Missed opportunities and missing markets: Spatio-temporal arbitrage of rice in Madagascar[*]

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Abstract:

This paper uses an exceptionally rich data set to test the extent to which markets in Madagascar are integrated across space, time, and form (in converting from paddy to rice) and to explain some of the factors that limit arbitrage and price equalization within a single country. In particular, we use rice price data across four quarters of 2000-2001 along with data on transportation costs and infrastructure availability for nearly 1400 communes in Madagascar to examine the extent of market integration at three different spatial scales—sub-regional, regional, and national—and determine whether non-integration is due to high transfer costs or lack of competition. The results indicate that markets are fairly well integrated at the sub-regional level and that factors such as high crime, remoteness, and lack of information are among the factors limiting competition. A lack of competition persists at the regional level and high transfer costs impede spatial market integration at the national level. Only six percent of rural communes appear to be intertemporally integrated and there appear to be significant untapped opportunities for interseasonal arbitrage. Income is directly and strongly related to the probability of a commune being in interseasonal competitive equilibrium.

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1. Introduction

Markets aggregate demand and supply across actors at different spatial and temporal scales. Well-functioning markets ensure that macro-level economic policies (e.g., with respect to exchange rates, trade, fiscal or monetary policy) change the incentives and constraints faced by micro-level decision-makers. Macro policy commonly becomes ineffective without market transmission of the signals sent by central governments. Similarly, well-functioning markets underpin important opportunities for welfare improvements at micro-level that aggregate into sustainable macro-level growth. For example, absent good access to distant markets that can absorb excess local supply, the adoption of more productive agricultural technologies typically leads to a drop in farmgate product prices, erasing the gains from technological change and thereby dampening incentives for farmers to adopt new technologies that can stimulate economic growth. Markets also play a fundamental role in managing risk associated with demand and supply shocks in that well-integrated markets facilitate adjustment in net export flows across space and in storage over time, thereby reducing price variability faced by consumers and producers.

The micro-level realities of markets in much of rural Africa, however, involve poor communications and transport infrastructure, limited rule of law, and restricted access to commercial finance, all of which can sharply limit the degree to which markets function as effectively as textbook models typically assume. A longstanding empirical literature documents considerable commodity price variability across space and seasons in developing countries, with various empirical tests of market integration suggesting significant and puzzling foregone arbitrage opportunities (Fackler and Goodwin 2001).

This paper uses an exceptionally rich data set that includes rice price data across four quarters along with data on transportation costs and infrastructure availability for nearly 1400 communes in Madagascar. This enables us to test not only the extent to which markets are integrated across space, time, and form but also to undertake unprecedented comparison of results across different spatial scales of analysis and to explain some of the factors that limit arbitrage and price equalization within a single country. For example, within sub-regions (*fivondronana*), we find considerable co-movement of rice prices across communes linked by a single, nearby hub periodic market, signaling competitive spatial equilibrium with a high degree of price transmission. At the other end of the spatial scale, high interregional marketing costs (due to transport, etc.) dampen price transmission at the national level although markets remain largely in competitive spatial equilibrium. Meanwhile, at the intermediate regional level (inter-*fivondronana* market linkages), there appear considerable foregone arbitrage opportunities, i.e., competitive equilibrium does not hold and price transmission appears poor. This would indicate that policies intended to improve the performance of food markets need to focus on reducing market intermediation costs (e.g., through main trunk road improvements) at one level of (national) government but on competition policy at another (provincial) level. Such interventions are largely unnecessary at the local level.

The paper is organized as follows. The next two sections review the theory of market integration and introduce a simple model of trader entry into a given market, respectively. Section 4 provides background on markets in Madagascar. Section 5 describes the data. Sections 6 and 7 test the integration of markets across space and time, respectively.

Section 8 looks at the possibility of interseasonal flow reversals.[2] Section 9 tests for full market system equilibrium, that is, competitive equilibrium across space, time, and form simultaneously. The final section discusses the implications of our findings.

2. Theory and testing of market integration

The concepts motivating this paper come from basic trade theory dating back to the work of Enke (1951), Samuelson (1952), and Takayama and Judge (1971) on spatial market equilibria (Barrett 2001). If markets are efficient, in the sense of competitive equilibrium with zero marginal profits to arbitrage, we should expect prices to equilibrate across space, time, and form, accounting for transportation, storage and milling costs, respectively. In particular, we would expect to observe the following relationships:

$r_{it}=r_{jt}+\tau_{ijt}$	Spatial competitive equilibrium	(1)
$r_{i(t+1)}=r_{it}+\pi$	Intertemporal competitive equilibrium	(2)
$r_{it}=p_{it}+\alpha$	Processing competitive equilibrium	(3)

where r_{it} is the price of rice in location i in time t, τ_{ijt} is the transfer cost from j to i in time t, π is the nominal interest rate plus physical storage losses (here assumed to be constant across space and time, hence the absence of subscripts), p_{it} is the cost of paddy (i.e., unprocessed rice), and α is the cost of milling (also assumed to be constant across space and time).[3] By substitution, the relationship between the paddy price in location i at time t and the rice price in location j at time t + 1 is:

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[2] Interseasonal flow reversal occurs when a good flows from rural to urban areas at harvest, then back to rural areas again later when prices go up. This can be caused by insufficient storage or processing capacity, local liquidity constraints, or higher risk of theft or political instability in rural areas (as was the case in Madagascar in the early 1990s, see Barrett 1997, 1996b).

[3] We define the transfer costs, τ, to be the total market intermediation costs, which include the observed transport cost, T, plus the unobserved costs associated with loading, temporary storage, etc.

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$p_{it} = r_{j(t+1)} - \alpha - \tau_{jit} - \pi$ Integrated food marketing system equilibrium (4)

However, the above equilibrium conditions only hold if transfer and storage costs are sufficiently low for trade to occur. In the context of spatial market integration, Baulch (1997) refers to the competitive equilibrium condition (equation 1) as Regime 1. A second, non-trading or segmented competitive equilibrium also exists in the case of high transfer costs or low price differentials if $|r_{it}-r_{jt}| < \tau_{ijt}$, i.e., arbitrage is unprofitable at the margin (Samuelson 1952). This is Baulch's "Regime 2." Finally, in Regime 3, $|r_{it}-r_{jt}| > \tau_{ijt}$, and there appear to be positive marginal returns to intermarket trade, signaling foregone arbitrage opportunities and markets that are not perfectly competitive. Regime 3 can signal either temporary market disequilibrium or a non-competitive equilibrium characterized by positive marginal profits to arbitrage due, for example, to oligopsonistic or oligopolistic behavior or to binding quantitative restrictions on trade (e.g., quotas).

These spatial market regimes can also be extended to trade across form and time. Thus, if $r_{it} < r_{i(t+1)} - \pi$ holding rice is not optimal, and if the inequality holds in the other direction, the market is not perfectly competitive across time. Authors such as Williams and Wright (1990) and Deaton and Laroque (1992, 1996) have explored the consequences of competitive equilibrium commodity storage behavior, but there is scant empirical evidence as to whether commodity prices indeed satisfy the basic competitive storage equilibrium conditions in developing economies.

Market integration across form (e.g., between paddy and rice) has received little attention in the literature. High variability in access to efficient milling and transport likely create spatial and temporal differences in incentives to convert from paddy to milled rice. Processing is not optimal when and where $r_{it} < p_{it} + \alpha$. However, if spatial competitive equilibrium holds, then processing can take place in any location at any time, implying processing competitive equilibrium, i.e., (3) should hold with equality.

