INSTITUTE OF DEVELOPING ECONOMIES

IDE Discussion Papers are preliminary materials circulated
to stimulate discussions and critical comments

IDE DISCUSSION PAPER No. 503

Rice flows across regions in Madagascar

Tsilavo Ralandison, Yutaka Arimoto,
Hisaki Kono, Takeshi Sakurai, Kazushi Takahashi

March 2015

Abstract

Although spatial disintegration of rice markets in Madagascar has been well documented, little is known about actual rice flows across regions. Using weekly collected unique data from rice markets in 22 regional capital cities for one year, this study explores the physical distribution of rice in Madagascar and reveals that rice flows from sufficient regions to deficit regions, along with geographical proximity, have positive effects on rice flow. In contrast, season factors, such as harvest/non-harvest periods and weather conditions have a negligible effect on rice flow. These findings suggest that rice flows generally follow a rational pattern despite the fact that market indicators indicate that rice trade across regions is underdeveloped.

Keywords: commodity flow, origin, destination, rice, Madagascar

---

* Institut Superieur de Technologie d'Antananarivo (ralandisontsilavo@yahoo.fr)

The Institute of Developing Economies (IDE) is a semigovernmental, nonpartisan, nonprofit research institute, founded in 1958. The Institute merged with the Japan External Trade Organization (JETRO) on July 1, 1998. The Institute conducts basic and comprehensive studies on economic and related affairs in all developing countries and regions, including Asia, the Middle East, Africa, Latin America, Oceania, and Eastern Europe.

The views expressed in this publication are those of the author(s). Publication does not imply endorsement by the Institute of Developing Economies of any of the views expressed within.

INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

©2015 by Institute of Developing Economies, JETRO
No part of this publication may be reproduced without the prior permission of the IDE-JETRO.

Rice flows across regions in Madagascar*

Tsilavo Ralandison[a], Yutaka Arimoto[b], Hisaki Kono[c], Takeshi Sakurai[d], Kazushi Takahashi[e]

[a] *Institut Superieur de Technologie d'Antananarivo* (Email: tsilavo@gmail.com)

[b] *Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO)* (Email: arimoty@gmail.com)

[c] *Department of Economics, Kyoto University* (Email: kono@econ.kyoto-u.ac.jp)

[d] *Department of Agricultural and Resource Economics, University of Tokyo* (Email: atsakura@mail.ecc.u-tokyo.ac.jp)

[e] *Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO)* (Email: Kazushi_Takahashi@ide.go.jp)

March 10, 2015

Abstract

Although spatial disintegration of rice markets in Madagascar has been well documented, little is known about actual rice flows across regions. Using weekly collected unique data from rice markets in 22 regional capital cities for one year, this study explores the physical distribution of rice in Madagascar and reveals that rice flows from sufficient regions to deficit regions, along with geographical proximity, have positive effects on rice flow. In contrast, season factors, such as harvest/non-harvest periods and weather conditions have a negligible effect on rice flow. These findings suggest that rice flows generally follow a rational pattern despite the fact that market indicators indicate that rice trade across regions is underdeveloped.

Keywords: commodity flow, origin, destination, rice, Madagascar

* This survey was conducted as part of the rice market studies conducted in Madagascar for the PAPRIZ (Project for Rice Productivity Improvement in Central Highland) implemented by JICA (Japan International Cooperation Agency). We are grateful to project experts and the staff of the JICA Madagascar office. Financial support by Hitotsubashi University, the Institute of Developing Economies—Japan External Trade Organization, and JSPS KAKENHI (Grant Numbers 22223003 and 25245038) is greatly acknowledged. The standard caveats apply.

1. Introduction

Smooth movement of food products is widely recognized to play a vital role in protecting both producers' and consumers' welfare: for producers, such movement provides outlets for the surplus of local products, thus preventing farm gate prices from declining, and instead, contributing toward increasing farmers' income given the possibility of selling more products at better prices. For consumers, such movement can protect them from local supply shocks through trade across spaces, leading to price stability and improved food security (Moser et al., 2009). In Madagascar, rice markets are particularly important for the wellbeing of the population because rice is a staple food and has the highest production volume of all agricultural commodities in the country (Minten and Dorosh, 2006). Rice income is the primary source of household income for most farmers (INSTAT, 2010, Ministry of Agriculture, 2005). Furthermore, food expenditures represent an average of 65% of the household budget, of which 32% is occupied by rice purchases in poor households (INSTAT, 2010).

