that the next one will be more favorable to him). It may however make sense if one considers traders' real-life market activities when the overall number of farmers supplying their wheat is not known, and the distribution of certified vs non-certified wheat supply may not be homogeneously distributed over time during a market day.

As a last explanation, one may also consider the fact that some of the traders in our sample display investment and accept/reject behaviors that are systematically at odds with our model's prediction, which we investigate below.

Traders' characteristics and sub-optimal behaviors

Last, we investigate whether suboptimal behavior in investment and accept/reject strategy is concentrated among a selected group of traders. We find evidence of correlated sub-optimal behavior in investment and accept/reject decisions across treatments. For instance, 34% of the traders incurred the fixed cost in situations where the share of certified wheat was at its lowest (π = 10%) —reducing their expected profits —and the majority of them subsequently adopted the wrong acquisition strategy : only 12% (31%) accepted only certified outputs in small (large) markets until they reached the threshold draw. We find no a priori evidence of concentrated sub-optimal behavior in a subset of traders only: no trader in our sample systematically made both suboptimal investments and accept/reject decisions across all treatment conditions, 55% made the two types of errors in at most 2 of the 8 treatment conditions, and 92% in at most half (4) of the treatment conditions.

Yet, our data does suggest that sub-optimal behavior is concentrated in specific rounds where some traders' decision to incur the fixed cost and their following purchase behavior are consistently at odds with the profit maximizing behavior. In the following paragraphs we further explore predictors of traders' deviation from the model's optimal investment and accept/reject behavior through eXtreme Gradient Boosting (XGB) machine learning algorithms.[23] For each of the considered variable, we calculate the Shapley (SHAP) values which measures the magnitude and size of its relationship with traders' investment decisions: higher absolute SHAP values indicate a more meaningful variable for the model, and a positive (negative) sign means an positive (negative) contribution of the variable to the model's predicted outcome. Results are presented in Panel A of Figure 8 which plots the obtained SHAP values. Accordingly, the larger a trader's business activities in real life, the more likely that this trader made optimal investment decisions in our experimental setting. Further, the features of traders' network are significantly associated with their decision to invest in the fixed cost. Traders with an extensive network outside of the district are less likely to follow the optimal fixed cost decision, while those with strong connections to other traders within the district are more likely to incur the fixed cost. Results further indicate that attitudinal factors are among the 10 key predictors of traders' decisions that are selected by the model. While impatience and openness to change are positively correlated with traders' probability to make the optimal choice, higher aspirations and risk aversion are negatively correlated with it – albeit with a limited explanation power.

Turning to traders' accept/reject strategy once their fixed-cost investments has been made, our data suggests that traders start accepting the less profitable chips before the threshold value in 30% of the cases. On average, this sub-optimal decision occurs as early as 3 draws ahead of the threshold draw (after which they should indeed start accepting all chips). We follow the same approach as above to identify key predictors of traders' suboptimal accept/reject strategy and report the results in Panel B of Figure 8. Accordingly, traders with larger business network outside of their districts, those with more experience and with a larger number of employees are less likely to engage early in sub-optimal accept/reject decisions. To the contrary, those that are older, more favorable to change and with larger business volumes are more likely to accept unfavorable chips too early.

Overall, we find no clear patterns relating traders' characteristics to their pursuance of optimal investment and accept/reject behaviors. Perhaps more intuitively, we do find that traders who did make an optimal investment decision are more likely to follow it up with an optimal accept/reject strategy.

Conclusion

When formal contracting remains prohibitively costly, agrifood value chains in low income countries remain long and complex. In these settings, expectations about the behavior of other value chain actors may govern actors' business strategies and trap them in sub-optimal equilibria. In this paper we study Ethiopian wheat traders' willingness to invest in the logistical means necessary to value quality-certified output supplied by small-scale farmers, in the context of an emerging third-party certification system.

We develop a model identifying how different market conditions (i.e., market size, supply of certified output, and the share of high-quality uncertified output) affect traders' decision to invest in their capacity to keep certified output separate from non-certified one, and secure higher price from downstream buyers. We then test the model's key prediction through a lab-in-the-field experiment involving a representative set of Ethiopian wheat traders. We document that trader expectations regarding the flow of certified output they can acquire does affect their decision to invest in technologies to keep certified and uncertified output separate, and that market size further mediates their decisions. All of this is consistent with our theoretical predictions. We however find that some traders are either non-responsive or significantly at odds with our predictions regarding the share of uncertified high-quality output that is available for their purchase. We also document that the purchase strategy that traders adopt when purchasing crops is not entirely conditional on their investment, reducing their expected (and realized) profits. We do not find systematic behavioral reasons for these discrepancies and tentatively attribute them to the complexity of our design, the novelty of the lab-in-the-field experience, and the limited consequences of their errors in a non real-life setting.