Several methods exist for testing market integration empirically. Barrett (1996a), Baulch (1997) and others find fault with the common practice of studying market integration using only the comovement of prices in time series data. Among other problems, such studies assume fixed transfer costs and cannot accommodate interseasonal flow reversal (Barrett 1996a, Fackler and Goodwin 2002). Since highly variable transfer costs and interseasonal flow reversals are commonplace in rural areas of developing countries, such as Madagascar, we opt for an alternative method of market integration testing.

If we perfectly observed transfer costs in each period, then we could simply count the number of observations falling into each regime to determine the extent of market integration. With more limited information on transfer costs between the relevant markets, the Parity Bounds Model (PBM) advanced by Baulch (1997) allows us to establish probabilistic limits within which the spatial arbitrage conditions are likely to hold.

The PBM is specified using the following likelihood function:

$$L = \prod_{t=1}^{T} [\lambda_1 f_t^1 + \lambda_2 f_t^2 + (1-\lambda_1-\lambda_2) f_t^3] \tag{5}$$

where λ_1 and λ_2 are the estimable probabilities of the market being in Regimes 1 and 2, respectively. The three regimes are:

Regime 1: Competitive integrated equilibrium

$$f_t^1 = \frac{1}{\sigma_e} \phi \left[\frac{Y_t - \delta_t}{\sigma_e} \right] \tag{6}$$

Regime 2: Competitive non-trading/segmented equilibrium

$$f_t^2 = \left[\frac{2}{(\sigma_e^2+\sigma_u^2)^{1/2}}\right] \phi \left[\frac{Y_t - \delta_t}{(\sigma_e^2+\sigma_u^2)^{1/2}}\right] \left[1 - \Phi\left[\frac{(Y_t - \delta_t)\,\sigma_v/\sigma_e}{(\sigma_e^2+\sigma_u^2)^{1/2}}\right]\right] \quad (7)$$

Regime 3: Non-competitive equilibrium or disequilibrium

$$f_t^3 = \left[\frac{2}{(\sigma_e^2+\sigma_v^2)^{1/2}}\right] \phi \left[\frac{Y_t - \delta_t}{(\sigma_e^2+\sigma_v^2)^{1/2}}\right] \left[1 - \Phi\left[\frac{-(Y_t - \delta_t)\,\sigma_v/\sigma_e}{(\sigma_e^2+\sigma_v^2)^{1/2}}\right]\right] \quad (8)$$

$Y_t = |r_{it} - r_{jt}| - T_t$ is the apparent gains from arbitrage, where T is the vector of observed transport costs and δ_t is the unobserved component of the total transfer costs.[4] The parameters σ_e, σ_v, and σ_u represent the standard deviations of the three error terms, e_t, v_t, and u_t. The uncensored, normally distributed error term, e_t, relates to the transfer cost, while v_t, and u_t refer to the half normal error terms outside or inside the parity bounds, respectively. By estimating the frequency with which different communes fall into different regimes within the domain of spatial, intertemporal or full food marketing system arbitrage, we can get a sense as to how well markets perform different intermediation functions.

3. Explaining market integration through trader entry

Knowing whether markets are competitive, non-competitive or segmented and at what spatial or temporal scale has important policy implications. But the next obvious step is to try to understand what drives certain areas into a particular market regime. This section sketches a simple heuristic model of the barriers to entry that traders face and explores why we might observe non-trading and non-competitive equilibria across space, time, form, or some combination of these.

[4] This differs slightly from Baulch's original formulation, which uses the log form of the price differential and of transport costs and does not include the unobserved component of transfer costs. Barrett and Li (2002) introduce the adjustments we use here.

If a trader has the capacity and information, he/she should enter a market as long as there are positive rents to be made. First, we assume that trader k in commune j is informed about prices and costs in commune i through personal or business contacts or through public information coming out of the commune, which is increasing in mass media in the area, proximity, and the amount of traffic between i and j. If informed, and assuming now that that τ_{ijt} is trader specific, trader k in commune j enters market i to purchase rice in quantity q_{it} if $r_{jt}q_{it}>r_{it}\,q_{it}+\tau^{k}_{jit}(X_{it}, q_{it}, h^{k}_{i}, w^{k}, b^{k})$.[5] Unit transfer costs are a function of the time-varying commune i characteristics X_{it} (such as road conditions, crime, and village rice storage and milling capacity), the quantity purchased, the personal or business contacts k has in i, h^{k}_{i} , and k's wealth, w^{k}, and borrowing capacity, b^{k}. Having contacts in commune i reduces market intermediation cost by reducing costs of searching for the desired quantity and by potentially reducing the costs associated with protection and quality checks (Fafchamps and Minten 1999, 2002). Contacts are assumed to be decreasing in distance and increasing in ethnic ties. Crime is a major problem in some rural areas of Madagascar (Fafchamps and Moser 2003), and thus the risk of theft and highway banditry may deter both trade and storage (Fafchamps and Minten 2001). Greater wealth, assets, or borrowing capacity of the trader imply greater access to motorized transport and transactional credit, and thus the ability to take advantage of economies of scale.

Trader k must be able to finance the cost of purchase and transfer either through his own wealth, w^{k}, or borrowing, b^{k}, or both. Thus $r_{it}\,q_{it}+\tau^{k}_{jit}(X_{it}, q_{it}, w^{k}, b^{k})< w^{k}+b^{k}(X_{jt}, w^{k})$. His ability to borrow is a function of the characteristics of commune j (such as existence of banks, distance to the provincial or national capital, etc.). Trader entry is thus

[5] It is straightforward to reverse the flow such that the trader wants to take advantage of low prices in commune j to sell to commune i.

increasing in good road conditions, personal or business contacts in i and his wealth and ability to borrow.

The non-competitive Regime 3 emerges either through a lack of information about the opportunities in i, or because the number of traders who can enter the market is insufficient to render it competitive. High costs of entry in the presence of positive rents could allow monopsonistic or oligopsonistic behavior on the part of a small number of wealthy traders, yielding positive average returns to arbitrage in non-competitive equilibrium. At the sub-regional level we can imagine that proximity and ethnic ties might allow flow of information and competition in many areas, but that the lack of access to financial institutions and the inability of small traders to finance large transactions might also lead to a persistence of Regime 3. At the regional and national levels, we would expect more problems of information flow and fewer problems of finance, but also more cases of prohibitively high transport costs resulting in the non-trading Regime 2.

We can use the same basic model to consider trade across periods. Now trader k considers purchasing rice in commune j in period t to hold and sell in period t+1 in commune j. Thus, $r_{jt+1}q_{jt} > r_{jt}\, q_{jt} + \pi^{k}_{jt}\,(X_{jt}, q_{jt}, w^{k}, b^{k})$. The cost of storing rice is equal to the nominal interest rate for the period plus physical storage cost and loss due to spoilage, shrinkage, and pests. Storage loss and cost are a function of storage capacity and crime (through increasing the cost of protecting stocks). As in the previous model, the trader must be able to finance the project. We could similarly consider a trader's decision to conduct trade across space, time, and form (equation 4) such that the trader's entry is a function of access and ability to finance, transportation infrastructure, crime, storage and milling capacity, ethnic and physical proximity.

4. Background on Rice Markets in Madagascar

With a wide range of climates and transportation infrastructure, Madagascar provides an interesting and potentially valuable case study of agricultural prices and markets. Madagascar is a relatively large country—587,000 km^2, roughly the size of France—with a population of about 16 million (INSTAT 2003). It has approximately 6,300 km of paved road and 23,000 km of unpaved road, of which only 8,000 km are considered to be in good or fair condition (World Bank 2002).