Despite the importance of well-functioning rice markets, several signals indicate that rice trade across regions is underdeveloped. The first signal is the high intra-annual and inter-spatial price variability. Each year, prices during the harvest and the non-harvest seasons vary significantly. Weekly data collected by Madagascar's Rice Observatory[1] from January 2011 to December 2012 show a 40% average increase in retail prices between June 2011, when prices were the lowest, and January 2012, when prices were the highest (Ralandison et al., 2014). Prices are low primarily during the harvest season, which is typically between April and June, and high between January and March. Prices also vary substantially across regions. Using a regression analysis, Sakurai and Arimoto (2014) revealed that prices in the 31 major markets in Madagascar differed by approximately 20% in both positive and negative directions from prices in the country's capital city.

The second signal is that rice is still imported even though total production is believed to have surpassed domestic demand. According to the Ministry of Agriculture, total production reached approximately five million tons in 2013. This amount should suffice for the entire population if 140 kg of milled rice is consumed annually per capita (Arimoto et al., 2010). However, rice imports[2] account for approximately 35% of the total marketed rice during the past few years (Fews Net, 2013), suggesting that the distribution of domestic rice is spatiotemporally inefficient.

Significant research was conducted on Madagascar's rice market, particularly on the degree of integration. Several studies, which were based on the 2001 national census of communes (counties), showed that Madagascar's rice market is spatially relatively well integrated only at the sub-regional

[1] *Observatoire du Riz* or OdR in French is a governmental agency in charge of collecting and disseminating agricultural price information, primarily rice prices.
[2] Imported rice primarily comes from Pakistan, followed by Vietnam, India, and China. In Madagascar, two types of imported rice exist: low and high grades. The former is the most common and is sold in the local markets. The latter is more expensive and is primarily sold in supermarkets.

level and not at the provincial or national level (Moser et al., 2009). Moreover, the average probability of interprovincial integration of rice market is only approximately 56%, although the degree of integration varies largely across provinces (Butler and Moser, 2010). More recently, Miyake and Sakurai (2012) used mid-2000s data and revealed that the degree of market integration improved given recent infrastructural developments, primarily road improvements.

Although these studies revealed the extent of rice market integration in Madagascar, limited knowledge exists on the practical flows of rice. The market integration literature typically relies on price co-movement in two distinct places and does not necessarily consider actual trade flows. Therefore, we still lack knowledge on even the basic facts of rice flow: What is the origin of the rice sold in Madagascar's major markets? Do inter-regional trades exist? Does rice flow from surplus to deficit regions? When and where do these flows occur?

The main objectives of this paper are to investigate the rice flow in Madagascar and to account for the observed patterns. More specifically, we first present and describe the details of regional and seasonal rice flow. We then examine the association between rice flow and its potential factors, viz., each region's rice sufficiency and the proximity between origin and destination regions. To unveil the flow of rice in Madagascar, we utilize our original survey data collected in the main rice markets of Madagascar's 22 regions[3] during a 52-week period through a weekly retailer survey. The data contain information on the origins of the rice sold by the surveyed retailer in each region, thereby enabling us to identify the origin and destination of the rice. We also use secondary data from the Ministry of Agriculture and the Madagascar's National Statistics Institute[4], to substantiate the analysis and aid the interpretation of the results.

The main findings presented in this paper are as follows. First, rice-deficit regions tend to import rice from rice-surplus regions. Second, the probability of flow-ins is lower during the harvest season in destination markets, whereas the probability is higher during the harvest season in the origin regions. Third, rice flows are more frequent between proximate regions. Fourth, the probability of flow-ins did not decline in the rainy season. Fifth, no clear pattern shows that the probability of flow-ins increases as time passes after the main harvest.

This study is the first to provide information on regional and seasonal rice flow in Madagascar using systematic, quantitative data. The hope is that this information serves as a foundation for understanding the rice market in Madagascar and is considered when devising and revising rice-related policies.

The remainder of this paper is organized as follows. Section 2 describes the hypothesis, method, and data. Section 3 explains the flows. Section 4 accounts for the observed pattern of inter-regional

---

[3] The region is the highest administrative unit in Madagascar. Twenty-two regions are divided into 111 districts that are, in turn, divided into 1,566 communes.