Overall, our results contribute to explain why the introduction of third party certification systems has so far mostly failed in smallholder agriculture of low-income countries. As elsewhere, buyers are reluctant to costly changes in the way they source and value products unless they expect that sellers will supply the type of products that will make these changes profitable. Where transactions are small and buyers must aggregate from a large number of small-scale sellers, buyers' expectations of a large number of sellers' using new TCP services are unlikely to be high and their willingness to invest in means to keep quality separated correspondingly low.

Our work calls for additional studies. In particular, we have developed, solved and tested a "partial equilibrium" model of trader behavior that takes the quality of crop supply and certification status as given and does not capture the reverse direction of causality —how farmer expectations with respect to intermediation strategies chosen by traders affect production and certification decisions of farmers. Obviously, this relation is important in any "full model" of rural intermediation. Only when "taken together" does the story about farmers, traders, and expectations takes its full shape.

Traders in agricultural value chains are a vitally important yet under-researched group of actors. Inducing traders to adopt business practices that start rewarding the production of high-quality crops by smallholder farmers would be a major step forward in enhancing agricultural development in low-income countries, and notably in sub-Saharan Africa where this study takes place.

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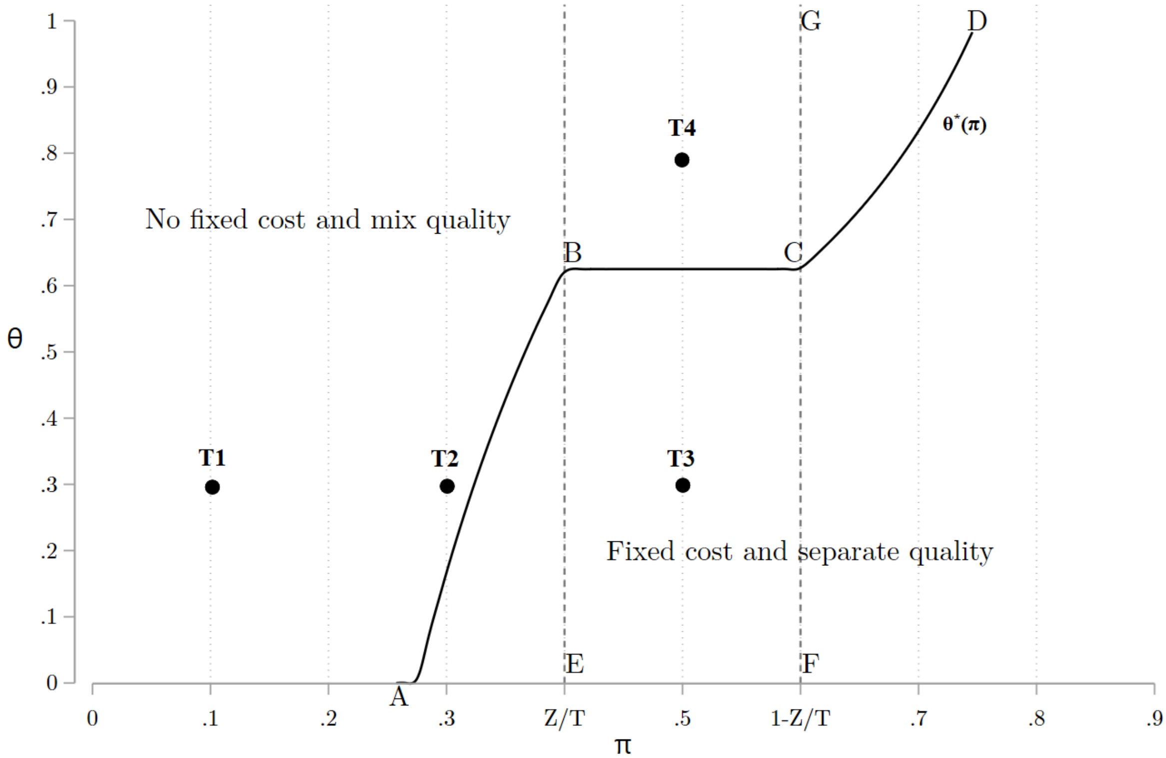
Figure 1. Model's prediction and treatment parameters in large markets



Notes. This figure presents the optimal theoretical choice to incur the fixed cost as function of the share of certified and high-quality uncertified output supply, in large markets. θ is the share of high-quality among uncertified wheat. π is the share of certified-wheat. The ABCD curve represents π-θ combinations for which traders are indifferent between incurring the fixed cost or not. The optimal choice for π-θ combinations located above the curve is to not incur the fixed cost and mix certified and uncertified output. The optimal choice for π-θ combinations located below the curve is to incur the fixed cost and separate certified and uncertified output. One expects traders to buy both certified and uncertified crops in the area ABE and CGD, but to specialized in the other areas, in certified crops below ABDC, in uncertified crops above. Black dots indicate the empirical values used in the experimental game. T1, T2, T3, and T4 correspond to different treatments (i.e., games).