Rice is the obvious commodity to study because it is nearly universally grown and consumed, and, more than any other good in Madagascar, its price and price variability have an enormous impact on welfare (Barrett and Dorosh 1996). Rice accounts for approximately 44 percent of land under cultivation and nearly 50 percent of caloric intake (FAO 1998). Yet most farmers are actually net buyers of rice (Barrett and Dorosh 1996; Minten and Zeller 2000) and many liquidity-constrained smallholders sell some rice at harvest at low prices and buy rice later in the year at high prices.

The government of Madagascar was heavily involved in the rice market and had a legal monopsony on the purchase of rice for much of the 1970s and early 1980s. The resulting downward pressure on rice producer prices caused stagnation in rice production and a huge rice import bill, and ultimately pushed the government to take steps toward liberalization in 1983 that continued throughout the 1980s and into the 1990s (Barrett 1994). However, policy reform may not have been sufficient to foster competitive markets. Total rice production increased little in the country during the 1990s. Yields remained stagnant and well below world average yields (IRRI 2000). In some cases it appears that politically connected families ran regional monopsonies. A survey in 1990 revealed that few rice farmers had access to more than one collector, the initial marketing intermediary who buys crop at farmgate and then resells for a miller or wholesaler (Barrett 1994).

Market liberalization should have enabled traders to enter the rice market to take advantage of new opportunities. However, Barrett (1997) found that barriers to entry, such as lack of credit and state connections, limited competition in the areas of wholesale crop collection, interregional transport and interseasonal storage. Subcollection (local collection for sale to a wholesaler), ox-cart transport and casual retailing had low barriers to entry, but appeared to be very low profit activities taken up primarily by those needing additional income in hard times.

The means used to transport rice vary widely. While motorized transport is the most commonly used means, ox-carts, hand-drawn carts, and porters are also used. Although the presence and conditions of roads largely determines the choice of transport, small retailers are more likely to use more expensive non-motorized means of transport even where motorized transport exists. Fafchamps et al. (2003) do not, however, find evidence of increasing returns in trade in Madagascar.

Traders are highly localized. In a study of traders conducted in 1996-97, only 8.8 percent of wholesalers made purchases from areas more than 100 km away (Mendoza and Randrianarisoa 1998). Traders cited numerous police checkpoints, high transportation costs, and informal regulations on the movement of rice as the main obstacles to expanded interregional trade. The use of formal and informal sources of credit is rare among traders. Eighty-nine percent of traders used their own money to support current operations and 85 percent used their own money to finance new investments. Among those who did borrow to finance investment, only 13 percent borrowed from banks. Large traders were more likely to borrow from banks than smaller ones. Traders most often used informal sources to obtain market information and the use of telephones and fax machines (even where available) was rare (Mendoza and Randrianarisoa 1998).

Fafchamps and Minten (2001) find that incidents of theft and contractual breach are low among traders, but that this is due to low exposure to risk rather than low ex-ante risk or ex-post enforcement of laws. Traders incur high transfer costs in order to guard against theft through such actions as sleeping on rice stocks, minimizing the number of hired workers, and avoiding overnight storage. Furthermore, competition does not appear to improve the efficiency of markets as larger, more profitable firms do not use their advantage to lower prices and drive out smaller firms. Social networks are an important resource for Malagasy traders, and personal relationships with other traders and lenders have a positive effect on efficiency (Fafchamps and Minten 2002).

5. Data and descriptive statistics

This paper takes advantage of a unique data set from Madagascar that includes rice and paddy prices and transportation costs for nearly all of the 1394 communes (districts) in the country for four calendar quarters. The 2001 commune census was conducted in collaboration between Cornell University and the Malagasy agricultural research institute (FOFIFA) over a three-month period in 2001. The survey was conducted at the commune's administrative center. The remoteness of some communes and the general lack of national data on certain subjects meant that little was previously known about the spatial distribution of public goods and services, prices, or economic activity prior to this study. Most of the commune census questions, such as those concerning local prices, transportation, access to various goods and services, major economic activities, ethnic groups, and community perceptions of existing conditions, were answered by a focus group composed of residents of the commune.

The commune is the smallest administrative unit in Madagascar. The mean (standard deviation) area of the communes is 426 (514) square kilometers and population is 8,800 (20,425) residents. A dozen or so communes are grouped to form the next highest administrative unit, the *fivondronana*. The *chef-lieu*, or seat, of the *fivondronana* is usually the largest town and the center of commerce in the area. The 111 *fivondronana* are further grouped into the six provinces of Madagascar. Figure 1 shows the provinces, *fivondronana*, communes and major cities of Madagascar.

The administrative units described above form the basis of the three market scales used later in the empirical analysis. Transport to the capital, Antananarivo, defines the national level market. The sub-regional and regional scales correspond roughly, but not exactly, to the administrative boundaries of *fivondronana* and provinces, respectively. The six provincial capitals plus three other major cities (Morondava, Fort-Dauphin, and Antsirabe) are the hubs that define the regional markets.[6] The transport section of the commune census allowed the respondents to choose which of the nine major cities commune residents travel to most frequently. This city is usually, but not necessarily, the provincial capital or the nearest city. The commune census collected data on transport costs of 50 kg of rice to this city and to the capital for both the rainy season (calendar quarters 4 and 1) and the dry season (quarters 2 and 3).

The commune census did not collect information on transporting rice from the commune to the *chef-lieu de fivondronana*. However, the commune census did include detailed questions on the costs of transportation per *person* for each step of the trip from the

[6] Two of these cities, Morondava and Fort Dauphin, are extremely difficult to get to from their provincial capital, Toliara, and little trade occurs between them. The third city, Antsirabe, in the province of the capital city, Antananarivo, is the second largest city in the country and is an important area for agricultural production and processing.

commune to the nearest major city. In order to estimate the transport cost for rice at the sub-regional level, we first took the transportation cost per person from the commune to the first *chef-lieu de fivondronana* passed on the way to the major city. Then, the rice transport costs at the sub-region are calculated by multiplying the fraction of the total human transportation cost incurred in traveling to the sub-region by the regional rice transport cost.

Because the sub-regional towns were identified as the first *chef-lieu de fivondronana* passed in transit to the major city, the sub-regional town does not necessarily correspond to the *fivondronana* to which the commune belongs. Out of 111 *fivondronana* in the country, 105 are used by at least one commune in transit to the major city. Thus these 105 form the group of sub-regional towns.[7]

Table 1 presents some selected descriptive statistics from the commune census as well as the 1993 population census and income data from the World Bank poverty map (Mistiaen et al. 2002). The data are split into rural and city/town communes, where the latter refers to the 111 communes containing the city or town serving as the *chef-lieu de fivondronana*. These communes are not urban in the sense that they may have significant land outside the town or city devoted to agriculture, but, as mentioned above, can be thought of as sub-regional market hubs. The city/town communes tend to have higher mean incomes, lower poverty rates and percent of population in agriculture, and higher literacy rates and populations. Rural communes are slightly more likely to be classified as *zone rouge*, an official government designation given to high crime areas.

[7] While our definition of the sub-regional towns is data driven, it is not unreasonable to assume that the *chef-lieu de fivondronana* that one must pass through to get to a larger city is the town with which the commune trades. Periodic markets are ubiquitous at spots where travelers change vehicles or modes of transport. Without detailed information on actual flows of goods, this choice is no more arbitrary than strictly using administrative boundaries.