[4] *Institut National de la Statistique* or INSTAT, in French.

flow. Finally, we make our concluding remarks in Section 5.

2. Method and data

2.1. Hypothesis and method

Hypothesis

To achieve the research objectives stated in Section 1, we hypothesize that rice flow is determined by two main factors: rice sufficiency and proximity of regions. Clearly, regions with a rice shortage (deficit regions) need to import rice from other regions, whereas regions with rice surpluses are capable of supplying rice to other regions. The origin–destination proximity may also play an important role in trade; given transportation costs, rice flows are expected to occur more frequently between proximate regions.

Notably, seasonality could affect these two factors. A region may be rice-sufficient immediately after the harvest season but might run out of stock as time passes and become rice-deficit in the lean period. Thus, the extent of self-sufficiency changes temporally. Similarly, whereas the physical distance between two regions may not change across seasons, the time duration for traversing the distance may change and become longer in the rainy season than in the dry season, which is likely to be magnified with poor road quality and heavier rainfall.

Method

To examine the observed pattern of rice flow using the aforementioned hypothesis, we estimate variants of the following basic equation:

$$y_{ijt} = \beta_0 + \beta_1 \mathrm{SURPLUS}_i + \beta_2 \mathrm{DIST}_{ij} + \beta_3 \mathrm{SEASON}_{it} + \beta_4 \mathrm{SEASON}_{jt} + \delta_t + \varepsilon_{ijt}, \qquad (1)$$

where y_{ijt} is the dummy variable equal to one if rice flows from origin region j to market (destination) region i in week t; $\mathrm{SURPLUS}_i$ represents the extent of rice surplus; DIST_{ij} represents the variable that captures the proximity of the two regions; SEASON_{it} represents a vector of seasonal variables; δ_t represents the week's fixed effects; and ε_{ijt} is the error term. We expect β_1 to be negative (indicating that rice-surplus regions tend to experience lower flow-in frequency) and β_2 to be negative (long-distance pairs are less likely to trade).

2.2. Survey

The data used in this paper are based on the "Rice Price and Trade Survey" funded by Japan International Cooperation Agency (JICA). The survey covers all major markets in Madagascar, which is the largest rice market in each of the 22 region capital cities (Figure 1). Data collection was conducted weekly in these 22 markets by enumerators, who are officials of Madagascar's National

Statistics Institute, from April 2012 to August 2013. To focus on a year-situation beginning from the main harvest month in most regions, this study uses partial data from June 4, 2012 to May 27, 2013, for a total of 52 weeks. For each time that data collection occurred, five retailers—defined as rice traders who sell primarily to consumers and who have a fixed place in the market—are randomly selected in each market. The survey excluded occasional traders, such as farmers who come to the market only on a market day to sell rice on the street around the market. Enumerators interviewed selected retailers on the given market day[5] of the assigned market in each city through face-to-face interviews and asked for information on all types of rice sold by retailers, including names, region of production, price, sale quantity, and observable quality such as color, shape, and milling method.

== Figure 1 Regions of Madagascar ==

2.3. Data

Rice variety

Our data classify rice into five types (varieties): *vary gasy*, *tsipala*, *makalioka*, *import*, and unknown variety. In the following analyses, we focus on the movement of the three main domestic rice varieties: *vary gasy*, *tsipala*, and *makalioka*.[6] All three varieties are indigenous even though some may have undergone improvements. The varieties belong to the javanica rice group. *Vary gasy* includes any locally produced rice other than *tsipala* and *makalioka*. In contrast, *tsipala* and *makalioka* are very specific, although they do not seem to be single varieties in the agronomic sense. However, their appearances are quite different and they are easily distinguished in the market. Generally, they have a longer grain compared with *vary gasy*. *Tsipala* is relatively shorter than *makalioka*, which is considered high-grade rice, and cleanly processed *makalioka* is the most expensive rice in Madagascar. They are packed in branded packages and sold in supermarkets in cities.

Flow

A commodity flow analysis is comprised of origins and destinations. Origins are the regions for rice production, whereas destinations are the consuming markets, i.e., the regional capitals in which the survey was conducted. We define origins and destinations at the regional level (N = 22). Interchangeably, we call origins and destinations "producing region" and "consuming region or

---

[5] The market day is the best day of the week to capture all types of rice sold in the market. In contrast, the market is deserted on Sundays. For cities without a specific market day, the survey was conducted at any time, except for Sunday and on the same day every week.

