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Understanding traders' regional arbitrage
The case of rice traders in Antananarivo, Madagascar*

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Abstract

This paper reports facts about arbitrage of rice traders in Antananarivo, Madagascar. First, even in the same period, for the same variety, some traders are purchasing from districts with higher prices when some others are purchasing with lower price in different district, indicating scope for better arbitrage. Second, although the cheapest district changes over time, most of the traders specialize in trading in few, limited, popular districts, which are not always the cheapest district. Third, consequently, traders often fail to purchase from the cheapest district and therefore are paying substantially higher prices than the cheapest price. Fourth, traders do not search price in other districts extensively, and their knowledge on price is concentrated in very few districts. Fifth, our randomized controlled trial intervention to provide regional price information via SMS had no effect on purchasing behavior, arbitrage efficiency, or quantity, price, and margin of purchase.

Keywords: arbitrage, search, traders, price information, rice, Madagascar
JEL code: L81, O13, Q13

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1. Introduction

Well-functioning agricultural market is vital for efficient marketing and distribution of food across time and space. Under well-functioning markets, prices would signal surplus and deficiency across regions, and induce traders to arbitrage. Successful arbitrages would smooth the regional distribution of produce and enhance welfare by supplying consumers with lower price and offering producers a higher price. Eventually, markets would be integrated and price would converge across regions to form the law-of-one-price.

Many studies however, find that agricultural markets are not well-functioning: markets are not fully integrated (see for example Fackler and Goodwin 2001, and Sexton et al 1991)). Number of obstacles can raise transaction costs and prevent the full functioning of agricultural markets. Poor transportation infrastructure is often the major cause of market disintegration (Cirera and Arndt 2008; Donaldson, forthcoming; Hanan 2000, Minten and Steven 1999, Sakurai and Miyake 2012). Constraint in flow of market information is another crucial element that prohibits sufficient and timely arbitrage (Allen 2012; Aker 2010; Camacho and Conover 2011; Fafchamps 2012; Goyal 2010; Jensen 2007, 2010; Muto and Yamano 2009; Ouma et al 2010; Nakasone 2013).

Unfortunately, however, not much is known about traders' arbitrage itself, despite of being one of the fundamental economic activities. Since market integration is achieved through arbitrage by many traders, it is vital to understand its details of how and how well the traders arbitrage in practice. Identifying the causes the impede traders from better arbitrage is essential to consider policies to improve the efficiency of agricultural market. To our knowledge, however, there is hardly any study that quantitatively document traders' arbitrage in developing economies.

This paper focuses on traders' arbitrage and attempt to answer the following questions: Is agricultural traders' arbitrage in developing countries efficient? To what regional extent do they search and trade? How do they obtain price information in various regions? How efficient are their arbitrage? What prevents them from making a better arbitrage? Does provision of price information improve the efficiency of arbitrage?

To answer these questions, we study the case of rice traders in Madagascar. Rice is the most important staple food in Madagascar and the Malagasy rice market is one of the most studied cases on market integration. It is reported that the Malagasy rice market is spatially disintegrated at the province level around 2000 and therefore, inefficient (Moser et al 2009; Butler and Moser 2010). Recent studies also reconfirm this conclusion (Miyake and Sakurai 2012; Arimoto et al 2014). Thus, there is scope for better arbitrage and improvement of rice marketing in Madagascar.

To document the traders' arbitrage in the Malagasy rice market, we collected detailed data on rice trade for 224 rice traders operating in Antananarivo, the capital of Madagascar. The data was collected throughout one year from August 2012 to August 2013, every two weeks for 27 rounds. The data covers information on price search in different regions, details of purchase of rice including information on district of purchase, transportation, price and payment, and management indicators such as stock, quantity of purchase and sales, average price and margin, and costs. Moreover, in order to examine whether price information is the key determinant of successful arbitrage, we also randomly selected half of the traders and provided price information in 10 major rice producing districts via SMS from the middle of the survey.

Our main findings can be summarized in five points. First, we find that there is scope

of better arbitrage. Even in the same period, depending on the variety, rice is purchased from 7 to 10 different districts with large price differences. In other words, some traders are purchasing from districts with higher prices when some others are purchasing with lower price in different district. The cheapest district however, does change over time. Therefore, traders need to trade with many different districts in order to fully capture the arbitrage opportunities. Second, however, most of the traders specialize in trading in few, limited, popular districts, which are not always the cheapest district. Third, consequently, traders often fail to purchase from the cheapest district and therefore are paying much higher prices than the average price in the cheapest district. For example, for active inter-district trades (i.e. traders visiting other districts to purchase) for the most common variety (Vary gasy), only 13% of the trade–round observations were purchased in the cheapest district, and the average price paid was 13% higher than the average price in the cheapest district. Fourth, traders are "price blind" in a sense that they do not extensively search price in other districts, which is the premise for regional arbitrage. Even if they do, their knowledge on price is concentrated in very few districts such as Tana and Ambatondrazaka and some other major districts. Fifth, our randomized controlled trial intervention to provide regional price information via SMS had no effect on purchasing behavior, arbitrage efficiency, quantity and price of purchase, or margin.

This paper adds to our knowledge on traders' arbitrage and marketing activities. This paper is probably the first study that directly investigates agricultural traders' arbitrage and quantifies its efficiency in a systematic way. In relation to traders' activities, Fafchamps and Minten (2001, 2002) reports that Malagasy traders tend to limit the extent and scope of trade in order to limit their exposure to risks of theft and breach of contract. Our finding that arbitrage links are limited is in line with their observations;

we interpret that because of lack of trust, traders are limiting the number of links and therefore missing arbitrage opportunities.

Second, we contribute to the understanding on the causes of the disintegration of rice markets in Madagascar. Previous studies have repeatedly reported that Malagasy rice markets are spatially disintegrated using the co-movement of prices over regions (Moser et al 2009; Butler and Moser 2010; Miyake and Sakurai 2012, Arimoto et al, 2014). We provide evidence that this is at least partly because traders' arbitrage is not efficient.

Third, we add evidence on the impact of providing price information to traders. Information friction can lead to failure of arbitrage. Study of regional rice markets in Philippines indicates the presence of substantial information frictions (Allen 2012). Several studies have examined the impact of providing market information through randomized controlled trial (RCT). Fafchamps and Minten (2012) reports that randomized provision of market information to farmers improved arbitrage by selling at distant wholesale markets rather than at the farm-gate in India. Nakasone (2013) finds that farmers who received price information got higher sales prices in Peru, but no such effect is found in Colombia (Camacho and Conver 2011). While informative, these studies provided information to farmers. In this paper, we distribute information to traders. To our knowledge, this is the first evidence on the impact of price information on traders under RCT. Since traders are specialized in trading and arbitrage, and bear the fundamental role in marketing and distributing the agricultural produce, we believe that the impact of price provision to traders is more relevant for the understanding of efficiencies of agricultural markets.

The paper is organized as follows. Section 2 describes the survey and data. In Section 3, we show evidences that there remain opportunities of arbitrage and Section 4 reports

evidences of the traders' inefficiency of arbitrage. In Section 5, we offer some background about the traders' inefficiency and report the results of the SMS price provision intervention. In Section 6, we summarize our findings.

2. Survey and data

The subjects of our survey are the rice traders operating in the Greater Antananarivo Area (also referred to as "Tana"), formed by the city center and suburb. Since we are interested in regional arbitrage, the population of focus is the rice traders who engage in inter-district rice trade (i.e., trade between Tana and districts outside Tana). Rice traders such as retailers who only purchase from wholesalers or farmers in Tana and sell at retail are not participating in regional arbitrage, so these traders are not considered as our subject. We distinguish two types of inter-district trade: active and passive. Active inter-district trades are purchases that are made outside of Tana by traders actively visiting other districts. Traders engaged in active trades are also often called collectors ("collecteur" in French). On the other hand, passive inter-district trades are purchases made in Tana from sellers (trucks) who came from other districts to sell in Tana. Such purchases may take place at the traders' store where sellers directly come regularly, or at the parking place at major wholesale markets such as the Anosibe market.

The survey was conducted from June 2012 until August 2013. We started by conducting a one month-long survey in June 2012 to create a list of rice traders, because there is no such list. We first identified the geographical cluster where there is a high probability of finding rice traders. We selected 44 out of 192 wards in the city center, and 17 out of a total of 40 communes in the suburb based on five criteria[2]. We then

[2] In the city, we selected 2 wards where the main rice markets are located: Anosibe Andrefana and Andravoahangy Tsena, 10 wards surrounding those two markets where rice traders most likely own a

made a list of rice traders by: (a) visiting the ward markets ward markets for Antananarivo city and the largest markets in the commune for the suburbs and list all rice traders (retailers/wholesalers/traders/millers) operating in the markets; (b) visiting the ward and municipality officials to introduce us the largest rice traders that they know in their area, including wholesalers, collectors and millers; (c) visiting millers and ask information about traders based in the ward and municipality. All the listed traders were visited and identified whether they engaged in inter-district trading. We ended up with a list of 318 inter-district rice traders.

In July 2012, we conducted the baseline survey to collect general information about the traders and their trading activities. 241 out of 318 (76%) listed traders agreed to cooperate and completed the baseline survey. We then conducted the periodic survey from August 6, 2012 to August 13, 2013 every two weeks, making 27 rounds in total. The periodic survey was conducted to collect information on price search, details on sales and purchases, and stock and profit margins. Among 241 traders who completed the baseline survey, 234 initially agreed to participate in the periodic survey, but 10 dropped during the course. Thus, our final number of sampled traders is 224. The number of observation at the trader–round level is 6,033[3].

Among 224 sampled traders, 104 traders (46%) engaged in active inter-district trading and 209 traders (93%) engaged in passive inter-district trading during the course of one-year period survey. 91 traders (41%) engaged in both active and passive inter-district trading.

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shop and/or live, 32 wards in which there is a market managed by Antananarivo city government. In the suburbs, we selected 12 communes where traders reside from the INSTAT list of registered traders and wholesalers, and 5 communes located along the national highways that are potentially active in rice trading.