Turning to the rice prices in Table 2, the second calendar quarter (April to June) is the main harvest period in most regions of the country and thus the second and third quarters tend to have the lowest rice prices. Notice that the rural communes have lower average rice prices than towns in the second and third quarters (April to September), but higher prices in the fourth and first quarters (October to March). Figure 2 shows the median and span of the rice price across the quarters for all communes. Given that both the urban and rural price changes considerably exceed prevailing interest rates (even adjusted for stock loss due to spoilage, etc.), there appear to be considerable foregone intertemporal arbitrage opportunities in Madagascar's rice markets.

The correlation of prices across time, space, and form (Table 3) provides further preliminary evidence of the state of markets in Madagascar. The pre-harvest, low season rice price (January-March) is not highly correlated with the price of the harvest season that follows (April-June). As we would expect in fragmented markets, the commune price is more highly correlated with the sub-regional price than with the regional price. The price of paddy, or unmilled rice, is highly correlated with the (milled) rice price in the second and third quarters, but there is likely little rice left in paddy form by the fourth and first quarters, explaining much lower correlations in those periods. The high variability in the correlation between imported rice and local rice is striking, yet also consistent with the fact that there is low demand for imported rice in the post-harvest (second and third) quarters.

6. Spatial market integration

Using the price and transport cost data, we now turn to estimating the extent of spatial market integration at the three different spatial scales (sub-regional, regional and national). Recall that $r_{it}-r_{jt} = \tau_{ijt}$ is the integrated competitive equilibrium (Regime 1), $| r_{it}-$

$r_{jt}| < \tau_{ijt}$ implies a segmented competitive equilibrium (Regime 2), and $|r_{it}-r_{jt}| > \tau_{ijt}$ implies Regime 3, the non-competitive equilibrium or disequilibrium outcome.

The sub-regional level market scale uses the absolute value of the difference between the commune price, r_{it}, and the sub-regional town's price, r_{jt}, in the calculation of arbitrage opportunities. The regional level scale r_{jt} is the price in the nearest of the country's major cities. The national scale uses the period specific rice price in the capital. In this section, we do not consider the sign of the price difference (i.e., whether the town or city price is greater than the commune price or vice versa) although this has obvious implications for the direction of trade. Section 8 on interseasonal flow reversals addresses this topic.

Because we only observe reported transport cost and cannot observe all transfer costs (including loading, temporary storage, quality control, etc.), the Parity Bounds Model (PBM) described earlier enables us to establish a band within which a competitive equilibrium is likely to exist. Using the PBM, we estimate the probabilities associated with each market regime at each of the three spatial scales (Table 4).[8] We have four observations (one per quarter) for each commune, resulting in roughly 5,000 observations at each spatial scale.

As expected, markets are more integrated at the sub-regional level than at higher scales. An estimated 69 percent of communes are in competitive equilibrium at the sub-regional level. Yet even at this highly localized scale, 22 percent are in Regime 2, which implies that these communes do not trade with the larger towns. Furthermore, that nearly 10 percent of communes are out of competitive equilibrium (Regime 3) indicates positive

[8] We used the Davidon-Fletcher-Powell algorithm to solve the maximum likelihood problem (equation 5). Local maxima were compared across a range of starting values to find the global maximum at each spatial scale. The sub-regional towns and regional cities are omitted from the analyses at all scales since these are the presumed destinations of rice. All standard errors are bootstrapped with 150 replications.

economic profits to trade exist. At the regional level, there appear to be large potential gains to market entry as 63 percent of communes fall into Regime 3 (not in competitive equilibrium). Only 5 percent are in competitive equilibrium and 31 percent have no incentive to trade. High transportation costs result in little incentive to trade at the national level. Thus, we estimate that eighty-three percent of observations fall into Regime 2. These results imply that the government should encourage competition and market entry at the regional level, but needs to work on reducing market intermediation costs at the national level.

Section 3 outlined a simple model of trader entry. We now use this model to study why communes fall into a particular regime. We use a multinomial logit model with the dependent variable taking on values 1, 2, or 3, corresponding to the regime we predict the commune falls into in that period according to the PBM estimates. The estimation results at the sub-regional level are presented in Table 5. Regime 1 (competitive equilibrium) is the comparison group. Sub-regional fixed effects were included in the estimation, but are not included in the table.[9]

High crime areas are more likely to be in Regime 3 (disequilibrium or non-competitive equilibrium) than in competitive equilibrium. Traders are clearly reluctant to engage in trade in more dangerous areas and, as a result, marginal trading profits are higher, perhaps reflecting higher risk premia, perhaps less competition. Communes with banks and with the same ethnic group as the sub-regional town are also more likely to be in Regime 3. These findings contradict the predictions of our model of trader entry. It is possible that because finance is not available to all those seeking it, only a few larger

[9] The estimation was repeated without the sub-regional level fixed effects. The results are quite consistent with those presented here and are available upon request. For brevity, the national scale multinomial logit results are omitted. The regional level estimation (Table 6) includes regional (but not sub-regional) fixed effects.

traders access formal credit. The existence of excess rents where ethnic ties are strong might signal that outsiders have difficulty breaking into these markets, i.e., that trader networks are effective not only in ensuring contract enforcement and obtaining information, but also in facilitation collusion and/or restricting entry, a possibility suggested in previous work on Malagasy trader networks (Fafchamps and Minten 2002).

Communes closer to the town are more likely to be in competitive equilibrium (Regime 1) and those farther away are statistically significantly more likely to be in Regimes 2 or 3. The latter result may indicate that information concerning arbitrage opportunities in remote areas does not reach a sufficient number of traders. Similarly, communes with no motorized transport available are more likely to be in Regime 3. Higher income communes are less likely to be in Regime 3, possibly because there are more potential traders who can finance their operations and enter the market. Consistent with our model concerning the role of information, radio reception appears to reduce the incidence of non-competitive equilibrium or disequilibrium.[10] The quarter-specific dummies show that, relative to the January-March period, communes are statistically significantly more (less) likely to be in Regime 2 (Regime 3) in the July-September and October-December periods. Most of the opportunities for arbitrage thus appear to occur just prior to the harvest and at harvest.

The multinomial logit results for the spatial market regimes at the regional level are presented in Table 6. High crime areas are statistically significantly more likely to be in Regimes 1 and 3 than Regime 2, indicating that trade is generally feasible in these areas, but security concerns likely limit arbitrage. As in the sub-regional model, because of higher transport costs, more remote communes tend to fall in Regime 2. The higher

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[10] In rural areas, radio is the most important source of information (among the mass media)—print sources and television are much less common.

prevalence of Regime 3 where more people engage in agriculture probably reflects that there are few traders in these areas. Radio reception appears to increase the likelihood of being in Regime 3 at the regional level. This finding is quite counter-intuitive and radio had the opposite effect at the sub-regional level. One possible explanation is that merchants at the commune level receive information about prices in the cities, but merchants in the cities do not receive information about prices in individual communes. Thus, if there are only one or two local merchants wealthy enough to finance trips to the city, they may be able to earn excess profits.

The results of the analysis of markets across space indicate that markets are fairly well integrated at the sub-regional level and that factors such as high crime, remoteness, and lack of information are among the factors limiting competition. At the regional level, only a small percentage of communes are integrated and most communes appear to be in disequilibrium or non-competitive equilibrium. At the national level, market intermediation costs are the main obstacle to integrated markets. The striking differences in market functioning at the three different scales and the existence of non-competitive equilibria or disequilibria imply that policies such as improving transportation infrastructure to reduce transport costs are extremely important but will not be sufficient for the emergence of competitive markets.