Figure 2. Model's predictions and treatment parameters in small markets

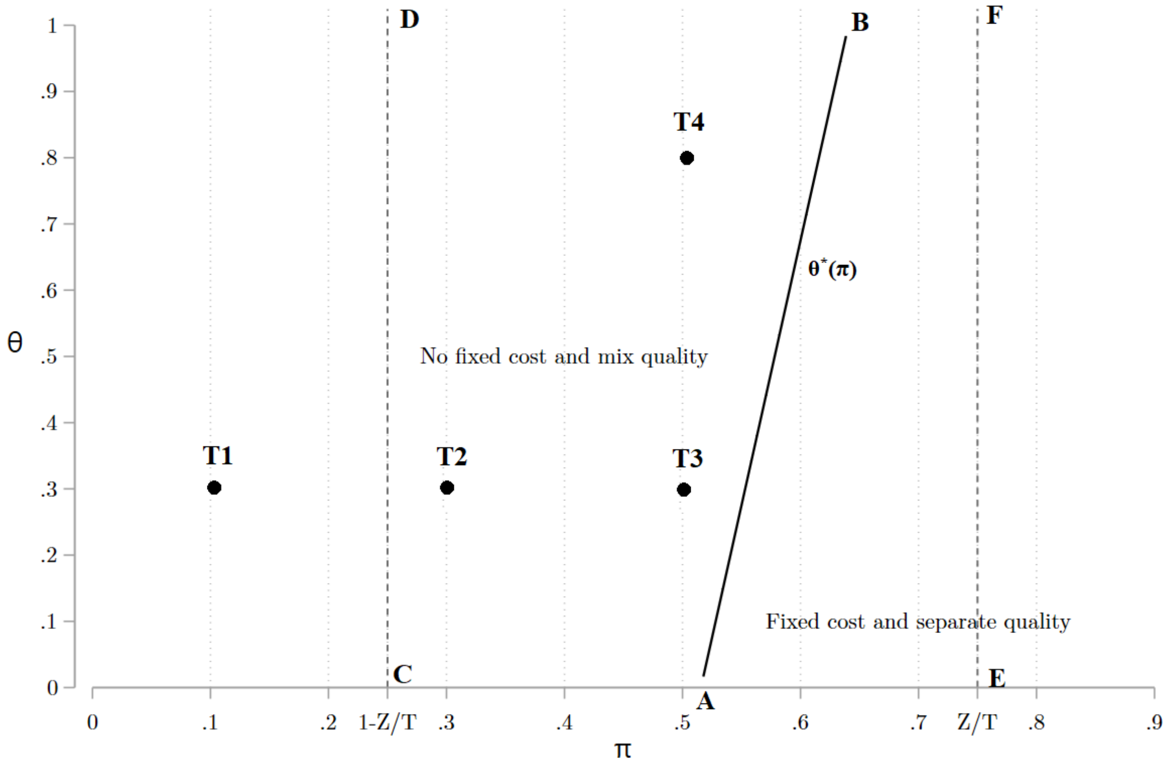


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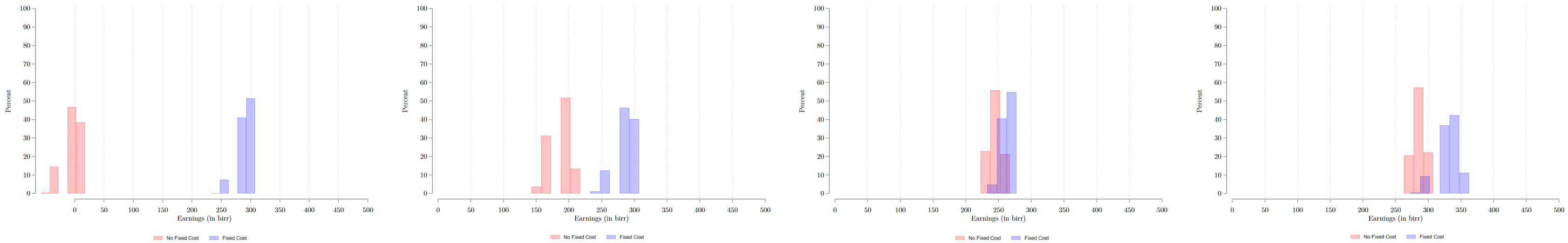
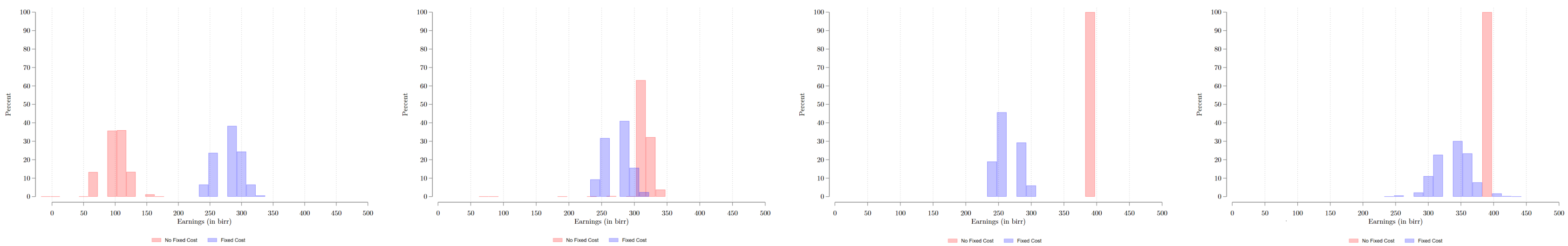
Figure 3. Simulated earnings distribution, by treatment combinations and market size