[3] The full number of observation at the trader–round level should be $224 \times 27 = 6{,}044$. We had 11 missing trader–rounds due to refusal or loss of questionnaire.

3. Opportunities of arbitrage

In this section, we show that there remain chances for arbitrage. Even in the same period, for the same variety, rice is purchased from several different districts with large price differences. In other words, some traders are purchasing from districts with higher prices when some others are purchasing with lower price in different district. The cheapest district however, does change over time. Therefore, traders need to trade with many different districts in order to fully capturing the arbitrage opportunities.

3.1. Regional extent of trade

We first show that even in the same period, for the same variety, rice is purchased from various different districts. Figure 1 depicts the number of different districts where we confirmed actual purchase of rice for active and passive inter-district trade for each round. Averaged over rounds, for active purchases, Vary gasy was purchased from 7.9 different districts and Tsipala was purchased from 7.5 different districts in the same round. Districts purchased for passive inter-district trade were more diverse: Vary gasy was purchased from 8.7 different districts and Tsipala was purchased from 10.3 districts. The number of different districts purchased for Makalioka is small (2.8 districts for active and 3.6 for passive) because it is grown in limited areas.

== Figure 1. Number of different districts purchased ==

3.2. Price difference among districts

There are large price differences among these purchased districts. To see how prices differ among districts, we represent the price for each round–activity (active and

passive) –variety–district by averaging the actual prices paid by the traders. The prices are the purchase price of milled rice plus transportation costs[4]. For passive inter-district purchases, we also consider the prices in Tana (i.e. prices at Anosibe and Andravoahangy markets, and purchase price from sellers in Tana) since these are important alternatives for traders if they decide to purchase rice in Tana.

Figure 2 shows the ratio of the price in the most expensive district (maximum price) over price in the cheapest district (minimum). Averaged over rounds, the max–min price ratio for active inter-district purchases is 118% for Vary gasy and 108% for Tsipala. Thus, traders visiting the most expensive district are paying prices that are 8 to 18% higher than those visiting the cheapest district. Similarly, the max–min price ratio for passive inter-district purchases is 114% for both Vary gasy and Tsipala. These facts imply that there is scope for better arbitrage; traders not purchasing from the cheapest district can gain by changing the district of purchase to the cheapest district.

== Figure 2. Max–min price ratios among districts ==

3.3. Where is the cheapest district?

One difficulty for traders to make better arbitrage is that the cheapest district changes over time. Table 1 and Table 2 reports the average price for each district by round–activity–variety. The cheapest district for each round is emphasized in red. For example, for active purchase for Tsipala, districts in Sofia region (Mandritsara, Bealanana, and Mampikony) tend to be the cheapest in the earlier rounds, whereas Arivonimamo,

[4] Traders could purchase in either paddy or milled rice. We are not able to calculate the purchase price for paddy because of lack of milling costs. Therefore, the average purchase price for districts without purchase in milled rice is missing.

Ankazobe, and Ambohidratrimo become the optimal choice in the later rounds. This suggests that in order to make an efficient arbitrage, it is essential for the traders to keep track of the prices in several districts and to switch the district of purchase according to changes of the cheapest district.

At the same time, traders need to purchase from many different districts depending on the rounds in order to make full use of arbitrage opportunities. For active purchases, 6 different districts had become the cheapest district at least once during the one-year survey period for Vary gasy, whereas 8 districts won the place for Tsipala. Passive purchases are harder: traders need to purchase from 13 different districts (including Androavoahangy market and sellers in Tana) for Vary gasy and 12 different districts for Tsipala to make perfect arbitrage.

== Table 1. Average price by round–variety–district (passive) ==

== Table 2. Average price by round–variety–district (active) ==

4. Evidences of arbitrage inefficiency

In this section, we provide evidences showing that traders' arbitrage is inefficient. First, despite that the cheapest district changes over time, many traders tend to specialize in purchasing from the same few districts they are familiar with. Second, popular districts where many traders purchase are not always necessary the cheapest district. Third, we show that many traders are indeed failing to purchase from the cheapest district and are paying much higher prices than the average price in the cheapest district.

4.1. Number of districts purchased

We begin by showing that despite that traders need to purchase from many different districts to fully capture the opportunity of arbitrage, most traders tend to specialize in trading with the same few districts.

Table 3 reports the average number of different districts purchased by trader types and varieties. Panel A of Table 3 indicates that on average, traders purchased from 4.0 different districts during the one-year survey period, including both active and passive inter-district purchases. Vary gasy and Tsipala are purchased from 2.5 and 2.7 different districts, respectively. Panel B of Table 3 indicates that traders purchase from 1.9 different districts per round, but for each variety, traders purchase from a single district. Table 3 reports the figures by active and passive purchase for traders engaged in active inter-district trade. Active traders visit 2.1 and 2.2 different districts for active purchase for Vary gasy and Tsipala, respectively.

== Table 3. Average number of districts purchased ==

Figure 3 depicts the distribution of number of different districts purchased by variety and trader-types. At the trader level, more than 60% and 50% of traders purchase from at most two different districts throughout the year for Vary gasy and Tsipala, respectively. For the purchase of Makalioka, 80% of the passive-only traders and 70% of the active traders had connection with only one district, which is most likely Ambatondrazaka. At the trader–round level, Figure 3 shows that almost all traders concentrate on purchasing from a single district for each variety, per round. These facts imply that for each variety, traders purchase from a single district in each round and

more than half of the traders switch between only two districts per variety throughout the year.

== Figure 3. Distribution of the number of districts purchased ==

4.2. Popular districts are not necessary the cheapest district

Traders not only tend to specialize in few districts, but they also tend to concentrate in popular districts. Table 4 to Table 7 describes the percentages of traders who purchased from each district for purchase of Vary gasy and Tsipala, by passive and active inter-district purchase. For passive inter-district purchase, we also consider purchase in Tana (i.e. wholesale markets and sellers in Tana). Districts attracting more traders for each round are emphasized in deeper red.

== Table 4. Percentage of traders purchasing from each district (active, Vary gasy) ==

== Table 5. Percentage of traders purchasing from each district (active, Tsipala) ==

== Table 6. Percentage of traders purchasing from each district (passive, Vary gasy) ==

== Table 7. Percentage of traders purchasing from each district (passive, Tsipala) ==

For active purchases, the tables indicate that purchases are largely concentrated in regions in the west of Tana (Itasy and Bongolava region). Arivonimamo (Itasy region), Tsiroanomandidy (Bongolava region), and Anjozorobe (Analamanga region) is the major destinations for Vary gasy, whereas Arivonimamo, Tsiroanomandidy, and Miarinarivo (Itasy region) is the common destinations for Tsipala. For passive purchases,

the districts are relatively more dispersed. While Arivonimamo, Anjozorobe, and Tsiroanamandidy is the major districts for Vary gasy, purchases at the wholesale markets in Tana (Anosibe and Andravoahangy markets) and purchase from sellers in Tana is also common. For Tsipala, Arivonimamo, Anjozorobe, Tsiroanomandidy, and purchase in Tana continue to be the major sources, but purchase from sellers from Sofia region (Mandritsara and Bealalana) is also noticeable.

It is important to note that these popular districts are not always the cheapest district to purchase. We marked the cheapest district for each round with bold squares. If the squares match with darker red, then it indicates that many traders are purchasing from the cheapest district. At a glance, active purchases for Vary gasy are relatively well targeted. Tsiroanomandidy, which turns out to be the cheapest in 9 out of 27 rounds, do tend to attract many traders. However, Anjozorobe, which is cheapest for 10 rounds, is not as popular as Tsiroanomandidy or Arivonimamo. In other words, many traders are visiting Arivonimamo despite that it is not as often cheap as Tsiroanomandidy or Arivonimamo. Active purchases for Tsipala are miss-targeted especially in the earlier rounds where districts in Sofia region win the cheapest district. Passive purchases are also inefficient, since the major popular districts such as Arivonimamo, Anjozorobe, and Tsiroanomandidy are rarely the cheapest.

4.3. Measures of arbitrage efficiency

Here, we examine the efficiency of arbitrage at transaction and trader level. The unit of observation for the transaction level is trader–round–activity–variety. In case a trader purchased rice from different districts within round–activity (passive or active) –variety (Vary gasy, Tsipala, and Makalioka), we identified the cheapest purchase. In total we

have 12,466 trader–round–activity–variety level observations.

We define two indicators to measure arbitrage efficiency. The first measure is a dummy variable indicating whether a trader purchased from the cheapest district. The second measure is the actual–optimal price ratio. The actual–optimal price ratio θ is defined as

$$\theta = \frac{p_{itav} - p^*_{tav}}{p^*_{tav}}$$

where p_{itav} is the actual cheapest price paid by trader i in round t for activity a in purchase for variety v, and p^*_{tav} is the average purchase price in the cheapest district for the same round–activity–variety.

Table 8 reports the summary statistics of the arbitrage efficiency. In only 8.6% of the whole observations, the purchase was made from the cheapest district (Panel A). The actual–optimal price ratio (Panel B) is 0.061, indicating that traders paid prices that are 6.1% higher than the average price in the cheapest district. The price premium is on average completely due to purchasing from wrong districts; if a trader purchased from the cheapest district, the average price premium is 0.1%.

== Table 8. Summary statistics on arbitrage efficiency (trader–round–activity–variety level) ==

Figure 4 depicts the average of the two indicators by activity–variety. At the trader–round level, active purchases are relatively well-targeted towards the cheapest district compared to passive purchases. The high percentage of observations (72%) purchased from the cheapest district for Makalioka in active purchase is due to the fact that the districts producing Makalioka is limited and there are few choices in the first place.

Consequently, the actual–optimal price ratio for Makalioka is relatively small, indicating that the prices are converged.