7. Intertemporal market integration

Large fluctuations in prices and the variability of these fluctuations across time in and of themselves suggest market inefficiencies. While the <u>annual</u> interest rate on lending in 2001 in Madagascar was approximately 26.6 percent (International Monetary Fund 2002), the mean <u>quarterly</u> change in price was 29 percent between quarters 2 and 3. Using the implied quarterly interest rate of 6.6 percent, $r_{it+1} - r_{it}*(1.066)$ is greater than zero for 62 percent of communes. Thus even assuming very relatively high storage costs there appear to be foregone gains to intertemporal arbitrage.

To assess the extent of intertemporal market integration, we again employ the PBM method. The spatial integration model of the previous section used $|r_{it}-r_{jt}| - T_t + \delta_t$ as its measure of arbitrage, where δ was the unobserved component of transfer costs. In the intertemporal context, we use $\log(r_{it}/(r_{it+1}*(1+i))) - \mu_t$, where i is the national quarterly interest rate and μ_t is the unobserved storage cost to be estimated.[11] Because the primary harvest for most areas of the country occurs in the second quarter, and our fourth quarter data are from 2000 (preceding the 2001 harvest) we limit the estimation to arbitrage between the second and third quarters of 2001. In other words, the fourth and first quarter prices tend to be higher than the second quarter and the expectation of a lower price at harvest implies that no stocks should be held over to the second quarter.[12] We estimate the PBM for the rural communes and the sub-regional (urban) towns separately in order test whether a rural-urban difference exists in temporal arbitrage (Table 7).

Only 6 percent of rural communes appear to be intertemporally integrated and 56 percent fall into the non-trading Regime 2. There are significant opportunities to make money on storage in rural areas (38% in Regime 3) but next to no positive marginal profits to storage in urban areas (only 1% in Regime 3), consistent with the observation that commercial food storage is widespread and competitive in towns but woefully undersupplied in rural areas (Barrett 1996b). The town communes tend to have much lower intertemporal price variation and thus have much higher incidence of Regime 2,

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[11] We use logarithms in this case so that the dependent variable is in percentage terms, making interpretation of μ, the unobserved storage cost (e.g., interest rates and storage losses to pests, spoilage and shrinkage) more intuitive, since it too is then in percentage terms.

[12] See Deaton and Laroque (1992, 1996) and Williams and Wright (1990) for a complete discussion of competitive storage behavior.

likely reflecting better integration into international markets through access to imported rice when local supplies are low. There is very little opportunity for profitable intertemporal arbitrage in the urban communes, with 87 percent of observations falling into Regime 2, given the estimated unobserved component to storage, μ_t, of 32.1 percent per quarter. These estimated unobserved costs are three times higher in the rural areas than in the urban areas, consistent with higher costs of borrowing and less efficient storage technologies in rural communes.

As we did in studying the spatial market regimes, we use a multinomial logit model to assess the commune characteristics that affect the prevalence of each intertemporal arbitrage regime (Table 8). We use only the rural communes for the intertemporal arbitrage opportunities between the second and third quarters because there are insufficient degrees of freedom in the urban sub-sample to perform this analysis. Not surprisingly, we find that communes with banks are statistically significantly more likely to be in competitive storage equilibrium. The coefficients on this variable are also quite high. Despite previous studies showing little use of formal finance (Barrett 1997, Fafchamps and Minten 1999), it appears that banks may in fact play a crucial role in intertemporal market integration. Income is directly and strongly related to probability of competitive equilibrium. Areas with a higher percentage of people working in agriculture are more likely to be in a segmented equilibrium across periods, reflecting their poor access to finance and storage. Communes in the eastern coastal region of Toamasina are less likely to be in competitive equilibrium, both across space and time. This area in particular would benefit from government interventions that aim to both reduce transfer costs and facilitate competition.

8. Interseasonal flow reversals—Integration across space and time

In the earlier discussion of spatial market integration, we did not address the direction of the flow of rice, i.e., whether the commune price was less than the town price or vice versa. In radial markets theory, agricultural goods are assumed to flow continuously from the rural areas to the cities and towns. However, in many developing countries, this flow occurs primarily during the harvest period and may actually reverse in the pre-harvest season (Timmer 1974, Barrett 1996b).

Even if the flow itself does not reverse, it is common to find that interseasonal price variability is higher in rural areas than in urban ones. Some of the reasons cited for this include local liquidity constraints, inadequate storage, market thinness, and intermediary market power in rural areas (Barrett 1996b). Although we do not have data on physical flows of rice, Table 2 shows that price variability is indeed higher for rural communes in Madagascar. When rural areas experience significantly higher price variability, rural households are much more vulnerable to seasonal undernutrition.

If interseasonal flow reversals do take place, and, letting i be the rice-producing rural commune and j the rice-consuming town, we would expect r_{it}-r_{jt}<0 at harvest and r_{it}-r_{jt} >0 in at least one later period under the flow reversal hypothesis. Inter-commune rice price differences do indeed change sign in precisely this manner for a large number of communes, as shown in Table 9 and Figure 3. During the harvest period 59 (69) percent of communes have a lower price than their sub-regional (regional) urban counterparts, but this percentage falls with each subsequent quarter. Between the first quarter and the second, 24 (25) percent communes have both a price that is higher in the first quarter and lower in the second than the sub-regional (regional) price. For 83 (62) percent of these cases, PBM Regime 1 or 3 conditions hold in both quarters—indicating that given transport costs, it is feasible to move rice to the sub-regional town (regional city) at harvest and back to the commune in the low season. Interseasonal flow reversals thus seem a regular feature of Malagasy rice markets.

What types of communes are likely to experience interseasonal flow reversals? To answer this question, we use a simple probit model where the dependent variable equals one if, given the transport costs, it appears feasible to buy rice in the commune in one quarter, and ship it back to the same commune from the sub-regional town and sell it in another quarter (Table 10).[13] The potential for interseasonal flow reversal is statistically significantly more likely in high crime areas, which is consistent with the earlier finding that high crime areas have higher opportunities for spatial arbitrage, and suggests trader reluctance to store rice in areas with a high risk of theft. Reflecting high transport costs, more remote areas have less potential for flow reversals. Communes with a major ethnic group in common with the trading town are statistically significantly less likely to experience interseasonal flow reversals.

From a research methods standpoint, evidence of flow reversals implies that linear time series analysis (such as cointegration and error correction techniques) that assume a constant unidirectional flow of product are not well suited to studies of market performance. Furthermore, higher seasonal price variation in rural versus urban areas reveals the need for using different seasonal price deflators for rural and urban areas in contrast to the common practice of using a single regional deflator. The welfare and food security implications of high rural price variability cannot be overstated, especially

[13] More precisely, if the central market price less the rural commune price is equal to or greater than the transport costs between the two communes post-harvest, and in the subsequent, pre-harvest lean season the rural commune price less the central market price is equal to or greater than the transport costs between the two, we identify the commune as likely to experience seasonal flow reversals, assigning them value 1 for the indicator dependent variable used in this probit regression Any commune that does not meet both of these conditions is labeled unlikely to experience seasonal flow reversals. We therefore assign those communes value 0 for the indicator dependent variable.

considering that the majority of rural Malagasy are poor and most Malagasy rice farmers are net rice buyers. Potential policy interventions include improving infrastructure, financial institutions, and storage capacity in rural areas.