[6] Madagascar's Rice Observatory officially classifies rice sold in the market into four groups: *vary gasy*, *tsipala*, *makalioka*, and *importé* (imported rice). This paper focuses on the first three categories.

market," respectively. Using our weekly survey data, we consider that a directed "flow"[7] occurs from origin *j* to destination (market) *i* if rice sold by our sampled retailer in market *i* was produced in region *j*. In the following analyses, we also consider intra-regional flows, which are trades that occur within a region, i.e., the origin and destination are the same ($i = j$)..

Region characteristics

For each region, we attributed rice-sufficiency status and seasonal characteristics (harvest and rainy season). For rice sufficiency, we estimated total rice production and consumption in each region[8] and identified whether the district is rice-surplus (i.e., a region's rice production exceeds its consumption). The two season variables (rainy season and harvest season) are obtained at the month level, and we attributed that information to the week level. **Appendix Tables A1** and **A2** show the data for region characteristics and season variables and their sources. We identified 10 deficit regions and 12 surplus regions. The largest deficit region is Analamanga, which is the most populated region and the location of Madagascar's capital city. In contrast, Vakinankaratra, which is the second most populated region, is the largest surplus region.[9]

Region pair characteristics

For all 231 ($= \mathrm{C}(22,2) = (22 \times 21)/2$) (non-directed) combinations of region pairs that could form an inter-regional flow, we constructed a dataset of road distances (km) between the capitals of two regions and a dummy variable equal to one if two regions are adjacent. **Appendix Table A3** shows the data and sources.

Weeks elapsed since the last main harvest

Given that rice sufficiency may change over time, we construct a variable measuring the weeks

---

[7] "Link" and "trade" are also words used depending on the context. "Flow" implies a direction, whereas "link" and "trade" do not.

[8] Because official data on rice consumption in Madagascar were not available, for consumption, we rely on the results of estimations of per capita consumption during the 2005 household survey conducted by INSTAT. Even if the data are not perfectly accurate, they are actually the most reliable available data on rice consumption in Madagascar. This household survey shows that on average, rice consumption differs across regions and between urban and rural areas. Therefore, to obtain total consumption by region, we added urban and rural consumption for each region. To obtain urban and rural consumption for each region, we multiplied the per capita consumption for urban and rural areas by the urban and rural population, respectively. For production, the Ministry of Agriculture estimates production per region every year.

[9] The surplus status of the region could be partly explained by the fact that the population consumes less rice than other regions in the central part of the country. Rice consumption per capita averages only 87.6 kg per year and 77 kg per year in urban and rural areas, respectively. Low consumption is compensated by the high consumption of potato, which the region produces abundantly (Ministry of Agriculture, 2005).

that elapsed since the last main harvest using information on the main harvest month for each region (presented in **Appendix Table A2**). For example, if the main harvest season (defined by month) is during April and May, then the value of this variable for the first week of June is 1, the second week is 2, the last week of December is 31, and the first week of January is 32. The end of the counting is 43, for the last week of March. This variable is defined only for weeks during non-main harvest months.

3. Description of the flows

In this section, we document the flow of rice in Madagascar. We present facts on rice flow across regions and seasons.

3.1. Observations

Our basic unit of observation is the combination of origin–destination–week–variety. With 22 regions, 52 weeks, and three rice varieties, the maximum number of observations is 75,504 (including intra-region flows).

Out of 75,504 possible observations, 2,428 flows (3.1%) actually occurred during the observation period. **Table 1** shows the composition of the flow by variety, origin, and market (destination). As for variety, 1,398 observations out of 2,428 (57.6%) are *vary gasy*, 649 (26.7%) are *tsipala*, and 381 (15.7%) are *makalioka*. Regarding regions of origin, Alaotra Mangoro by far represents the largest number of observations for origin of the flow, which accounts for 16.8% of the total observations, followed by Sofia and Bongolava with 8.4% and 7.6%, respectively. Whereas Alaotra Mangoro is the main producer of *makalioka*, Sofia and Bongolava are large producers of *tsipala* rice. Regarding market (destination) regions, Analamanga, Vakinankaratra, and Vatovavy Fitovinany are the regions in which rice flowed in and represent 10%, 9%, and 7% of the total observations, respectively. These three regions are the first, second, and fifth largest regions in term of population, respectively.