== Figure 4. Measures of arbitrage efficiency ==

We also report arbitrage efficiency at the trader level in Figure 4. For each trader–activity–variety, we counted the rounds which the trader purchased from the cheapest district. We then divided that by the number of rounds the trader engaged in the purchase of that activity–variety. The figure shows that, depending on the variety, traders are only able to purchase from the cheapest districts for passive purchase in 5–9% of the rounds. On the other hand, traders purchase from the cheapest districts for active purchase in 18–55% of the rounds. Each trader is paying on average, 3–7% higher prices from the optimum for passive purchase and 1–10% higher prices for active purchase.

5. What explains traders' arbitrage efficiency?

Why is traders' arbitrage inefficient? In this section, we examine the sources of inefficiency.

5.1. The "price-blind" traders

We begin by examining whether traders knew the prices in places other than the districts they purchased. In each round, we asked whether the trader knew the purchasing price in 42 major rice producing districts.

Searching price in these rice producing districts is common, though not many districts

are searched. At the trader level, 95% of the traders did search prices in the listed 42 districts, at least once during the one-year survey period. Among those who did search price, the average number of districts knowing the price is 5.1. At the trader–round level, search was conducted in 76% of the 6,033 observations and 2.1 districts were searched on average. Figure 5 shows the average number of districts knowing price by trader types. Active traders are more likely to search than passive-only traders.

== Figure 5. Number of districts knowing price ==

However, the traders' knowledge on prices is limited to Tana and Ambatondrazaka and some other major districts. For each round, we calculated the percentage of traders who searched the price in each district. Averaged over rounds, the most common district where traders knew the price is Antananarivo Renivohitra (61%), followed by Ambatondrazaka (35%), Miarinarivo (20%), Tsiroanomandidy (15%), Ankazobe (6%), Bealanana (6%), Marovoay (6%), and Mandritsara (5%).

Therefore, many traders are "price-blind". Given lack of knowledge on prices in different districts, there is no wonder why traders fail to arbitrage efficiently.

5.2. Correlates of arbitrage efficiency

To examine the correlation between search behavior and arbitrage efficiency, we estimate the following model with OLS:

$$y_{itv} = \beta_0 + X_i\beta_1 + X_{it}\beta_2 + d_i + d_t + d_v + \varepsilon_{itv}.$$

The unit of observation is trader–round–variety, where i, t, and v index trader, round, and variety, respectively. We run the regression separately for passive and active purchases. We focus on purchase of Vary gasy and Tsipala only, since the regional choice of purchase for Makalioka is rather limited. X_i is the vector of trader level covariates, where we include the number of different districts knowing price and the number of different districts purchased during the one-year survey period. These variables capture the trader level characteristics in terms of search and extent of trade. X_{it} is the vector of trader–round level covariates. We include the number of different districts knowing price and the number of different districts purchased in round t. d_i, d_t, and d_v is trader, round, and variety fixed effects.

Table 9 reports the results for the purchase from the cheapest district. The result shows no clear evidence that the extent of search does make a better arbitrage. The signs of the coefficients of the number of districts knowing price and the number of districts purchased at the trader-level is positive, which implies that traders who make extensive search have higher likeliness of purchasing from the cheapest district. However, the coefficients are mostly statistically insignificant.

== Table 9. Correlates of purchasing from the cheapest district ==

Table 10 reports the results for the actual–optimal price ratio. The general pattern is similar to Table 9. Number of districts searched at the trader level is negatively correlated with actual–optimal price ratio and it is statistically significant for passive purchases, suggesting that extensive searchers are able to purchase with prices close to that in the cheapest district. However, the same figure at the trader–round level is

positive and statistically significant in all of the estimates without trader fixed effects. We do not have clear interpretation for this result at this moment. Table 10 also shows that it is critical to purchase from the cheapest district in order to narrow the price gap between the cheapest price and the paid price.

== Table 10. Correlates of actual–optimal price ratio ==

5.3. Did provision of price information improve arbitrage efficiency?

In order to examine whether price information is the key determinant of successful arbitrage, we randomly selected half of the traders (112 out of 224) and provided price information via SMS after round 16. The information provided is the milled rice price of Vary gasy in 10 districts (Arivonimamo, Miarinarivo, Tsiroanomandidy, Ankazobe, Ambatondrazaka, Mahabo, Bealanana, Befandriana, Madritsara, and Marovoay) collected by Observatoire du riz (OdR). We provided information in distant districts in Sofia region where prices are generally quite cheaper than the major purchasing districts near Tana. We expected that this information would trigger trade with new districts.

We estimate the following simple difference-in-differences regression to examine the effects of the intervention:

$$y_{it} = \beta_0 + \beta_1 \mathrm{TREAT}_i + \beta_2 \mathrm{AFTER}_t + \beta_3 \mathrm{TREAT}_i \times \mathrm{AFTER}_t + \varepsilon_{it}$$

where TREAT_i is the dummy that indicates that the trader has received the price information, and AFTER_t is the dummy indicating rounds after intervention.

Table 11 reports the estimates for search and purchasing. The unit of observation is

trader–round. The DID estimate (β_3) is positive and significant for whether a trader searched price in other districts (column 1) and the number of districts knowing price (column 2). This implies that the intervention successfully improved the traders' knowledge of price in diverse districts. However, the intervention had no impact on purchasing behavior. The treated traders did not engage more in active trading after intervention (compared to control group), and the number of districts purchased in each round did not increase.

== Table 11. SMS treatment effects for search and purchasing (DID estimates) ==

Table 12 and Table 13 report the estimates for arbitrage efficiency. The unit of observation is trader–round–activity–variety. We find absolutely no impact on both purchase from the cheapest district and actual–optimal price ratio.

As a consequence, the provision of price information had no impact on profits. For each rounds, we obtained crude measure of management indicators by asking the overall quantity and average price of purchase and sales, and margin. We report the results in Table 14. The estimates indicate that the intervention had no impact of quantity and price of purchase and sales, and margin.

== Table 12. SMS treatment effects for purchasing from the cheapest district (DID estimates) ==

== Table 13. SMS treatment effects for actual–optimal price ratio (DID estimates) ==

== Table 14. SMS treatment effects for management indicators (DID estimates) ==

6. Concluding remarks

In this paper, we revealed several facts about arbitrage of rice traders in Antananarivo, Madagascar. We have five major findings. First, we find that even in the same period, for the same variety, some traders are purchasing from districts with higher prices when some others are purchasing with lower price in different district. This means that there is scope for better arbitrage. Second, although the cheapest district changes over time, most of the traders specialize in trading in few, limited, popular districts, which are not always the cheapest district. Third, consequently, traders often fail to purchase from the cheapest district and therefore are paying substantially higher prices than the cheapest price. Fourth, traders do not search price in other districts extensively, and their knowledge on price is limited in very few districts such as Tana and Ambatondrazaka and some other major districts. Fifth, our randomized controlled trial intervention to provide regional price information via SMS had no effect on purchasing behavior, arbitrage, efficiency, or quantity, price, and margin of purchase.

These findings suggest that there is opportunity for better arbitrage and improvement in the Malagasy rice market. The evidences indicate that the following two behavioral patterns of the traders are fundamental sources that impede better arbitrage. First, traders limit the regional extent of trade by concentrating on purchasing from few fixed districts. Second, traders do not extensively search prices in other districts. However, the negative results of our experimental intervention in providing price information imply that the information friction suggested from the latter is not the only reason of the traders' arbitrage inefficiency. We suspect that there are other reasons that force the traders to limit the extent of trade.

Probably, there is considerable fixed cost to establish a link (i.e. start trading) with a

new district. As Fafchamps and Minten (2001, 2002) suggest, traders need to find a trading partner who is trustworthy. They also need to protect themselves from theft and breach of contract. Further, price information itself may not be sufficient to start trading. Traders also need information on quantity and quality, where they can meet with sellers, who are trustworthy, and so on. Further investigation on the obstacles that restrict traders from expanding the extent of trade is remained for future research.