Panel A. Small market



A. Low π - Low θ | B. Medium π - Low θ | C. High π - Low θ | D. High π - High θ

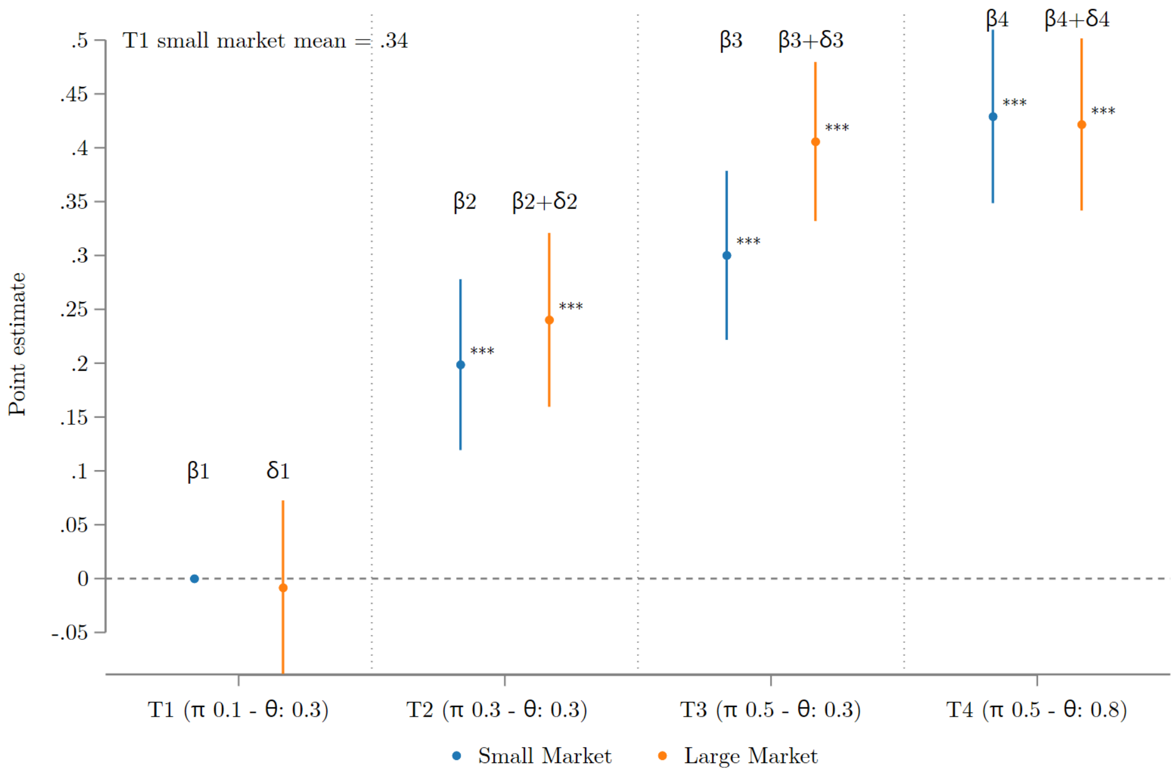
Panel B. Large market



E. Low π - Low θ | F. Medium π - Low θ | G. High π - Low θ | H. High π - High θ

Notes. This figure shows simulated earnings distributions (in Birr) from 1,000 Montecarlo simulation by fixed cost decision and game. Panel A corresponds to small market cases and Panel B to large market cases. Red bars show earnings after incurring the fixed cost. Blue bars show earnings after incurring the fixed cost. π is the share of certified-wheat. θ is the share of uncertified high-quality wheat.