9. Integration across space, time, and form

Section 6 found that markets were fairly well integrated spatially at the sub-regional level, but that there was very little integration at the regional level. Section 7 considered integration within a single commune between quarters, demonstrating that there are significant missed opportunities for intertemporal arbitrage in the rural areas, and the previous section discussed the potentially important consequences of seasonal flow reversals. The present section combines elements of all three sections in looking at integration across space, time and form.

Equation (4) reflects the integrated food marketing system competitive equilibrium: $p_{it} = r_{j(t+1)} - \alpha - \tau_{jit} - \pi$. We observe prices, transport costs (T) and the quarterly interest rate (i), and are left with an unobserved component that includes other (unobserved) transfer costs, milling and storage costs. The measure of arbitrage for purchasing paddy in i, transporting, milling and selling in location j in period t+1 is $Y_t = \log(r_{j(t+1)} /(p_{it} *1.066)) - \log(T)$. The PBM estimation results for the sub-regional and regional scales are presented in Table 11. As in the intertemporal model, we consider only movements from quarters 2 to 3 in rural communes. Most communes—79 percent—appear to be competitively integrated at the sub-regional level. At the regional level, however, there are essentially no communes in competitive equilibrium, only 5 percent of communes in the segmented Regime 2, and 96 percent in Regime 3. These results are consistent with the spatial model results (Table 4) in which Regime 3 dominated and there was very little Regime 1 at the regional level, and as in previous models, point to the need for policies that encourage competition and market entry at this scale. Although highly localized markets appear competitive in Madagascar, once one tries to integrate markets across broader spaces representing major regions within a large country – much less the whole nation – the competitiveness of the food marketing system appears to break down.

10. Conclusions

Market integration is crucial for both effective macro-level policies and for micro-level welfare improvements. Macro-level policies rely on markets to transmit price signals to affect micro-level decision-makers, yet these signals cannot be transmitted or are transmitted unevenly across space and time when markets are not integrated. Similarly, at the micro-level, households may be unable to take advantage of potentially welfare-improving agricultural technologies when the local markets must absorb increases in supply. By reducing price variability, integrated markets also play a crucial role in dampening the effects of localized and temporary demand and supply shocks and in reducing seasonal poverty and food insecurity.

However, market integration analysis frequently fails to account for the complexity of integration across space, time, and form. Agricultural markets in developing countries, in particular, may be highly fragmented and integrated to varying degrees at different spatial scales with trade flowing in different directions over the course of a year. This paper illustrates this complexity through an examination of the extent of integration in the rice market in Madagascar at three spatial scales and across periods using rice price data from a 2001 census of communes (districts).

Our analysis shows that there is very little integration of markets at the national level, mostly due to prohibitively high transport costs. At the regional level, however, the lack of contemporaneous spatial integration is more often due to the existence of excess rents to spatial arbitrage. Markets are fairly well integrated spatially at the sub-regional level, where nearly 70 percent of communes appear to be in competitive equilibrium. Similarly, markets appear well integrated across space, time and form at the sub-regional level, but non-competitive equilibrium or disequilibrium dominate at the regional level. All of the evidence points to significant spatial and intertemporal market fragmentation in Madagascar.

Given that even at the sub-regional level 22 percent of communes fall in the segmented category for spatial integration, reducing transportation costs at all levels seems to be a critical policy priority if rural rice producers—a majority of the nation's poor—are to have improved market access. The residents of many of these areas seem to agree; improved roads were cited as one of the top development priorities in the Commune census in 2001. The government of Madagascar seems to recognize this as it embarks on a massive transportation infrastructure project (World Bank 2003). However, reducing transportation costs is necessary, but clearly not sufficient for better integration of markets. For sixty-three percent of communes, trade at the regional level appears profitable but the lack of competition allows excess rents to persist. The existence of spatial and intertemporal arbitrage opportunities implies that the government also needs to facilitate competition and market entry, possibly through access to finance for traders (particularly at the commune and sub-regional level), providing information on prices throughout the country, or reducing rural crime.

The message of this analysis for policy makers and researchers is a powerful one: because markets are highly fragmented both spatially and temporally in Madagascar, both macro-level policies and micro-level development projects will likely not have the intended effects and some standard methods for analyzing market integration may not be suitable. Integrating markets through reducing high transfer costs (especially at the national level) and encouraging competition (at the regional level) needs to be a top priority for the government. However, this will clearly take years and many millions of dollars. In the meantime, policy-makers need to think creatively about how they can take advantage of well-integrated sub-regional markets.

Table 1 Selected commune characteristics*

	Rural	Town/city	Total
Mean income of commune 1993 (Fmg)[14]	297,756	434,391	307,404
	(86,389)	(295,391)	(119,417
Poverty rate (percent of households below poverty line)	75	60	74
	(0.13)	(0.19)	(0.14)
Literacy rate	54.43	71.10	55.60
	(23.64)	(21.10)	(23.85)
Population total 1993	7443.78	26087.32	8750.11
	(4754.16)	(75280.57)	(20898.70)
Percent working in agriculture 1993	58.84	35.54	57.12
	(17.15)	(21.62)	(18.54)
Travel time to nearest major city (hrs)	19.60	17.16	19.43
	(24.03)	(21.79)	(23.88)
Distance to nearest major city (km)	264.90	293.95	266.92
	(262.37)	(313.44)	(266.21)
Percent of communes:			
in which rice is a major crop	70.1	57.6	69.3
in which vanilla is a major crop	6.8	7.6	6.9
in which coffee is a major crop	14.4	7.6	13.9
in which maize is a major crop	10.1	7.6	9.9
in which walking required to leave commune	30.3	3.3	28.4
with a *Route Nationale* passing through it	29.0	82.6	32.7
with a wholesaler	7.8	68.5	12.0
with a mechanical rice mill	38.7	73.9	41.1
classified as *zone rouge*, or high crime zone	30.2	25.0	29.8
with a commercial bank	3.2	59.8	7.1
with radio reception	46.1	76.1	48.2
with access to imported rice	55.2	76.1	56.7

*Town/city refers to the 105 communes whose main towns or cities are *chef-lieu de fivondronana,* or sub-region, the others are classified as rural. Standard deviations are in parentheses

[14] $1≈6,000 Fmg in 2001

Table 2 Rice prices and transport costs

	Rural	Town/city	Total
Rice price Oct-Dec 2000 (Fmg/kg)	2,525.81	2,468.26	2,521.78
	(1,024.26)	(487.42)	(996.13)
Rice price Jan-March 2001 (Fmg/kg)	2,558.69	2,517.15	2,555.77
	(979.28)	(691.55)	(961.77)
Rice price April-June 2001 (Fmg/kg)	1,780.85	2,156.88	1,807.18
	(982.43)	(2,113.64)	(1,102.89)
Rice price July-Sept 2001 (Fmg/kg)	1,953.81	2,012.50	1,957.92
	(520.41)	(402.13)	(513.11)
Percentage change in rice price	85.40	64.73	83.96
(from min to max across four quarters)	(67.10)	(46.47)	(66.06)
Transport cost to major city (Fmg/kg)	319.09	253.10	314.49
	(414.52)	(259.09)	(405.90)