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Figures

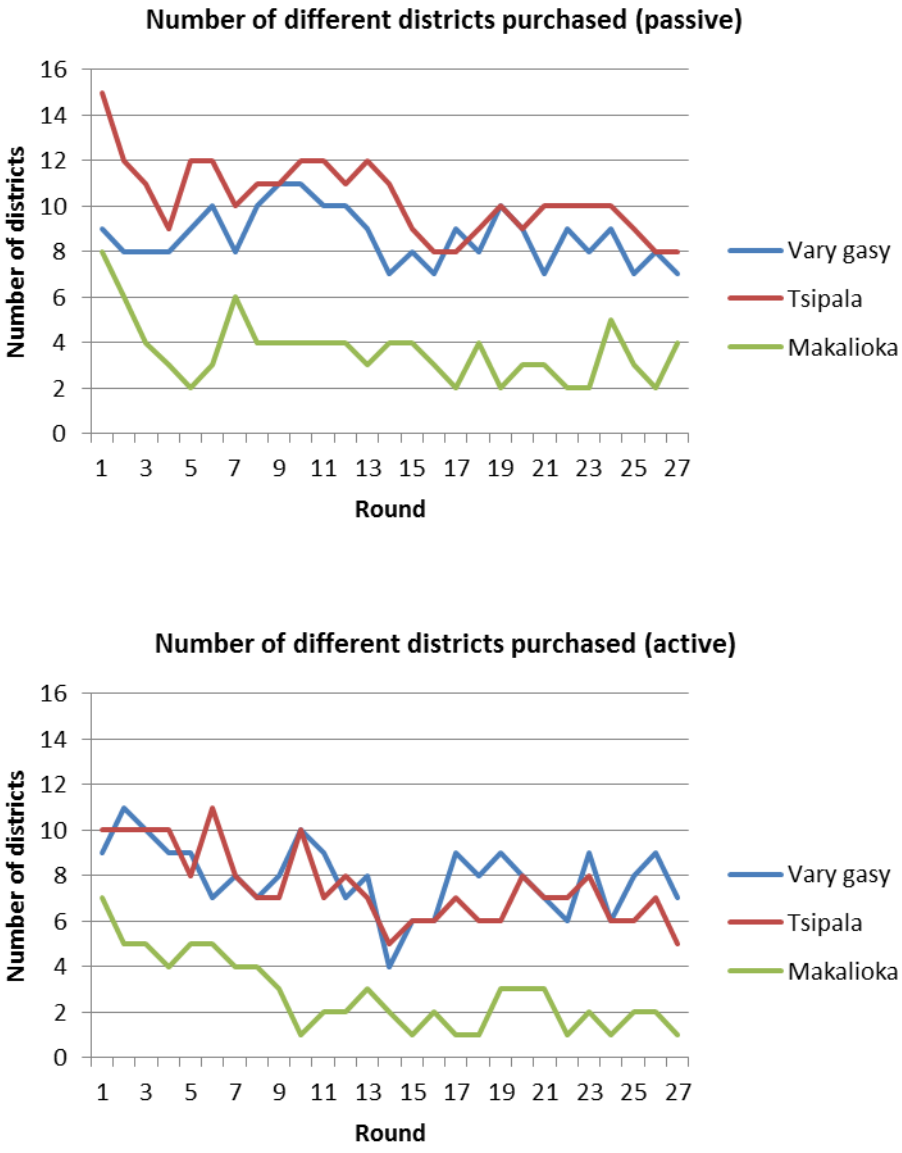

Figure 1. Number of different districts purchased

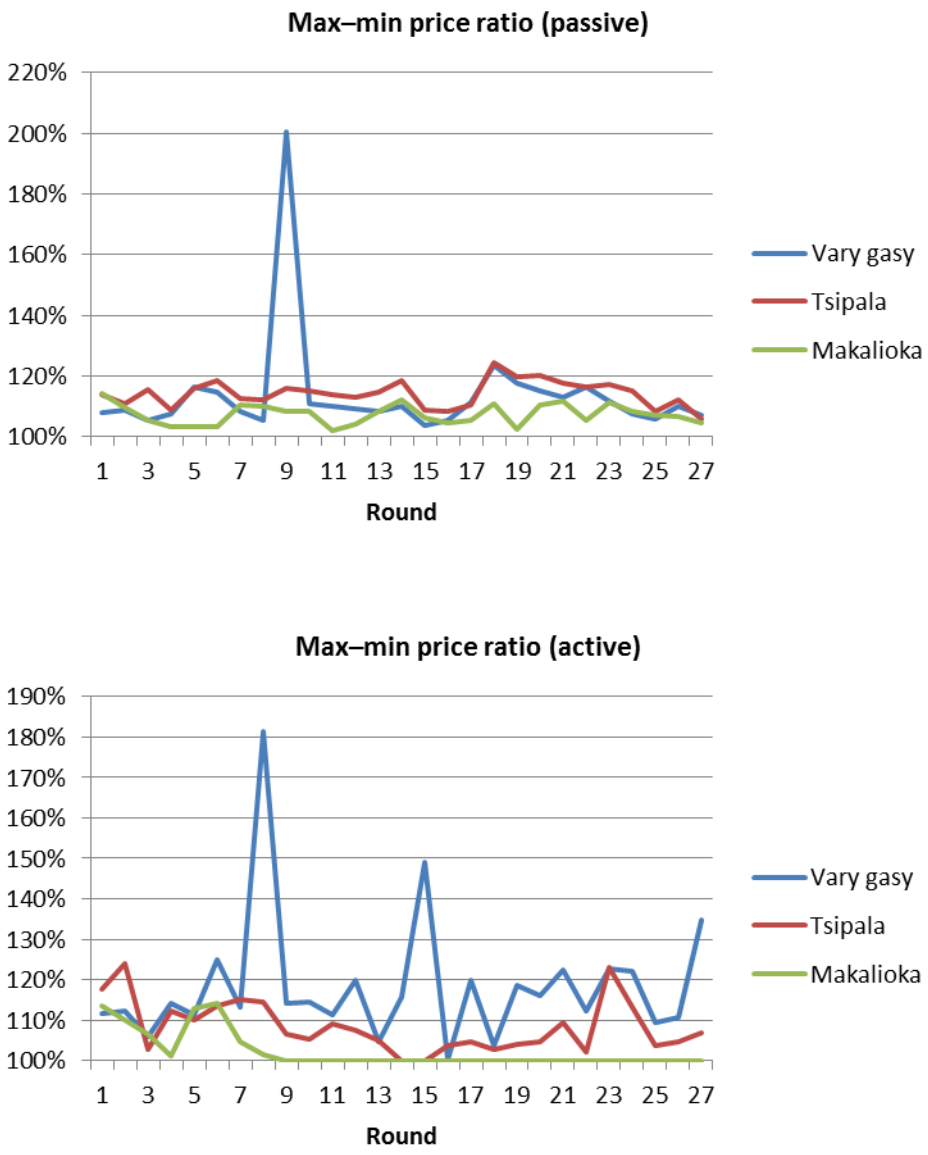

Figure 2. Max–min price ratios among districts

Note: The figure describes the ratio of the price in the most expensive district (maximum) over average price in the cheapest district (minimum). Each district price is obtained by averaging all observed paid prices in each round–activity–variety–district. The price is based on the price of milled rice plus transportation costs. Districts without any purchase in milled rice are omitted due to lack of milling costs for purchase in paddy.

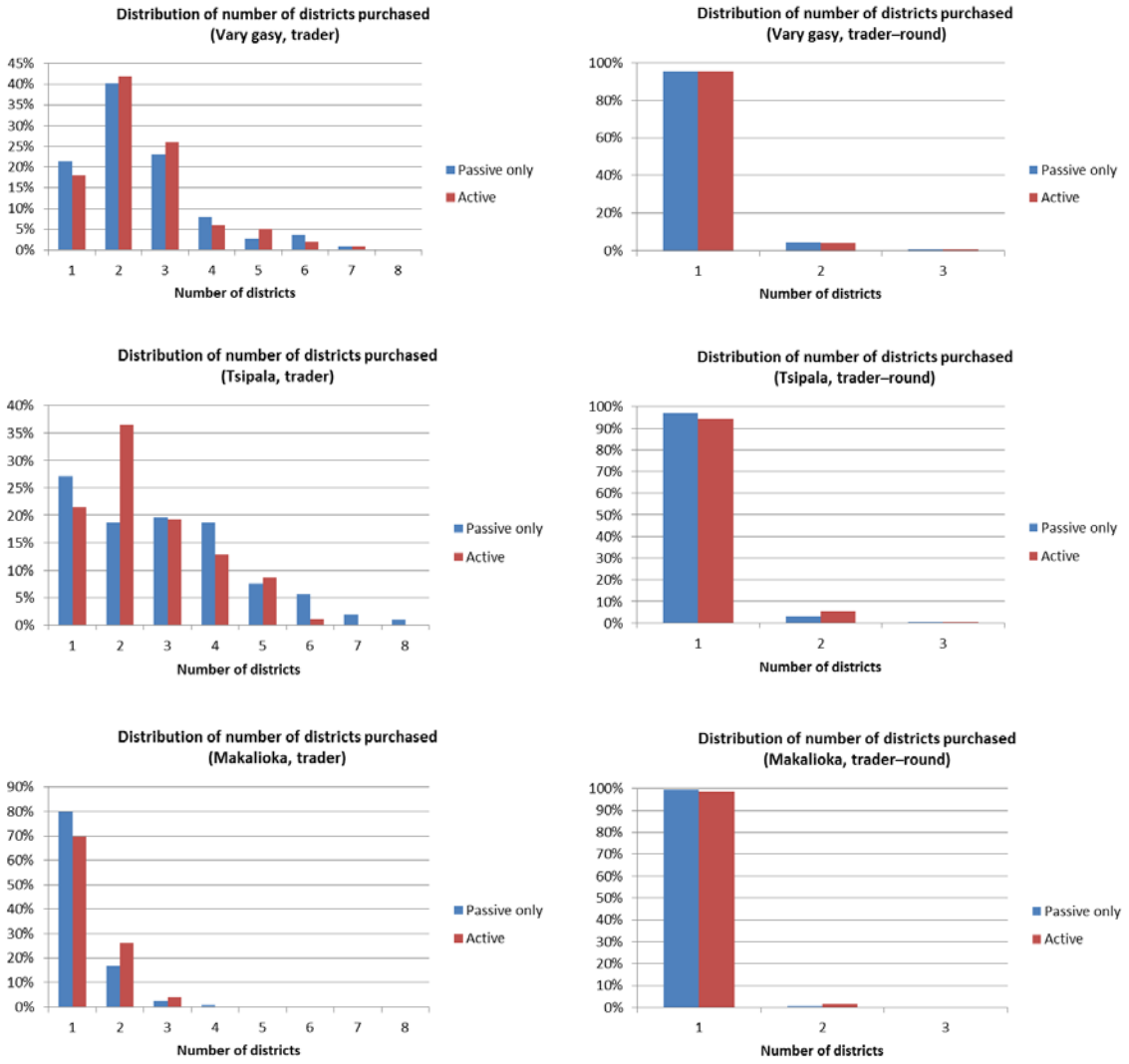

Figure 3. Distribution of the number of districts purchased

Note: "Passive only" indicates traders engaged in passive inter-district trading only.