Figure 2 shows the number of observations by week and rice variety. Rice transactions are implemented throughout the year at almost equal frequency. The pattern is similar for the three rice varieties.

== Table 1 Number of flows ==

== Figure 2 Number of flow-ins by week and rice variety ==

3.2. Regional flow

The regional flow of rice by variety is presented in a matrix from **Tables 2** to **4**. The rows are the “origins” and indicate the producing regions in which rice flows out, whereas the columns are the “destinations” indicating the consuming markets in which rice flows. As previously discussed, two types of flow exist that are based on the regional origin of rice sold in one market. Inter-regional flow is defined as trade across regions, whereas intra-regional flow is defined as trade within a region. The number in each cell indicates the frequency of the flow within the 52-week observations. Some flows occur throughout the period and some do not. For the purposes of this paper, we also differentiate the flows according to their frequency: permanent and seasonal. A flow is called “permanent” if it occurs for more than 28 weeks (inclusive) during the 52 weeks, and the cell is colored in dark gray. A flow is “seasonal” if it occurs for less than 28 weeks, and the cell is colored in tint gray. Flows shorter than four weeks are apparently only temporary and are not considered as established flow.

Flow of vary gasy

Table 2 reports the flow of *vary gasy* during a one-year period. In 18 of the 22 regions, we observe permanent intra-regional flows as shown by the diagonal line, except in four destination regions: Analamanga, Atsinanana, Androy, and Boeny. Analamanga, Atsinanana, and Androy are all rice-deficit regions and have permanent inter-regional trade with the neighboring regions of Itasy and Bongolava, Alaotra Mangoro, and Anosy, respectively. Boeny is a major producing region of *tsipala* in which domestic production and consumption of *vary gasy* does not seem to be active. Additionally, twenty inter-regional flows are mostly seasonal.

== Table 2 Flow of *vary gasy* ==

Flow of tsipala

Table 3 reports the flow of *tsipala*, which has 11 intra- and 12 inter-regional flows. For the latter, only two flows (17%) are permanent and the rest are seasonal. In contrast, for the former, 7 of the 11 intra-regional flows are permanent (64%) and four are seasonal (36%). The 7 permanent intra-regional flows are all found in rice-surplus regions. 5 of these 7 surplus markets also import *tsipala* from other producing regions, primarily Boeny and Sofia. In Sofia, the frequency of intra-regional flows was even lower than that of inter-regional flows. Therefore, rice (*tsipala*) produced in this region is primarily sold to other regions instead of within the region. Four of the 12 inter-regional flows of *tsipala* originate from this region.

== Table 3 Flow of *tsipala* ==

Flow of makalioka

Table 4 reports the flow of *makalioka*. Producing regions of this variety are limited and primarily concentrated on Alaotra Mangoro. Thus, 10 out of the 12 flows recorded are inter-regional (83%)

and mainly export from Alaotra Mangoro. Half of these inter-regional flows are permanent. These results indicate that *makalioka* is a variety for which inter-regional flows are dominant.

== Table 4 Flow of *makalioka* ==

Visual presentation of inter-regional flow

In **Appendix Figures A1 to A3**, we visually present the inter-regional flows for each rice variety that has either permanent or seasonal links and that is constructed from **Tables 2** to **4**. Clearly, greater flows occur between a pair of neighboring regions than between distant market–origin pairs. Flows between neighboring regions represent 70% (14 out of 20), 63% (7 out of 11), and 60% (6 out of 10) of inter-regional flows for *vary gasy*, *tsipala*, and *makalioka*, respectively.

Figures A1 to A3 also indicate that most of the inter-regional flows occur on the paved national roads.[10] Sixteen out of 20 inter-regional flows and 10 out of 12 flows occur on paved roads for *vary gasy* and *tsipala*, respectively. As for *makalioka*, all inter-regional flows generally occur on paved national roads.

3.3. Seasonality of flow

Figure 3 indicates the number of regions experiencing flow-ins by type of flow (i.e., inter- and intra-regional) for each of the rice varieties during the 52-week period. The unit of observation is the market (N = 22) for each variety-week. Figure 3 indicates that most of the regions self-support (intra-regional flow) *vary gasy*. For *tsipala*, approximately half (10 regions) are self-supporting. For *makalioka*, very few regions are able to self-support, and inter-regional flow is clearly dominant because this variety is only produced in certain regions.