Figure 4. Traders investment decisions across market conditions and market sizes

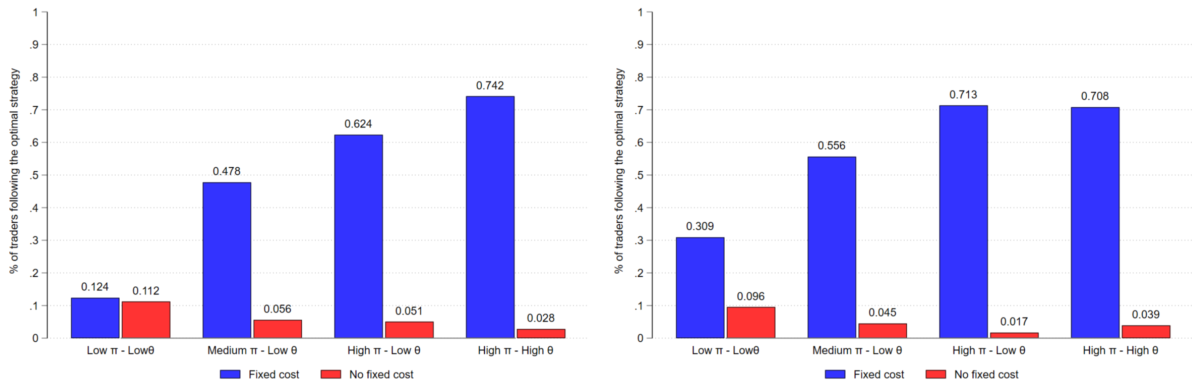


Notes. This figure shows the probability of paying the fixed cost in a given game, relative to the probability of paying it in the T1 small market game. Each dot corresponds to the estimated coefficient associated with a given a treatment arm (specific combination of π and θ), along with its interaction with market size, as per equation 13. π is the share of certified wheat. θ is the share of high-quality wheat among uncertified wheat. Coefficient estimates are in blue for small market games and orange for large market games. T1 small market is the omitted category (β_1). 95% confidence intervals are base on robust standard errors. Controls include game order and trader fixed effects. *** p<0.01, ** p<0.05, * p<0.1. Unit of observation is participant × game level.

Differences across parameter estimates: statistical significance

$\beta^2 = 0 : p - value = 0.00$; $\beta^2 = \beta^3 : p - value = 0.00$; $\beta^3 = \beta^4 : p - value = 0.00$; $\delta^1 = 0 : p - value = 0.84$; $\beta^2 = \beta^2 + \delta^2 : p - value = 0.30$; $\beta^3 = \beta^3 + \delta^3 : p - value = 0.03$; $\beta^4 = \beta^4 + \delta^4 : p - value = 0.85$; $\delta^1 = \beta^2 + \delta^2 : p - value = 0.0$;$\beta^2 + \delta^2 = \beta^3 + \delta^3 : p - value = 0.00$;$\beta^3 + \delta^3 = \beta^4 + \delta^4 : p - value = 0.66$.

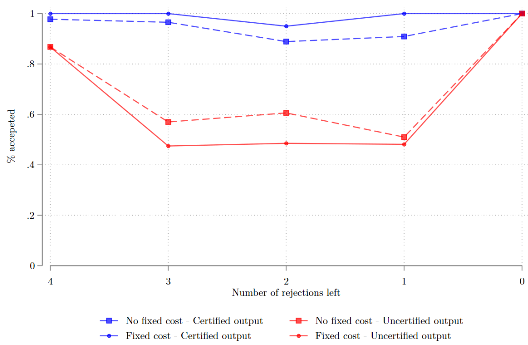
Figure 5. Proportion of traders following the optimal purchase strategy



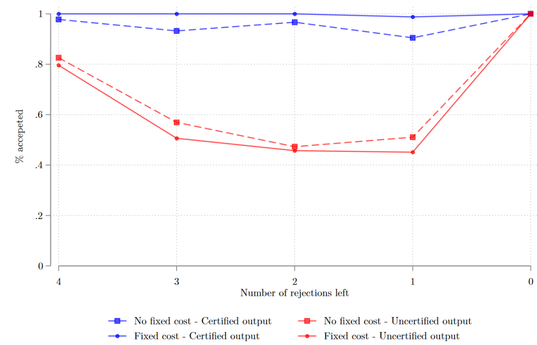
A. Small market B. Large market

Notes. This figure shows the proportion of traders accepting only (uncertified) certified output before the Farmer N (M) threshold if they (do not) pay the fixed cost. Farmer N (M) is the farmer after which the number of remaining encounters with farmers on that day is equal to the number of remaining empty slots on the rented truck. Panel (a) shows results for the small market case. Panel (b) shows results for the large market case. Blue bars are the proportion of traders incurring a fixed cost accepting only certified output before the Farmer N. Red bars are the proportion of traders not incurring a fixed cost accepting only uncertified output before the Farmer M.