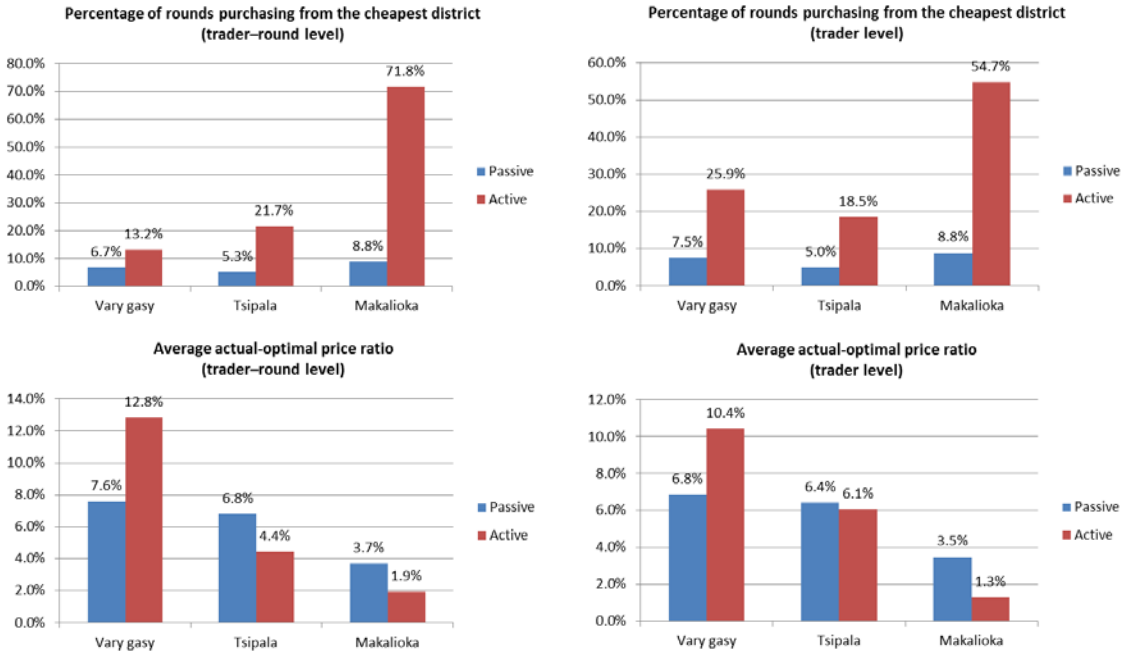

Figure 4. Measures of arbitrage efficiency

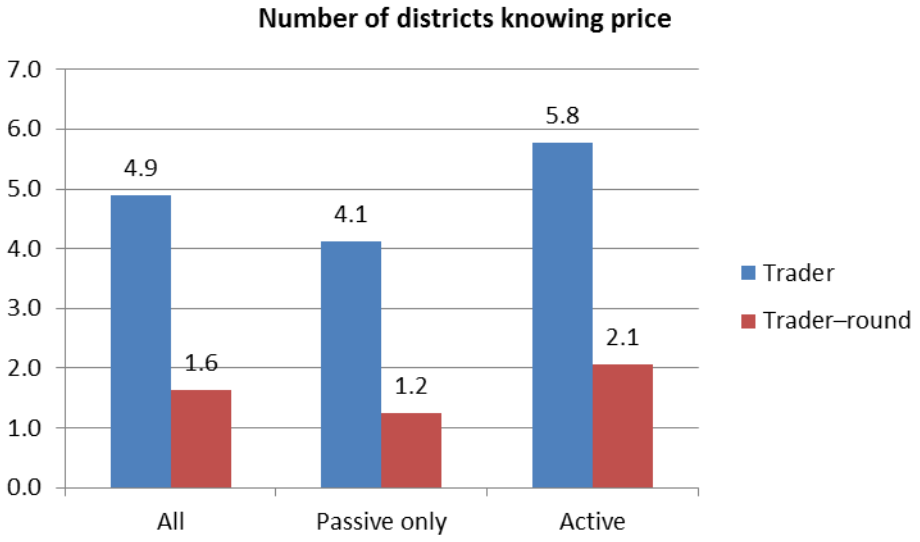

Figure 5. Number of districts knowing price

Note: “Passive only” indicates traders engaged in passive inter-district trading only.

Tables

Table 1. Average price by round–variety–district (passive)

Variety	District	Rd. 1	Rd. 2	Rd. 3	Rd. 4	Rd. 5	Rd. 6	Rd. 7	Rd. 8	Rd. 9	Rd. 10	Rd. 11	Rd. 12	Rd. 13	Rd. 14	Rd. 15	Rd. 16	Rd. 17	Rd. 18	Rd. 19	Rd. 20	Rd. 21	Rd. 22	Rd. 23	Rd. 24	Rd. 25	Rd. 26	Rd. 27
Vary gasy	Ambohidratrimo	1000			1150	1257	1296	1150	1190	1282	1285	1275	1265	1230	1269	1254	1252	1243	1223	1210	1145	1162	1068	1184	1158	1170	1180	1117
Vary gasy	Ankazobe	1018	1086	1083	1146	1254	1293	1164	1203	1248	1255	1264	1252	1206	1251	1253	1262	1247	1252	1241	1207	1118	1232	1170	1194	1193	1244	1181
Vary gasy	Arivonimamo	1056	1088	1125	1178	1223	1205	1205	1209	1229	1223	1216	1221	1232	1267	1263	1258	1255	1195	1161	1120	1147	1132	1141	1158	1152	1163	1163
Vary gasy	Manjakandriana														1300	1300												
Vary gasy	Anjozorobe	1046	1053	1093	1140	1168	1223	1211	1210	1167	1164	1194	1192	1204	1227	1260	1273	1278	1255	1208	1170	1139	1089	1105	1180	1175	1190	1156
Vary gasy	Tsiroanomandidy	1023	1036	1085	1184	1162	1175	1174	1186	1188	1210	1185	1185	1203	1273	1262	1263	1213	1116	1106	1078	1091	1095	1092	1112	1149	1130	1135
Vary gasy	Miarinarivo	1080	1100	1093	1100	1280	1305	1180	1210	1237	1247	1233	1255	1190		1290	1280	1245	1250	1197	1216	1213	1243	1217	1157	1213	1245	1196
Vary gasy	Soavinandriana															1260												
Vary gasy	Antananarivo Atsimondrano	1050		1120	1100	1150	1260		1220	1180	1160	1200	1160	1180				1250	1280	1180	1240	1140	1200	1200	1180	1180	1180	1160
Vary gasy	Toamasina I								1250																			
Vary gasy	Ambatondrazaka	1001	1013	1083	1133	1180	1195	1120	1195	640	1190	1180	1195	1208	1350		1300	1240	1380	1300							1220	
Vary gasy	Andilamena						1140																					
Vary gasy	Marovoay	1050								1160	1160	1160	1160															
Vary gasy	Mandritsara		1080	1080														1150					1190				
Vary gasy	Befandriana Avaratra									1220																		
Vary gasy	Bealanana		1080				1240	1177		1037	1215	1252	1239	1250						1240			1220	1220				
Vary gasy	Other districts in Boeny					1100																						
Vary gasy	Tana: Anosibe	1063	1066	1116	1170	1206	1212	1183	1216	1238	1208	1221	1242	1276	1316	1265	1273	1262	1250	1177	1110	1133	1145	1148	1160	1160	1170	1149
Vary gasy	Tana: Andravoahangy	1076	1068	1101	1160	1181	1201	1197	1197	1204	1191	1201	1206	1242	1306	1280	1236	1244	1193	1160	1126	1072	1132	1110	1170	1165	1156	1180
Vary gasy	Tana: Seller in Tana	1064	1052	1069	1117	1185	1162	1150	1186	1202	1226	1232	1205	1268	1300	1278	1269	1252	1238	1161	1101	1086	1099	1118	1182	1184	1185	1168
Tsipala	Ambohidratrimo				1148	1263	1290	1163	1192	1279	1270	1261	1260	1240	1254	1289	1266	1245	1220	1203	1250	1200	1180	1177	1195	1180	1120	1160
Tsipala	Ankazobe	1005	1041	1084	1145	1270	1288	1135	1194	1274	1277	1254	1251	1170	1258	1235	1271	1252	1238	1248	1253	1232	1249	1180	1182	1183	1249	1185
Tsipala	Arivonimamo	1048	1073	1130	1170	1191	1202	1194	1207	1217	1221	1196	1206	1199	1213	1210	1222	1228	1200	1183	1143	1146	1163	1151	1155	1171	1174	1161
Tsipala	Anjozorobe	1035	1069	1086	1132	1168	1265	1229	1219	1140	1144	1180	1169	1181	1181	1200	1273	1286	1294	1278	1247	1176	1182	1175	1245	1193	1248	1180
Tsipala	Tsiroanomandidy	1025	1046	1086	1145	1175	1146	1173	1183	1168	1153	1148	1156	1197	1185	1207	1201	1165	1115	1089	1075	1063	1073	1063	1090	1129	1126	1128
Tsipala	Miarinarivo	1070	1100	1110		1273	1305	1180	1200	1230	1233	1250	1250	1220	1200	1225	1243	1265	1238	1182	1189	1248	1238	1216	1192	1221	1255	1158
Tsipala	Soavinandriana		1040											1140	1250		1200					1080	1080	1060	1080			
Tsipala	Antananarivo Atsimondrano	1050		1120	1120	1150	1260		1220	1160	1140	1180	1140	1180				1250	1270	1160	1240	1120	1160	1200	1160	1160	1160	1160
Tsipala	Fianarantsoa I						1160																					
Tsipala	Ambatondrazaka	1080	1072	1105		1180			1250		1200	1200	1223	1200					1040	1080							1230	
Tsipala	Mahajanga I	1050																										
Tsipala	Marovoay	990		980			1160	1200	1200	1130	1120	1120	1115	1151		1250												1130
Tsipala	Port-Berge														1150													
Tsipala	Mandritsara	1050	1050	1047	1103	1130	1109	1121	1113	1102	1110	1107	1120	1160	1257	1190				1100	1043	1073	1097	1113	1140	1160		
Tsipala	Befandriana Avaratra	980	1020	1020	1080	1100	1100	1090		1245																		
Tsipala	Antsohihy	1000	1100																									
Tsipala	Bealanana	987	1023	1056	1120	1132	1165	1138	1125	1150	1126	1159	1172	1172	1190	1200	1180	1163	1197	1138	1060	1070	1220	1240	1138	1153		
Tsipala	Mampikony	980				1200					1150	1200			1140													
Tsipala	Other districts in Boeny	950																										
Tsipala	Tana: Anosibe	1035	1044	1113	1173	1195	1217	1188	1218	1228	1220	1212	1237	1274	1289	1296	1275	1260	1266	1164	1115	1124	1146	1136	1160	1156	1160	1151
Tsipala	Tana: Andravoahangy	1066	1130	1097	1153	1200	1185	1160	1195	1150	1162	1178	1175	1190	1210	1215	1260	1270	1165	1190	1118	1100	1142	1138	1160	1175	1160	1120
Tsipala	Tana: Seller in Tana	1068	1068	1083	1152	1173	1155	1162		1203	1200	1183	1200	1306	1353	1263	1276	1257	1231	1066	1075	1124	1117	1123	1170	1182	1183	1173
Makalioka	Ambohidratrimo															1400									1260			
Makalioka	Ankazobe	1200	1100																									
Makalioka	Arivonimamo	1090	1060	1160	1240	1265	1250	1296	1270	1200	1280	1310	1320	1375	1420	1400			1380		1400	1400			1300			1300
Makalioka	Anjozorobe	1120	1110		1200			1320	1320	1230	1200	1300	1290													1300		
Makalioka	Tsiroanomandidy	1100	1100					1280							1350		1370		1300									
Makalioka	Antananarivo Atsimondrano	1145	1160	1200			1290	1327		1267	1290	1290	1280	1290	1298	1350	1377	1368	1387	1380	1348	1263	1290	1338	1283	1280	1293	1285
Makalioka	Ambatondrazaka	1111	1132	1180	1224	1252	1267	1263	1266	1280	1279	1288	1302	1350	1387	1400	1415	1412	1395	1382	1344	1272	1248	1247	1252	1262	1258	1244
Makalioka	Mahajanga I	1050																										
Makalioka	Marovoay	1100		1200				1200	1200																			
Makalioka	Tana: Anosibe	1093	1102	1139	1240	1263	1270	1251	1301	1298	1302	1308	1331	1383	1420	1409	1429	1429	1440	1412	1340	1284	1316	1275	1298	1304	1303	1284
Makalioka	Tana: Andravoahangy	1120	1094	1150	1220	1224	1283	1271	1270	1268	1263	1288	1322	1363	1453	1433	1428	1440	1428	1400	1270	1253	1252	1200	1200	1218	1223	1292
Makalioka	Tana: Seller in Tana	1130	1107	1137	1217	1250	1262	1280	1273	1250	1275	1309	1333	1398	1435	1404	1431	1442	1439	1405	1357	1268	1254	1249	1289	1273	1276	1276