However, occurrence of inter-regional flow increases during the off-harvest season. The number of regions with flow-ins from other regions increases between October and January and between September and January for *vary gasy* and *tsipala*, respectively. This finding suggests that as *vary gasy* and *tsipala* are primarily traded within their regions of production, inter-regional trade increases when locally produced rice is less available in the market during the off-harvest season. The inter-regional flow of *makalioka*, although quite stable throughout the year, also slightly increases during the off-harvest season.

---

[10] Paved roads are scarce in Madagascar. Not all national roads are paved. The main national roads that are paved connect the regional capital to the following regions: #1: Analamanga–Itasy–Bongolava; #2 and #44: Analamanga–Alaotra-Mangoro–Atsinanana; #4: Analamanga–Betsiboka–Boeny; #5: Atsinanana–Analanjirofo; #6: Boeny–Sofia–Diana; #7: Analamanga–Vakinankaratra–Amoron'Imania–Haute-Matsiatra–Ihorombe–Atsimo Andrefana; #12 and #45: Haute-Matsiatra–Vatovavy Fitovinany–Atsimo Atsinanana; #34 and #35: Vakinankaratra–Menabe.

== Figure 3 Number of regions with flow-ins by type of flow ==

In summary, flow can be intra- or inter-regional and permanent or seasonal. For the two varieties of *vary gasy* and *tsipala*, permanent intra-regional flow is dominant and inter-regional flow is primarily seasonal. However, *makalioka* has more inter-regional flows than intra-regional flows because the producing regions are limited. Transportation costs may matter, and inter-regional trade apparently occurs when market and origin are adjacent. Regarding seasonality, inter-regional flow apparently increases slightly during the off-harvest season. In the next section, we conduct a more detailed analysis on the relevance of these findings.

4. Accounting for the pattern of rice flow

This section attempts to account for the observed pattern of inter-regional rice flow presented in the previous section. Our prediction is that rice flow is affected by each region's rice sufficiency and proximity between the regions. We first examine the binary relation between rice flow and these factors, and then proceed to multivariate regression analysis.

4.1. Bivariate analysis

Rice sufficiency, proximity, and seasonality

Table 5 reports the bivariate relation between rice flow and each factor. We report the percentage of observations of flow-ins using (1) the market's rice sufficiency status (deficit vs. surplus); (2) market–origin proximity (adjacent vs. non-adjacent); and (3) the market's seasonality (dry vs. rainy season, and off-harvest vs. harvest season). The *p*-values of the Welch's *t*-tests for the mean differences are also reported.

== Table 5 Bivariate relations of flow-ins and potential factors ==

First, rice deficit markets (regions) tend to experience flow-ins more frequently than surplus regions. The unit of observation is the market (N = 22). The percentage of regions experiencing (at least one) flow-ins during the observation period does not differ substantially between surplus and deficit regions; most markets import rice from other regions, regardless of rice sufficiency. However, the mean number of weeks experiencing flow-ins for any variety (max = 52 weeks) is almost twice as high for deficit markets as surplus markets (30.6 weeks vs. 15.9 weeks, p = 0.125).

Second, flow-ins are more common between adjacent market–origin pairs than non-adjacent pairs. The unit of observation is directed market–origin pairs excluding intra-regional trade ($\square = 22 \times 21 = 462$). The percentage experiencing flow-ins is 4.5 times higher for adjacent pairs than for non-adjacent pairs (26.0% vs. 5.8%, p < 0.000; any variety) and the mean number of weeks with flow-in is larger for adjacent pairs (6.3 weeks vs. 0.6 weeks, p < 0.000; any variety). The mean-adjusted lowess smoother of flow-ins on road distance (km) depicted in **Figure 4** supplements this observation. Figure 4 indicates that the probability of flow-ins diminishes with road distance between market and origin and converges to almost zero when the regions are more than 1,500 km apart.

== Figure 4 Mean adjusted lowess smoother of flow-ins on road distance ==

Third, we find no evidence that the rainy season reduces flow-ins. The percentages of market–week observations ($N = 22 \times 52 = 1{,}144$) for the dry season and the rainy season are almost equivalent (43.1% vs. 43.9%, p = 0.774; any variety).