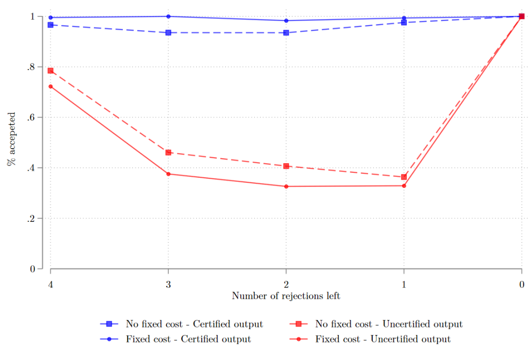
Figure 6. Acceptance rate per round in small market



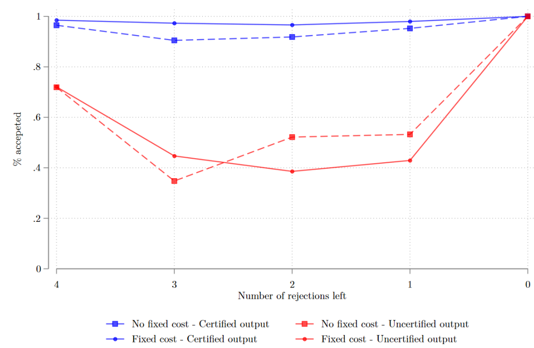
A. Low π - Low θ



B. Medium π - Low θ



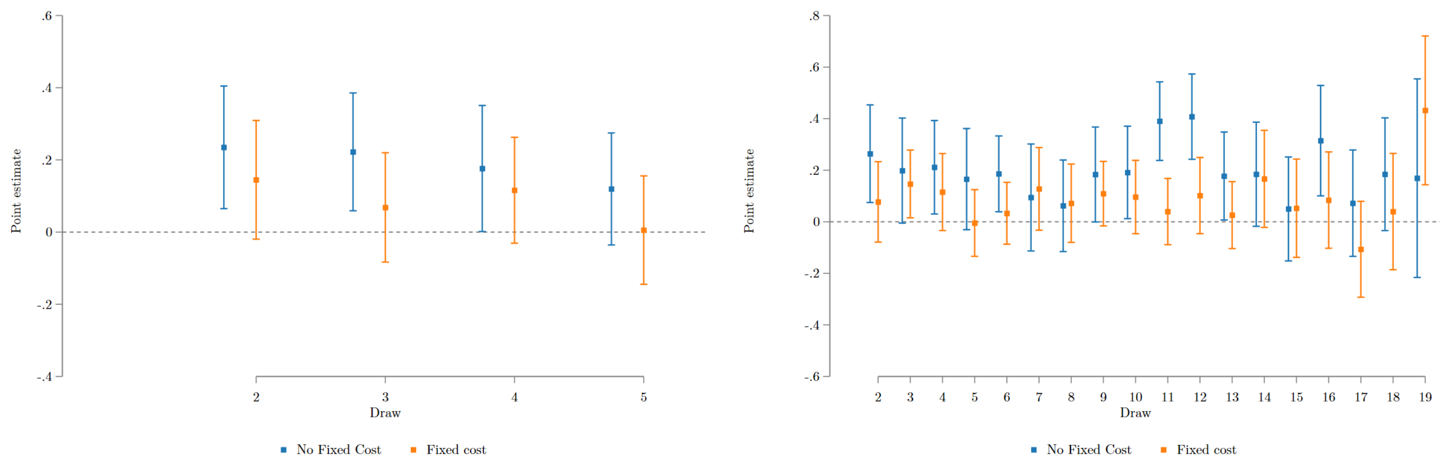
C. High π - Low θ



D. High π - High θ

Notes. This figure shows for each treatment the proportion of chips drawn accepted at a given round before and after the Farmer N (M) threshold if they (do not) pay the fixed cost. Farmer N (M) is the farmer after which the number of remaining encounters with farmers on that day is equal to the number of remaining empty slots on the rented truck. Red lines represent the proportion of uncertified wheat output accepted at a given round. Blue lines represent the proportion of certified wheat accepted at a given round. Plain lines represent cases for which the trader did not incur the fixed cost. Dashed lines represent cases for which the trader did incur a fixed cost. π is the share of certified-wheat. θ is the share of uncertified high-quality wheat.