Table 2. Average price by round–variety–district (active)

Variety	District	Rd. 1	Rd. 2	Rd. 3	Rd. 4	Rd. 5	Rd. 6	Rd. 7	Rd. 8	Rd. 9	Rd. 10	Rd. 11	Rd. 12	Rd. 13	Rd. 14	Rd. 15	Rd. 16	Rd. 17	Rd. 18	Rd. 19	Rd. 20	Rd. 21	Rd. 22	Rd. 23	Rd. 24	Rd. 25	Rd. 26	Rd. 27
Vary gasy	Ambohidratrimo		1070	1105	1114	1255	1299		1145	1174	1222	1263	1260	1183		1237	1225	1258	1203	1217	1133	1200	1146	1140	1070	1097	1103	1120
Vary gasy	Ankazobe	1007								1200	1200		1230	1173				1220	1213		1220	1210	1160	930	1010		1140	1090
Vary gasy	Arivonimamo	1027	1026	1120	1169	1195	1235	1256	1230	1232	1226	1202	1183	1174	1216	1225	1228	1243	1248	1211	1183	1121	1161	1104	1134	1139	1150	1145
Vary gasy	Anjozorobe	1030	992	1170	1220	1127	1040	1360	1360	1340	1070	1340	1130							1050	1050	988	1035			1040	1040	1080
Vary gasy	Tsiroanomandidy	1030	1000				1170	1200	750				1050	1130	1050	830		1050			1140				950			850
Vary gasy	Miarinarivo	1019	1030	1140	1160												1225			1245					1160			
Vary gasy	Toamasina I	1115	1115																									
Vary gasy	Ambatondrazaka	1000	1020		1070																							
Vary gasy	Bealanana							1300	1300																			
Tsipala	Ambohidratrimo		1100	1103	1103	1255	1294		1135	1140	1206	1256	1266	1185		1227	1225	1265	1203	1245	1215	1190	1170	1145	1065	1095	1097	
Tsipala	Ankazobe	992								1190	1200		1240	1173				1210	1218		1205	1210	1170	930	1020		1135	1080
Tsipala	Arivonimamo	1028	1051	1135	1163	1179	1227	1257	1231	1213	1209	1197	1179	1163	1201	1227	1221	1224	1236	1197	1161	1107	1144	1108	1135	1134	1149	1153
Tsipala	Anjozorobe	1100	1200																									
Tsipala	Tsiroanomandidy	1100	1030											1130														
Tsipala	Miarinarivo	1019	1020	1130	1140												1205			1245	1190				1155			
Tsipala	Fianarantsoa I							1290	1290																			
Tsipala	Mandritsara	1000	1040		1240		1140	1120			1150	1150					1250											
Tsipala	Bealanana	935	967					1290	1300	1150																		
Tsipala	Mampikony	1005	980			1140																						
Makalioka	Arivonimamo	1058	1092	1146	1233	1270	1300	1290	1295																			
Makalioka	Anjozorobe	1100	1200			1150	1150																					
Makalioka	Tsiroanomandidy					1300																						
Makalioka	Amparafaravola	980	1110	1210	1230																							
Makalioka	Ambatondrazaka	1113	1106	1135	1218	1249	1139	1234	1278	1222	1260	1259	1245	1264	1296	1332	1255	1347	1260	1331	1300	1166	1174	1187	1182	1222	1158	1137

Notes for Table 1 and Table 2: Each district price is obtained by averaging all observed paid prices in each round–activity–variety–district. The price is based on the price of milled rice plus transportation costs. Districts without any purchase in milled rice are omitted due to lack of milling costs for purchase in paddy. The cheapest district for each round is emphasized in red.

Table 3. Average number of districts purchased

	Trader types		
	All	Passive-only	Active
Variety	traders	traders	traders
A. Trader level			
All varieties	4.0	4.2	3.8
Vary gasy	2.5	2.4	2.5
Tsipala	2.7	2.9	2.5
Makalioka	1.3	1.2	1.3
Import	1.1	1.1	1.2
Don't know	1.3	1.0	1.4
B. Trader–round level			
All varieties	1.9	2.1	1.6
Vary gasy	1.0	1.0	1.0
Tsipala	1.0	1.0	1.1
Makalioka	1.0	1.0	1.0
Import	1.0	1.0	1.0
Don't know	1.2	1.0	1.2

Table 4. Percentage of traders purchasing from each district (active, Vary gasy)

District \ Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Ambohidratrimo	0%	2%	5%	7%	2%	2%	0%	5%	5%	6%	8%	8%	5%	0%	7%	3%	6%	4%	4%	3%	1%	5%	3%	4%	5%	5%	2%
Ankazobe	3%	1%	1%	1%	1%	0%	1%	0%	1%	2%	1%	4%	5%	0%	0%	0%	2%	4%	3%	6%	4%	7%	10%	7%	2%	3%	2%
Arivonimamo	34%	32%	39%	37%	43%	40%	46%	38%	37%	34%	46%	48%	35%	47%	54%	31%	43%	30%	28%	19%	24%	28%	19%	22%	21%	17%	17%
Anjozorobe	22%	20%	22%	21%	21%	21%	20%	20%	18%	20%	7%	10%	6%	0%	0%	0%	0%	4%	12%	16%	19%	18%	26%	24%	23%	20%	23%
Antsirabe I	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ambatolampy	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	15%	13%	13%	6%	6%	0%	0%	0%	0%	0%	0%	0%
Tsiroanomandidy	20%	27%	22%	26%	23%	31%	20%	31%	33%	24%	24%	20%	39%	45%	24%	33%	21%	35%	39%	44%	46%	39%	31%	35%	37%	46%	50%
Miarinarivo	9%	7%	3%	1%	1%	1%	3%	0%	0%	2%	3%	4%	3%	6%	5%	15%	4%	4%	4%	4%	3%	0%	5%	9%	7%	3%	3%
Soavinandriana	5%	0%	3%	3%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Toamasina I	2%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ambatondrazaka	3%	3%	1%	1%	5%	0%	6%	4%	1%	7%	1%	0%	6%	0%	7%	3%	0%	0%	1%	0%	0%	0%	2%	0%	0%	2%	0%
Mahajanga I	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Maevatanana	0%	2%	3%	3%	1%	2%	1%	1%	1%	1%	3%	0%	2%	2%	0%	0%	4%	4%	3%	3%	0%	0%	0%	0%	4%	3%	3%
Marovoay	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mandritsara	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Befandriana Avaratra	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bealanana	0%	1%	0%	0%	0%	0%	1%	1%	3%	2%	6%	6%	0%	0%	2%	0%	0%	0%	0%	0%	1%	3%	2%	0%	2%	2%	0%
Mampikony	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%
Ambanja	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Number of traders engaged	93	88	74	76	86	84	69	81	73	88	71	50	66	49	41	39	47	46	69	70	67	76	58	55	57	65	64

Note: The denominator is the number of traders who purchased Vary gasy through active inter-district trade. Districts with higher percentage of purchasing traders for each round are emphasized in deeper red. The cheapest district for each round is marked by bold square.