Fourth, we find indicative signs that the occurrence of flow-ins is higher for the off-harvest season than the harvest season (46.3% vs. 35.3%, p = 0.001; N = 1,144; any variety). However, this tendency is not as apparent in a breakdown based on variety.

Weeks elapsed since the last main harvest

Because the extent of regions' self-sufficiency of rice changes over time, another prediction is that the prevalence of rice flow-ins increases as time passes after the main harvest season. **Figure 5(a)** depicts the percentage of markets experiencing flow-ins for any variety on the basis of weeks elapsed since the end of the main harvest (defined for each market). The unit of observation is market–week (elapsed). We truncated the period at 45 weeks because only one market (Androy) has a longer elapsed week (in fact, Androy does not have a main harvest season). Therefore, the final number of observation is 942. Figure 5(a) indicates that rice-deficit regions have higher percentages of experiencing flow-ins throughout the year than surplus regions. For rice-deficit regions, the percentages increase from 40% to 60% by the third week, although the overall trend is rather stable. For rice-surplus regions, the percentage climbs steadily from 17% in the first week to 42% in the thirteenth week. However, the increasing pattern is not clear. **Figure 5(b)** depicts the percentage of flow-ins based on variety, which increases over the weeks that elapse for *tsipala*. However, again, the figure fails to indicate a clear, conclusive trend.

== Figure 5 Probability of flow-ins by week elapsed since the last main harvest ==

4.2. Regression analysis

Although the bivariate analyses are so far suggestive, we implemented multivariate regression analyses to better understand the factors associated with inter-regional flows, *ceteris paribus*.

Table 6 reports the estimation results from the logistic regression model based on equation (1).

The unit of observation is (directed) market–origin–week–variety (*N* = 72,072) and the effect size is reported as an odds ratio. The 95% confidence interval (CI) is calculated using robust standard errors clustered by (non-directed) market–origin pairs. Columns (1) to (4) use road distance (km) between origin *j* and market *i* as a measure of proximity of the two regions, whereas columns (5) to (6) use a dummy indicating that two regions are adjacent. For each specification, we first run a regression that pools all varieties (columns (1) and (5)) and then a separate regression for each variety.

== Table 6 Estimates of logistic regression of flow-ins from origin *j* to market *i* ==

Table 6 indicates several statistical patterns. First, regarding rice sufficiency and consistent with expectations, rice-deficient regions tend to import rice: the odds ratio of the surplus market dummy is 0.348 (95% CI: 0.153–0.792) when pooling all varieties (column (1)). This result implies that surplus regions are 65% less likely to import rice than deficit regions, an observation that is reversed for *tsipala* (columns (3) and (7)), indicating that surplus regions are more likely to import *tsipala* than deficit regions (although the 95% CI is rather wide and crosses unity). The probability of flow-ins is also high when the origin is a surplus region. The odds ratio of the surplus origin dummy is 4.298 (95% CI: 1.571–11.76) in column (1): the probability of importing from the surplus origin is 4.3 times higher than importing from the deficit origin.

Second, on proximity between origin and destination, we find that trades occur between proximate regions: column (1) indicates that the odds ratio of road distance (100 km) is 0.701 (95% CI: 0.624–0.786), implying that an additional 100 km of road distance between two regions reduces the probability of flow-ins by 30%. Column (5) indicates that the odds ratio of adjacent regions is 12.12 (95% CI: 5.382–27.29), implying that the probability of importing rice from adjacent regions is 12.1 times higher than non-adjacent regions. These results hold true for the separate regression of each variety, although the magnitude differs.

Third, on seasonality, the results of the rainy season dummies are mixed and unstable. Although we expect that rainy seasons hamper the efficient physical spatial distribution of rice, the odds ratios are not consistently lower than one. However, the effects of the harvest season generally follow a logical pattern. Namely, the probability of flow-ins is lower when the market is in the harvest season, and is higher when the origins are in harvest season.

To investigate the detailed seasonal pattern, **Figure 6** indicates the average predicted probability of flow-ins for each week by market rice sufficiency status based on the estimates in **Table 6**, columns (6)–(8). The most active season differs between varieties. Whereas the probability of flow-ins is constant for *vary gasy*, an increase is observed between the periods of November to March and September to October for *tsipala* and *makalioka*, respectively.