Figure 7. Optimal accept/reject behavior given one's luck at previous draw

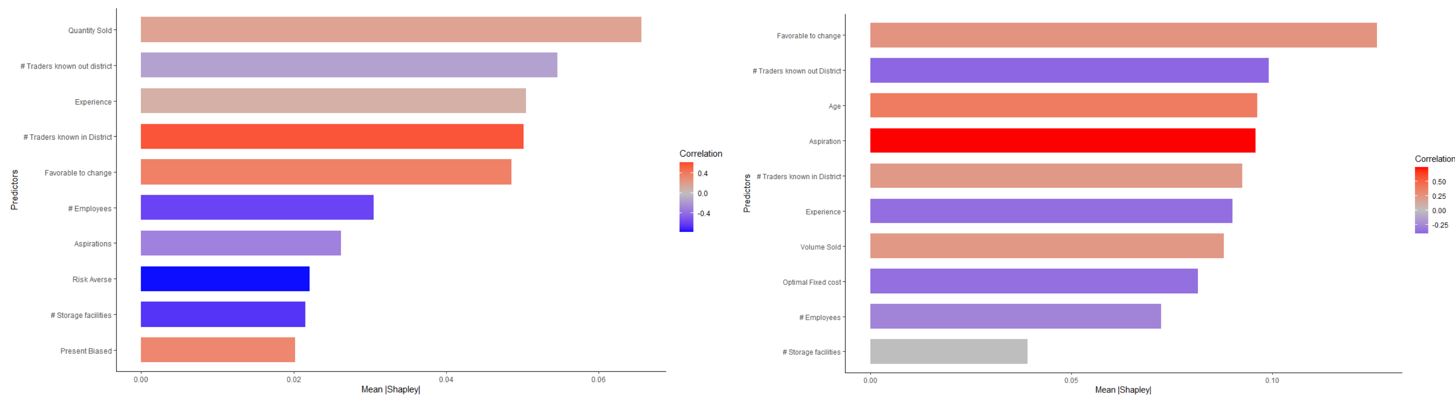


A. Small market case

B. Large market case

Notes. This figure shows correlation coefficients between traders' optimal accept/reject decision at draw t and whether she drew a favorable chip at $t-1$ —a favorable chip is certified ig she has invested in the cup, and uncertified otherwise. Panel A (B) shows the result for small (large) market cases. The model is estimated separately across traders who have purchased (blue) or not-purchased (orange) a cup at the beginning of the round. We plot the coefficients for each draw along with 95% confidence interval are based on robust standard errors. Controls include game order and trader fixed effects. Unit of observation is participant × draw × game level.

Figure 8. Predictors of traders' behavior: eXtreme gradient boosting model



A. Optimal investment decision

B. Optimal accept/reject behavior

Notes. This figure shows the tenth most predictive features predicting trader's behavior using an eXtreme gradient boosting algorithm. It provides the direction of the association (red for positive and blue for negative), and the predictor's marginal contribution in prediction based on the mean Shapley (SHAP) values. SHAP values are the unexplained part of the model for each observation, and the sign of predictors are the association with the outcome. Panel A outcome: Trader takes the optimal fixed cost investment decision. Panel B outcome: Trader switches too early to suboptimal accept/reject decision.

Table 1. Traders characteristics

	Mean	SD	N
Panel A. Trader characteristics			
Age	41.944	11.28	178
Male(0/1)	.949	.22	178
Formal Education (0/1)	.921	.27	178
Wheat Trading Exp. (years)	8.764	6.74	178
Panel B. Trading characteristics			
Traders Association (0/1)	.47	.5	178
Number of Trucks	.12	.38	178
Number of Grain Storage	1.05	.58	178
Family Members in Agr Trade	1.66	3.42	178
Traders Known in the Woreda	55.37	80.69	178
Number of Selling Markets	2.34	3.47	178
Volume Bought last season (Qt)	1925.57	8157.56	178
Average Selling Price (Birr/Qt)	2734.71	375.1	175
Panel C. Quality Practices			
Pay a Premium (0/1)	.76	.43	178
Price Premium (Birr/Qt)	78.26	47.08	135
Assess Quality (0/1)	.98	.15	178
Color(0/1)	.9	.3	174
Impurity(0/1)	.99	.08	174
Grain Size (0/1)	.94	.24	174
Moisture(0/1)	.85	.36	174
Extraction Rate (0/1)	.48	.5	174
Separate Quality (0/1)	.72	.45	178
Panel D. Behavioral Attributes			
Risk Aversion (0/1)	.81	.39	178
Loss Aversion (0/1)	.44	.5	178
Present Biased (0/1)	.66	.48	178