Table 5. Percentage of traders purchasing from each district (active, Tsipala)

District \ Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Ambohidratrimo	0%	3%	5%	5%	3%	3%	0%	8%	8%	9%	14%	10%	5%	0%	7%	3%	7%	6%	5%	2%	2%	7%	5%	5%	5%	7%	0%
Ankazobe	3%	0%	0%	0%	0%	0%	0%	0%	2%	2%	0%	5%	8%	0%	0%	0%	2%	6%	0%	2%	6%	7%	8%	2%	0%	2%	5%
Arivonimamo	46%	53%	65%	67%	73%	58%	67%	71%	71%	63%	67%	64%	68%	82%	66%	51%	46%	47%	33%	35%	44%	40%	38%	37%	43%	43%	53%
Anjozorobe	5%	7%	4%	4%	5%	3%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%
Tsiroanomandidy	24%	20%	9%	4%	8%	18%	16%	10%	8%	9%	2%	5%	10%	6%	17%	24%	29%	31%	49%	48%	38%	37%	36%	46%	43%	38%	34%
Miarinarivo	9%	3%	4%	2%	2%	2%	4%	0%	0%	0%	0%	5%	5%	6%	5%	16%	10%	6%	9%	7%	6%	2%	5%	7%	5%	5%	5%
Soavinandriana	1%	0%	4%	7%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fianarantsoa I	0%	0%	0%	0%	0%	0%	4%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ambatondrazaka	0%	0%	2%	0%	6%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Marovoay	3%	2%	2%	2%	2%	3%	2%	2%	2%	2%	2%	2%	3%	3%	2%	3%	2%	0%	2%	2%	0%	2%	3%	2%	2%	0%	3%
Mandritsara	3%	2%	0%	2%	0%	2%	2%	0%	0%	2%	2%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Befandriana Avaratra	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bealanana	3%	7%	4%	7%	0%	2%	2%	2%	6%	4%	12%	7%	0%	0%	0%	0%	0%	0%	0%	0%	2%	5%	3%	0%	2%	2%	0%
Mampikony	5%	3%	2%	2%	3%	3%	2%	2%	2%	2%	2%	2%	3%	3%	2%	0%	2%	3%	2%	2%	2%	0%	3%	0%	0%	2%	0%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Number of traders engaged	80	60	55	57	66	60	45	49	49	54	51	42	40	33	41	37	41	32	43	46	48	43	39	41	42	42	38

Note: The denominator is the number of traders who purchased Tsipala through active inter-district trade. Districts with higher percentage of purchasing traders for each round are emphasized in deeper red. The cheapest district for each round is marked by bold square.

Table 6. Percentage of traders purchasing from each district (passive, Vary gasy)

District \ Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Ambohidratrimo	0%	0%	0%	3%	4%	3%	5%	3%	4%	3%	2%	1%	1%	4%	5%	3%	2%	2%	2%	1%	3%	2%	3%	3%	1%	1%	2%
Ankazobe	5%	5%	4%	3%	3%	3%	5%	5%	4%	6%	4%	6%	4%	3%	5%	5%	6%	6%	5%	6%	15%	3%	5%	4%	4%	4%	6%
Arivonimamo	21%	24%	20%	23%	27%	33%	39%	35%	29%	31%	33%	24%	24%	27%	25%	23%	21%	21%	26%	21%	16%	18%	22%	18%	26%	22%	23%
Manjakandriana	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Anjozorobe	17%	19%	21%	21%	20%	17%	19%	21%	20%	20%	26%	25%	22%	22%	19%	20%	17%	19%	19%	22%	21%	27%	24%	23%	26%	22%	20%
Ambatolampy	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%
Tsiroanomandidy	11%	9%	13%	15%	11%	3%	4%	9%	11%	9%	7%	12%	10%	8%	9%	10%	11%	14%	20%	16%	16%	17%	13%	16%	11%	18%	19%
Miarinarivo	2%	1%	2%	1%	2%	1%	3%	1%	2%	2%	2%	1%	1%	0%	1%	2%	1%	1%	2%	3%	2%	2%	2%	3%	2%	2%	4%
Soavinandriana	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Antananarivo Atsimondrano	1%	0%	1%	1%	1%	1%	0%	1%	1%	1%	1%	1%	0%	0%	0%	0%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%	1%
Toamasina I	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ambatondrazaka	2%	5%	4%	2%	1%	1%	1%	3%	1%	1%	1%	1%	2%	1%	0%	1%	1%	1%	1%	1%	0%	0%	0%	1%	0%	1%	0%
Andilamena	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Marovoay	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
Mandritsara	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Befandriana Avaratra	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bealanana	0%	0%	0%	0%	0%	1%	5%	3%	2%	2%	4%	6%	1%	0%	0%	0%	0%	0%	1%	0%	0%	0%	1%	0%	0%	0%	0%
Mampikony	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other districts in Boeny	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tana: Anosibe	24%	16%	20%	17%	16%	25%	12%	14%	20%	14%	13%	18%	16%	14%	20%	16%	21%	17%	13%	16%	17%	16%	20%	21%	19%	18%	16%
Tana: Andravoahangy	3%	3%	5%	4%	4%	4%	4%	3%	4%	6%	5%	3%	4%	4%	4%	4%	3%	4%	2%	4%	3%	5%	4%	6%	3%	7%	4%
Tana: Seller in Tana	13%	17%	12%	10%	13%	7%	5%	3%	3%	4%	3%	2%	14%	16%	13%	18%	17%	15%	9%	10%	8%	9%	7%	5%	7%	6%	7%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Number of traders engaged	241	215	194	184	197	183	198	199	196	176	172	177	218	209	215	194	196	191	183	198	198	207	192	199	189	181	198

Note: The denominator is the number of traders who purchased Vary gasy in Tana. Purchase in Tana (i.e., at wholesale markets and sellers in Tana) is included. Districts with higher percentage of purchasing traders for each round are emphasized in deeper red. The cheapest district for each round is marked by bold square.

Table 7. Percentage of traders purchasing from each district (passive, Tsipala)

District \ Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Ambohidratrimo	0%	0%	0%	3%	4%	3%	5%	3%	4%	3%	3%	1%	1%	6%	4%	3%	2%	1%	2%	1%	2%	2%	3%	2%	1%	1%	1%
Ankazobe	4%	5%	3%	2%	2%	4%	5%	4%	3%	4%	4%	5%	3%	3%	4%	5%	3%	6%	4%	5%	5%	2%	3%	3%	2%	3%	5%
Arivonimamo	25%	19%	21%	29%	38%	28%	38%	39%	32%	35%	30%	28%	34%	41%	33%	27%	25%	21%	23%	18%	21%	19%	22%	21%	20%	30%	30%
Anjozorobe	2%	12%	8%	10%	10%	10%	9%	11%	9%	8%	12%	10%	9%	10%	7%	9%	8%	10%	11%	12%	10%	8%	10%	9%	11%	9%	9%
Tsiroanomandidy	15%	22%	10%	9%	8%	6%	6%	5%	10%	6%	4%	6%	4%	3%	7%	13%	15%	23%	28%	26%	28%	30%	22%	27%	26%	26%	23%
Miarinarivo	3%	1%	2%	0%	2%	1%	2%	1%	2%	2%	1%	1%	1%	1%	1%	2%	2%	1%	4%	4%	2%	2%	2%	2%	2%	2%	5%
Soavinandriana	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	0%	1%	0%	0%	0%	0%	1%	1%	1%	1%	0%	0%	0%
Antananarivo Atsimondrano	1%	0%	1%	1%	1%	1%	0%	1%	1%	1%	1%	1%	1%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Fianarantsoa I	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ambatondrazaka	2%	2%	1%	0%	1%	0%	0%	1%	0%	1%	1%	2%	4%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	1%	0%
Mahajanga I	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Marovoay	1%	1%	1%	0%	0%	1%	1%	1%	1%	2%	2%	3%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Port-Berge	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mandritsara	1%	1%	6%	4%	3%	5%	5%	6%	5%	3%	4%	3%	1%	2%	1%	0%	0%	0%	2%	2%	2%	4%	4%	1%	1%	0%	0%
Befandriana Avaratra	1%	1%	1%	1%	1%	1%	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Antsohihy	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bealanana	3%	5%	11%	6%	3%	8%	11%	10%	10%	16%	17%	20%	10%	7%	8%	8%	6%	4%	3%	2%	1%	1%	1%	2%	2%	0%	0%
Mampikony	1%	0%	0%	0%	1%	0%	0%	0%	0%	1%	1%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other districts in Boeny	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tana: Anosibe	27%	15%	21%	24%	16%	24%	15%	16%	20%	14%	15%	20%	19%	13%	19%	16%	20%	17%	12%	19%	20%	19%	22%	23%	23%	20%	17%
Tana: Andravoahangy	3%	1%	2%	2%	1%	2%	1%	1%	1%	3%	3%	1%	1%	1%	1%	1%	1%	1%	2%	3%	1%	3%	4%	3%	2%	4%	1%
Tana: Seller in Tana	9%	16%	13%	9%	11%	6%	3%	0%	2%	2%	2%	1%	10%	11%	14%	15%	17%	15%	9%	10%	5%	9%	6%	5%	7%	5%	8%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Number of traders engaged	179	172	155	169	167	169	172	159	173	160	156	152	183	156	191	176	179	164	170	171	168	171	162	175	163	164	162

Note: The denominator is the number of traders who purchased Tsipala in Tana. Purchase in Tana (i.e., at wholesale markets and sellers in Tana) is included. Districts with higher percentage of purchasing traders for each round are emphasized in deeper red. The cheapest district for each round is marked by bold square.