Table 3. Correlation coefficients

Rice Price	Oct-Dec 2000	Jan-March 2001	April-June 2001	July-Sept 2001
Jan-March	0.78			
April-June	0.11	0.13		
July-Sept	0.50	0.38	0.26	
Quarterly paddy price	0.42	0.63	0.79	0.74
Quarterly imported rice price	0.92	0.91	0.16	0.26
Sub-region price	0.20	0.44	0.54	0.50
Region price	0.19	0.38	0.21	0.42

Table 4. Spatial PBM estimation results

	Sub-region		Region		Tana	
	Coeff.	Std Error	Coeff.	Std Error	Coeff.	Std Error
λ1 (Regime1)	0.689	0.0249	0.055	0.0245	0.128	0.0276
λ2 (Regime 2)	0.215	0.0194	0.311	0.0228	0.830	0.0301
λ3 (Regime3)	0.096		0.634		0.043	
σ_E	1.512	1.91	1.530	3.11	0.025	1.76
σ_U	8.623	7.35	5.989	4.98	3.894	2.13
σ_V	4.39	11.65.	1.003	5.03	0.241	4.28
δ (unobserved costs, FMG/kg)	8.257	9.04	27.619	14.05	18.238	9.72
N	4930		5070		5070	
Chi-squared	680,941		814056		1,100,887	
P(Chi-sq > value)	0.000		0.000		0.000	

Table 5 Spatial market regimes—Sub-regional level

Multinomial logit with sub region fixed effects	**Regime 2 (Segmented)**		**Regime 3 (Non-competitive)**	
Regime 1 is comparison group	Coeff.	t-statistic	Coeff.	t-statistic
High crime area (dummy)	-0.074	-0.750	**0.462**	**2.850**
Bank (dummy)	-0.038	-0.170	**0.618**	**1.720**
Same ethnic group as town (dummy)	0.060	0.440	**0.463**	**2.210**
Travel time (log of hrs) to town	**0.450**	**10.260**	**0.188**	**2.690**
No motorized transport (dummy)	-0.071	-0.640	**0.584**	**3.070**
Mean income (log of Fmg)	-0.272	-1.250	**-2.127**	**-5.150**
Population (log)	-0.002	-0.700	0.006	1.330
Percent working in agriculture	-0.103	-1.310	-0.045	-0.330
Radio reception (dummy)	0.083	0.850	**-0.326**	**-1.920**
April-June (dummy)	-0.170	-1.440	0.063	0.420
July-September (dummy)	**0.271**	**2.440**	**-1.435**	**-6.990**
October-December (dummy)	**0.357**	**3.240**	**-1.441**	**-6.960**
Constant	2.908	0.980	**23.868**	**4.280**
N=	4089			
χ^2=	1104			
Pseudo R^2=	0.164			

Table 6 Spatial market regimes—Regional level

Multinomial logit with region fixed effects	**Regime 2 (Segmented)**		**Regime 3 (Non-competitive)**	
Regime 1 is comparison group	Coeff.	t-statistic	Coeff.	t-statistic
High crime area (dummy)	**-0.321**	**-2.040**	-0.086	-0.580
Bank (dummy)	0.509	1.100	0.632	1.450
Same ethnic group as city (dummy)	0.867	1.420	0.931	1.540
Travel time (hrs) to city	**0.494**	**7.550**	0.083	1.370
Mean income (Fmg)	-0.025	-0.090	-0.159	-0.570
Population (log)	0.048	0.400	0.107	0.940
Percent working in agriculture	0.005	1.220	**0.010**	**2.630**
No motorized transport (dummy)	0.111	0.620	0.025	0.140
Radio reception (dummy)	0.168	1.110	**0.308**	**2.150**
April-June (dummy)	0.026	0.130	**0.550**	**2.880**
July-September (dummy)	0.067	0.370	-0.151	-0.880
October-December (dummy)	0.201	1.060	0.160	0.890
Fianarantsoa	**0.506**	**2.210**	0.148	0.670
Toamasina	**1.356**	**3.290**	**0.839**	**2.050**
Toliara	**-0.804**	**-3.000**	-0.057	-0.230
Mahajanga	**-0.812**	**-3.350**	-0.229	-1.000
Antsiranana	**-1.477**	**-5.430**	**-0.537**	**-2.210**
Antsirabe	**-1.068**	**-3.600**	**-0.939**	**-3.600**
Morondava	0.789	1.430	0.489	0.900
Fortdauphin	0.675	1.470	**0.821**	**1.850**
Constant	0.212	0.050	2.514	0.650
N=	4716			
χ^2=	528.1			
Pseudo R^2=	0.069			

Table 7 Intertemporal PBM estimation results

	Rural		Town/city	
	Coeff.	Std Error	Coeff.	Std Error
λ1 (Regime1)	0.061	0.023	0.114	0.011
λ2 (Regime 2)	0.556	0.019	0.872	0.017
λ3 (Regime3)	0.383		0.014	
σ_E	2.293	.121	2.594	0.018
σ_U	1.772	0.106	1.677	0.029
σ_V	0.933	0.085	1.243	0.023
Unobserved costs (%/quarter)	0.972	0.020	0.321	0.014
N	1239		98	
Chi-squared	7560		390	
P(Chi-sq > value	0.000		0.000	

Table 8 Intertemporal market regimes

Multinomial logit with region fixed effects	**Regime 2 (Segmented)**		**Regime 3 (Non-competitive)**	
Regime 1 is comparison group	Coeff.	t-statistic	Coeff.	t-statistic
High crime area (dummy)	0.053	0.210	0.212	0.780
Bank (dummy)	**-1.092**	**-2.260**	**-1.162**	**-2.110**
Same ethnic group as city (dummy)	-0.372	-1.530	-0.130	-0.510
Travel time (hrs) to city	0.019	0.190	0.190	1.760
No motorized transport (dummy)	**-0.796**	**-2.850**	-0.197	-0.690
Mean income (Fmg)	**0.958**	**2.160**	-0.226	-0.480
Population (log)	0.197	0.990	**0.459**	**2.180**
Percent working in agriculture	**0.012**	**1.740**	0.005	0.670
Radio reception (dummy)	0.225	0.920	0.256	1.000
Fianarantsoa	-0.077	-0.230	**0.902**	**2.800**
Toamasina	**1.938**	**3.040**	**1.589**	**2.420**
Toliara	**1.237**	**2.730**	-0.386	-0.730
Mahajanga	**0.990**	**2.620**	0.018	0.040
Diego	0.672	1.430	0.415	0.800
Antsirabe	0.221	0.370	**1.162**	**1.990**
Morondava	**1.831**	**1.720**	1.457	1.330
Fortdauphin	**1.294**	**2.240**	-0.367	-0.530
Constant	**-12.994**	**-2.120**	-1.007	-0.160
N=	1044			
χ^2=	209.99			
Pseudo R^2=	0.112			

Table 9 Difference between sub-region price and commune price

Sub-region		**Harvest**		
Percent of communes with:	**Jan-March**	**April-June**	**July-Sept**	**Oct-Dec**
Higher price than town (r_{it}-r_{jt} >0)	49%	26%	33%	43%
Lower price than town (r_{it}-r_{jt} <0)	37%	59%	44%	32%
Price equal to town (r_{it}-r_{jt} =0)	14%	15%	23%	25%
Region				
Higher price than town (r_{it}-r_{jt} >0)	44%	21%	31%	36%
Lower price than town (r_{it}-r_{jt} <0)	43%	69%	49%	47%
Price equal to town (r_{it}-r_{jt} =0)	13%	10%	19%	17%