Notes. This table shows summary statistics for traders in our sample. Age is trader's age in years. Male is a dummy equal 1 if the trader is a male. Formal education equals 1 if the trader has formal education. Wheat trading exp. is the number of years of experience in wheat trading. Trader association equals 1 if she is member of a trader association. Number of trucks is the number of trucks a trader owns. Number of grain storage is the number of grain storage a trader owns. Family members in agr trade is the number of family members in agricultural trade. Traders known in the *woreda* is the number of traders one knows in the *woreda*. Number of selling markets is the number of markets where the trader is active. Volume bought last season is the wheat quantity (in Qt) a trader bought the previous season. Average selling price is the average price a trader is obtaining (in Birr per Qt). Pay a premium equals 1 if a the trader pays a quality premium. Price premium is the amount she pays for rewarding quality (in Birr per Qt). Assess quality equals 1 if the trader measures any quality characteristics. Color equals 1 if the trader measures color. Impurity equals 1 if the trader measures impurity. Grain size equals 1 if the trader measures grain size. Moisture equals 1 if the trader measures moisture. Extraction rate equals 1 if the trader measures extraction rate. Separate quality equals 1 if the trader separate wheat based on quality. Risk aversion equals 1 if the trader is risk averse. Loss aversion equals 1 if the trader is loss averse. Present biased equals 1 if the trader is impatient.

Appendix

Theory: Net benefit of paying fixed cost as function of market size, at given θ

Consider two markets of size S^L and S^S, with $S^L > S^S$.

1. If both are 'large' markets, as defined above, $2Z < S^S < S^L$.
   $\Delta^{fc} = \Pi^{fc} - \Pi^{nfc} = \pi S\Delta - F$ increases linearly in π, with slope $S\Delta$ until it reaches $Z\Delta - F$ for $\pi = \frac{Z}{S}$ and then remains constant for $\frac{Z}{S} < \pi < 1 - \frac{Z}{S}$. Beyond $\pi = 1 - \frac{Z}{S}$, Δ^{fc} increase linearly in π, with slope $S(p^c - p^u - b(1-\theta)$, to reach $Z(P^C - a - b) - F$ at $\pi = 1$.

   This shows that Δ^{fc} is weakly larger in the larger market for $\pi < 1 - \frac{Z}{S^S}$, but lower beyond that value.

2. If both are 'small' markets, as defined above, $S^S < S^L < 2Z$.
   $\Delta^{fc} = \Pi^{fc} - \Pi^{nfc} = \pi S\Delta - F$ increases linearly in π, with slope $S\Delta$ until it reaches $(S-Z)\Delta - F$ for $\pi = 1 - \frac{Z}{S}$. Then increases linearly in π with slope $S(P^C - a - b) > S\Delta$ until it reaches $Z\Delta + (2Z - S)(p^c - p^u - b(1-\theta)) - F$ for $\pi = \frac{Z}{S}$. Beyond $\pi = \frac{Z}{S}$, Δ^{fc} increase linearly in π, with slope $S(p^c - p^u - b(1-\theta) < S(P^C - a - b)$, to reach $Z(P^C - a - b) - F$ at $\pi = 1$.

   For $\pi < 1 - \frac{Z}{S^S}$, $\Delta^{fc} = \pi S\Delta - F$ for both markets is an increasing function of market size. Beyond that value for π, the smaller market falls under case 4 with a steeper slope in S, meaning that Δ^{fc} in the smaller market may overpass Δ^{fc} in the larger of the two markets. We can show that this overpassing only happens beyond $\pi = 0.5$ under certain conditions.

   Consider $\pi = 0.5$, which is the largest of the values $1 - \frac{Z}{S}$ among the small markets. In both markets $1 - \frac{Z}{S} \leq \pi \leq \frac{Z}{S}$. Therefore:

   $\Delta^{fc} = \pi S\Delta + (Z - (1-\pi)S(p^c - p^u - b + b\theta) - F = K + 0.5S[\Delta - (p^c - p^u - b + b\theta)]$

   Hence, if $\Delta > p^c - p^u - b(1-\theta)$, Δ^{fc} increases with market size at $\pi = 0.5$. Since all functions $\Delta^{fc}(\pi)$ are linear in π, with slope function of S, their can't be any crossing of two lines before $\pi = 0.5$. This shows that Δ^{fc} increases with market size for all $\pi \leq 0.5$. This condition can also be written $\Delta > (a + b\theta - p^u) - (a + b - p^c)$, meaning that the marginal benefit of trading certified rather than uncertified crop is greater than the loss that would be incurred by having to sell certified rather than uncertified crop as uncertified.

3. If $S^S < 2Z < S^L$, corresponding to one small and one large market.
The evolution of Δ^{fc} on each of the markets is similar to that described above. This shows that Δ^{fc} is larger in the larger market for $\pi < \max(\frac{Z}{S^L}, 1-\frac{Z}{S^S})$, but not beyond $\max(\frac{Z}{S^S}, 1-\frac{Z}{S^L})$.

Taken together, one can affirm that Δ^{fc} is larger in the larger market for $\pi \leq 0.5$, whatever categories those two markets belong to.