Table 8. Summary statistics on arbitrage efficiency (trader–round–activity–variety level)

Variable	Obs	Mean	Std. Dev.	Min	Max
A. Dummy if purchased from the cheapest district					
All trasanctions	12,466	0.086	dummy	0	1
Passive transactions	11,406	0.070	dummy	0	1
Vary gasy	3,831	0.067	dummy	0	1
Tsipala	3,497	0.053	dummy	0	1
Makalioka	4,078	0.088	dummy	0	1
Active transactions	1,060	0.252	dummy	0	1
Vary gasy	441	0.132	dummy	0	1
Tsipala	470	0.217	dummy	0	1
Makalioka	149	0.718	dummy	0	1
B. Actual–optimal price ratio					
All transactions	12,464	0.061	0.110	-0.294	1.031
If not purchased from the cheapest district	11,397	0.067	0.112	-0.178	1.031
If purchased from the optimal district	1,067	0.001	0.048	-0.294	0.252
Passive transactions	11,404	0.060	0.108	-0.215	1.031
Vary gasy	3,830	0.076	0.168	-0.178	1.031
Tsipala	3,497	0.068	0.062	-0.134	0.313
Makalioka	4,077	0.037	0.045	-0.215	0.192
Active transactions	1,060	0.076	0.125	-0.294	0.813
Vary gasy	441	0.128	0.164	-0.294	0.813
Tsipala	470	0.044	0.063	-0.100	0.301
Makalioka	149	0.019	0.070	-0.289	0.165

Table 9. Correlates of purchasing from the cheapest district

	(1)	(2)		(3)	(4)
	Active			Passive	
	OLS	FE		OLS	FE
Trader level covariates					
Number of districts knowing price	0.00627			0.00324	
	(0.00556)			(0.00166)	
Number of districts purchased	0.00446			0.00806**	
	(0.0112)			(0.00305)	
Trader–round level covariates					
Number of districts knowing price	-0.0212	0.00546		-0.00523	-0.000153
	(0.0127)	(0.00998)		(0.00281)	(0.00211)
Number of districts purchased	0.111	0.105*		0.00553	0.00320
	(0.0587)	(0.0424)		(0.00601)	(0.00629)
Variety (reference: Vary gasy)					
Tsipala	0.0946**	0.132***		-0.0168**	-0.0175**
	(0.0299)	(0.0228)		(0.00559)	(0.00589)
Constant	-0.149	-0.236**		-0.0357*	-0.00128
	(0.0830)	(0.0859)		(0.0170)	(0.0212)
N	911	911		6330	6330
R-sq	0.201	0.243		0.071	0.066

Note: Standard errors clustered by trader in parentheses. Round fixed effects included. * p<0.05, ** p<0.01, *** p<0.001

Table 10. Correlates of actual–optimal price ratio

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Active				Passive			
	OLS	FE	OLS	FE	OLS	FE	OLS	FE
Trader level covariates								
Number of districts knowing price	-0.00368		-0.00311		-0.00327***		-0.00305***	
	(0.00188)		(0.00195)		(0.000779)		(0.000720)	
Number of districts purchased	0.00583		0.00623		-0.00192		-0.00138	
	(0.00349)		(0.00350)		(0.00166)		(0.00151)	
Trader–round level covariates								
Number of districts knowing price	0.00757**	0.000209	0.00566*	0.000676	0.00356***	0.000172	0.00321***	0.000165
	(0.00262)	(0.00290)	(0.00222)	(0.00277)	(0.000902)	(0.000855)	(0.000835)	(0.000848)
Number of districts purchased	-0.0190	-0.00343	-0.00902	0.00551	-0.00878**	-0.00215	-0.00841**	-0.00199
	(0.0121)	(0.0123)	(0.00910)	(0.0118)	(0.00299)	(0.00254)	(0.00276)	(0.00253)
Purchased from cheapest district (dummy)			-0.0901***	-0.0855***			-0.0674***	-0.0502***
			(0.00863)	(0.00968)			(0.00495)	(0.00513)
Variety (reference: Vary gasy)								
Tsipala	-0.0813***	-0.0867***	-0.0728***	-0.0755***	-0.00870***	-0.00950***	-0.00983***	-0.0104***
	(0.00629)	(0.00661)	(0.00524)	(0.00645)	(0.00198)	(0.00238)	(0.00195)	(0.00237)
Constant	0.112***	0.103***	0.0986***	0.0824***	0.103***	0.0762***	0.101***	0.0762***
	(0.0199)	(0.0249)	(0.0172)	(0.0240)	(0.00697)	(0.00859)	(0.00650)	(0.00852)
N	911	911	911	911	6330	6330	6330	6330
R-sq	0.443	0.464	0.499	0.511	0.439	0.455	0.454	0.464

Note: Standard errors clustered by trader in parentheses. Round fixed effects included. * p<0.05, ** p<0.01, *** p<0.001

Table 11. SMS treatment effects for search and purchasing (DID estimates)

	(1)	(2)	(3)	(4)	(5)
	Searched price in other districts	Number of districts knowing price	Engaged in active trading	Number of active districts purchased	Number of passive districts purchased
Treatment	0.0810	0.0213	0.0981	-0.0152	-0.0736
	(0.0500)	(0.115)	(0.0503)	(0.0950)	(0.0888)
After	-0.136***	-0.587***	-0.0492	0.0712	0.0160
	(0.0262)	(0.169)	(0.0271)	(0.109)	(0.0793)
Treatment x After	0.0753***	1.504***	-0.00880	-0.136	-0.00130
	(0.0215)	(0.217)	(0.0221)	(0.0924)	(0.0484)
Constant	0.834***	1.771***	0.281***	1.374***	1.826***
	(0.0342)	(0.116)	(0.0375)	(0.106)	(0.0839)
N	6033	6033	6033	1628	4156
R-sq	0.025	0.125	0.018	0.026	0.009

Note: Standard errors clustered by trader in parentheses. Round fixed effects included. * p<0.05, ** p<0.01, *** p<0.001

Table 12. SMS treatment effects for purchasing from the cheapest district (DID estimates)

	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)
	All transactions				Active transactions				Passive transactions		
	Vary gasy & Tsipala	Vary gasy	Tsipala		Vary gasy & Tsipala	Vary gasy	Tsipala		Vary gasy & Tsipala	Vary gasy	Tsipala
Treatment	0.0150	0.0133	0.0173		0.0479	0.0683	0.0328		0.00467	0.00240	0.00743
	(0.00888)	(0.00938)	(0.0136)		(0.0350)	(0.0416)	(0.0436)		(0.00676)	(0.00858)	(0.0106)
After	0.0208	0.0278	0.0128		0.0355	0.0478	0.0400		0.0210	0.0237	0.0171
	(0.0144)	(0.0195)	(0.0177)		(0.0608)	(0.106)	(0.0861)		(0.0138)	(0.0184)	(0.0163)
Treatment x After	-0.0296	-0.0326	-0.0264		-0.0251	-0.0534	-0.0275		-0.0299	-0.0235	-0.0361
	(0.0205)	(0.0254)	(0.0222)		(0.0497)	(0.0928)	(0.0665)		(0.0215)	(0.0266)	(0.0216)
Variety (base = Vary gasy)											
Tsipala	-0.00171				0.0892**				-0.0146**		
	(0.00680)				(0.0304)				(0.00519)		
Constant	0.00700	0.00627	0.00585		-0.0189	0.0176	0.0336		0.0122	0.00613	0.00490
	(0.00885)	(0.00945)	(0.0124)		(0.0420)	(0.0527)	(0.0554)		(0.00682)	(0.00803)	(0.0100)
N	8239	4272	3967		911	441	470		7328	3831	3497
R-sq	0.047	0.057	0.131		0.182	0.209	0.505		0.054	0.078	0.155

Note: Standard errors clustered by trader in parentheses. Round fixed effects included. * p<0.05, ** p<0.01, *** p<0.001

Table 13. SMS treatment effects for actual–optimal price ratio (DID estimates)

	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)
	All transactions				Active transactions				Passive transactions		
	Vary gasy & Tsipala	Vary gasy	Tsipala		Vary gasy & Tsipala	Vary gasy	Tsipala		Vary gasy & Tsipala	Vary gasy	Tsipala
Treatment	-0.00326	-0.00269	-0.00427		0.00209	0.00937	-0.00122		-0.00498	-0.00631	-0.00377
	(0.00449)	(0.00470)	(0.00547)		(0.0133)	(0.0170)	(0.0129)		(0.00454)	(0.00429)	(0.00555)
After	-0.0205***	0.00938	-0.0554***		0.126***	0.285***	-0.0261		-0.0346***	-0.0142*	-0.0593***
	(0.00603)	(0.00846)	(0.00522)		(0.0204)	(0.0311)	(0.0197)		(0.00501)	(0.00575)	(0.00532)
Treatment x After	0.00376	0.00879	-0.00170		0.00463	-0.00395	0.00921		0.00272	0.00613	-0.00130
	(0.00667)	(0.00763)	(0.00631)		(0.0160)	(0.0220)	(0.0152)		(0.00686)	(0.00741)	(0.00672)
Variety (base = Vary gasy)											
Tsipala	-0.0164***				-0.0823***				-0.00797***		
	(0.00248)				(0.00664)				(0.00202)		
Constant	0.0751***	0.0472***	0.0917***		0.0976***	0.0198	0.0871***		0.0734***	0.0517***	0.0920***
	(0.00424)	(0.00476)	(0.00512)		(0.0124)	(0.0120)	(0.0159)		(0.00441)	(0.00499)	(0.00511)
N	8238	4271	3967		911	441	470		7327	3830	3497
R-sq	0.329	0.683	0.142		0.433	0.774	0.322		0.434	0.888	0.183

Note: Standard errors clustered by trader in parentheses. Round fixed effects included. * p<0.05, ** p<0.01, *** p<0.001

Table 14. SMS treatment effects for management indicators (DID estimates)

	(1)	(2)	(3)	(4)	(5)
	Bi-monthly amount sold (ton)	Bi-monthly amount purchased (ton)	Selling price (Ar/kg)	Purchasing price (Ar/kg)	Margin (Ar/kg)
Treatment	5.866	5.701	-3.030	-5.496	0.383
	(3.113)	(3.248)	(8.786)	(8.618)	(3.593)
After	2.054	-0.0435	103.8***	108.3***	-0.891
	(1.734)	(1.739)	(6.739)	(6.709)	(3.294)
Treatment x After	-2.179	-2.188	-5.529	-2.184	-0.721
	(1.127)	(1.180)	(7.762)	(7.202)	(2.280)
Constant	8.260***	11.91***	1125.5***	1069.0***	52.56***
	(1.656)	(1.905)	(6.245)	(6.355)	(3.145)
N	5769	5862	5830	5716	5814
R-sq	0.012	0.011	0.274	0.280	0.007

Note: Standard errors clustered by trader in parentheses. Round fixed effects included. * p<0.05, ** p<0.01, *** p<0.001