Table 10 Flow reversals

Probit		
=1 if flow reversal is feasible	Coeff.	t-statistic
High crime area (dummy)	**0.171**	**1.880**
Bank (dummy)	-0.026	-0.120
Same ethnic group as town (dummy)	**-0.171**	**-1.940**
Travel time (log of hrs) to town	**-0.169**	**-4.590**
No motorized transport (dummy)	0.065	0.600
Mean income (log of Fmg)	0.162	0.970
Population (log)	**0.137**	**1.920**
Percent working in agriculture	**0.005**	**1.890**
Radio reception (dummy)	**-0.168**	**-1.900**
Fianarantsoa	-0.074	-0.590
Toamasina	**-0.435**	**-2.730**
Toliara	**-0.362**	**-2.280**
Mahajanga	-0.076	-0.560
Antsiranana	**-0.264**	**-1.610**
Antsirabe	0.142	0.730
Morondava	-0.105	-0.410
Fortdauphin	**-0.372**	**-1.800**
Constant	-3.218	-1.400
N=	1049	
χ^2=	59.23	
Pseudo R^2=	0.041	

Table 11 Integration across time, space and form: PBM estimation

	Sub-region		Region	
	Coeff.	Std Error	Coeff.	Std Error
λ1 (Regime1)	0.793	0.014	0.000	0.019
λ2 (Regime 2)	0.052	0.014	0.045	0.003
λ3 (Regime3)	0.155		0.955	
σ_E	4.062	0.047	0.543	0.011
σ_U	1.318	0.034	0.532	0.008
σ_V	1.087	0.067	0.686	1.71
Unobserved costs (%/quarter)	1.947	0.059	0.073	0.028
N	1104		1136	
Chi-squared	7009		50975	
P(Chi-sq > value)	0.000		0.000	

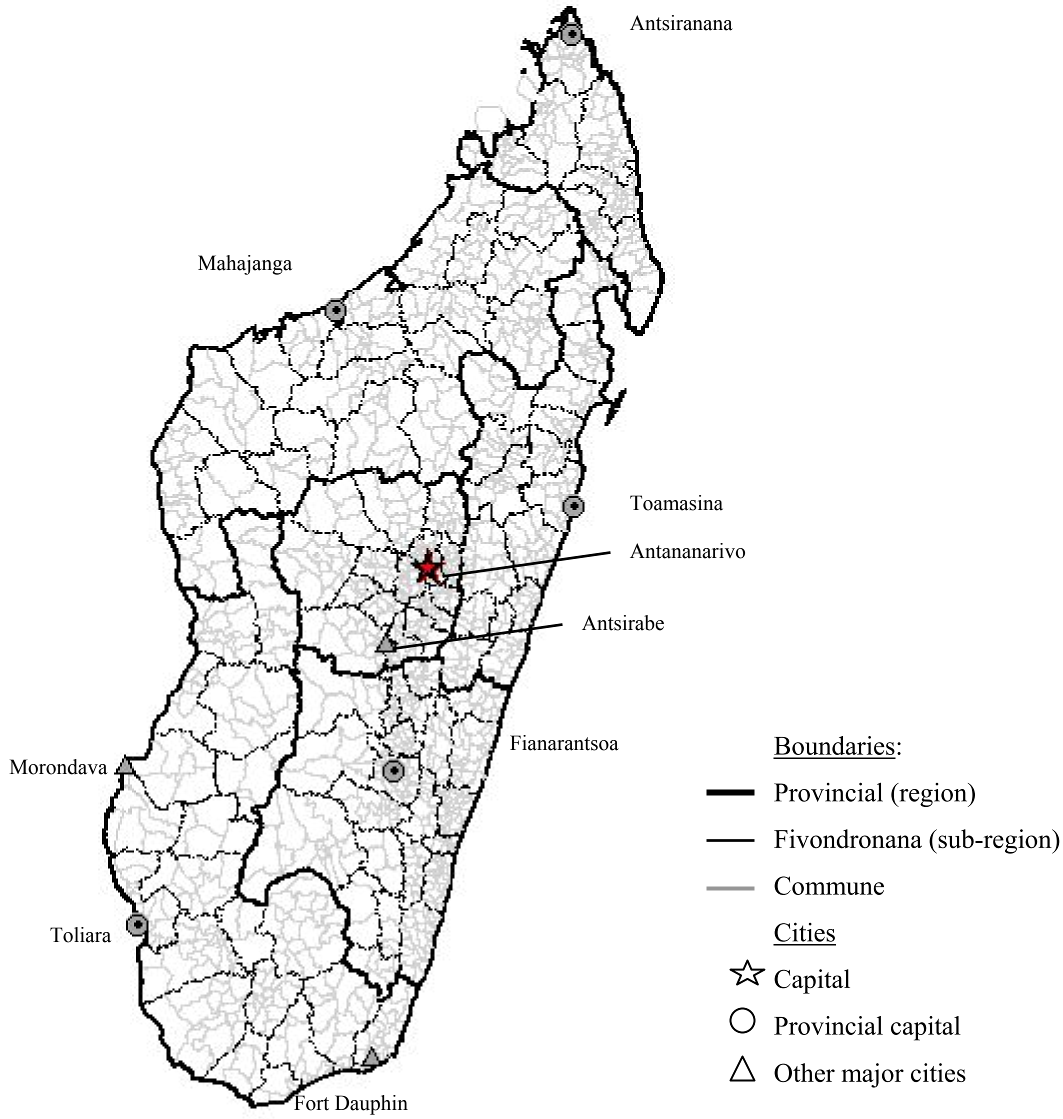

Figure 1. Administrative boundaries and major cities of Madagascar

Figure 2. Rice price by quarter
(Spans are trimmed at the 5th and 95th percentiles)

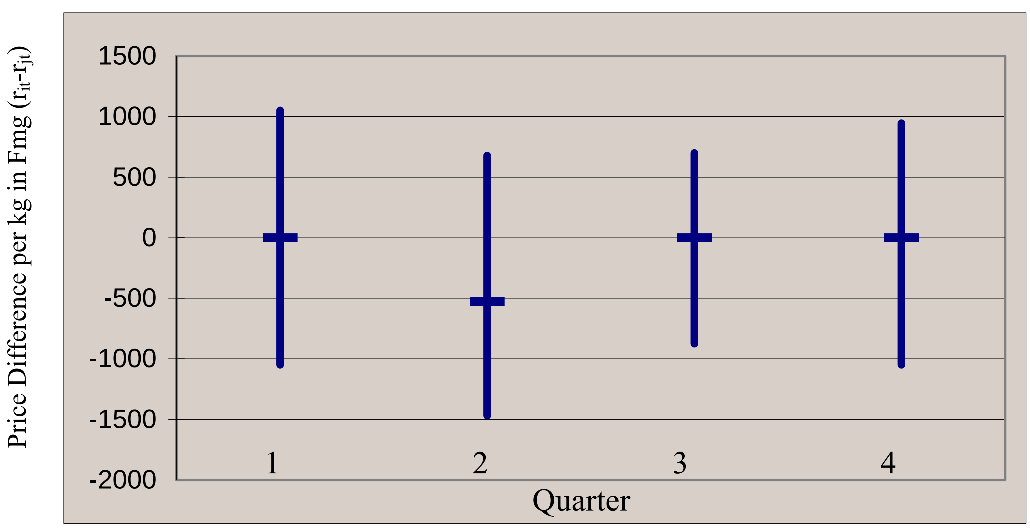

Figure 3. Median and span of price differences at the regional level
(Spans are trimmed at the 5th and 95th percentiles)

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