Fourth and finally, flows of *tsipala* and *makalioka* are less smooth than those of *vary gasy*. The odds ratio of the *tsipala* dummy in column (1) is 0.455 (95% CI: 0.219–0.945) and that for *makalioka* is 0.623 (95% CI: 0.282–1.378). Thus, the probability of flow-ins for *tsipala* and *makalioka* is 54% and 38% lower than for *vary gasy*, respectively.

Weeks elapsed since the main harvest

To examine the possibility that rice flow-ins may increase as time elapses since the main harvest, we estimated the same regression as **Table 6** with an additional variable for week elapsed since the last main harvest. Because this variable is defined only for the off-main harvest season, we limit our observation to weeks in the off-main harvest season. The results are reported in **Table 7**. Although we expected that the probability of flow-ins increases with elapsed week since the main harvest, the results indicate no clear support for such a prediction. We also predicted that such an effect should be stronger for rice-deficit regions and therefore, the interaction term of week elapsed and surplus-market dummy is smaller than unity. Again, no clear sign indicates that the effect is magnified by rice deficiency.

== Table 7 Estimates of logistic regression of flow-ins from origin *j* to market *i* with weeks elapsed since the main harvest ==

Figure 7 visually presents the relation between flow-ins and weeks elapsed since the last main harvest by depicting the average predicted probability of flow-ins over the market's rice sufficiency using the estimates in **Table 7**, columns (6)–(8). For *vary gasy*, we observe a mild increasing trend with higher average predicted probability of flow-ins for deficit markets, which is consistent with the prediction. However, *tsipala* shows a reverse pattern: the probability decreases by week elapsed for *deficit* regions and increases for *surplus* regions. *Makalioka* also shows a declining trend; however, the level of predicted probability is higher for deficit regions.

== Figure 7 Average predicted probability of flow-ins by weeks elapsed since the main harvest ==

4.3. Discussion

To summarize, we confirmed the following stylized facts about rice flow in Madagascar. First, deficit markets tend to import rice and experience flow-ins more frequently than surplus regions. Surplus regions are less likely to import rice than deficit regions. Second, distance has a strong negative association with inter-regional flow. For example, the percentage of experiencing flow-ins is 4.5 times higher for adjacent market–origin pairs than non-adjacent pairs. Third, in terms of seasonality, we found no evidence that indicates that the rainy season decreases the occurrence of flow, which is almost equivalent for any variety during the dry season and the rainy season. Fourth, the occurrence of flow-ins is higher for the off-harvest season than the harvest season, although the estimates of the regression analysis were not statistically significant. Fifth, we found no evidence that flow-ins become more active as time elapses after the main harvest.

Many of these findings are consistent with the rational thought that flows are directed toward deficit regions and that physical trade is easier and cheaper between proximate regions. The first finding implies that rice flows from surplus to deficit regions, a natural pattern of trade flow. The second finding on proximity is consistent with the common sense notion that when trade exists, trading between proximate regions is easier and more inexpensive given transportation and transaction costs.

Some findings simultaneously appear counterintuitive. First, although we expected a decrease of flow during the rainy season, we find no evidence whether the rainy season affects inter-regional flow. Possible reasons for this unexpected finding are as follows. First, regarding weather patterns, the general belief is that the rainy season hampers physical distribution because of its detrimental effect on the road infrastructure. However, most roads connecting regional capitals to other regional capitals are now paved and thus more weather resistant. As discussed in Section 3.2, most inter-regional flows occur on paved roads. If this study's scope included data at the district level, the results would likely show that weather has a significant negative effect on trade. Indeed, roads toward the main producing districts (e.g., in Alaotra-Mangoro, Boeny, and Sofia) are primarily unpaved and sometimes impassable during the rainy season. Nonetheless, produce is likely collected from the producing districts during the dry season and stored in the regional capitals that are easy to access. **Appendix Figures 1–3** also provide suggestive evidence that paved roads are important for inter-regional trade. Of the 22 regions, only two regions lack inter-regional flow: Melaky (#10) and Sava (#2). Melaky has no paved roads connecting the region with other regions, and thus, it may be isolated because of a poor infrastructure. In contrast, Sava is quite a large deficit region but not involved in inter-regional trade. This may be due to the fact that we collected the data in the region capital, Sambava, which is approximately two hours from the Andapa basin, a large rice producing district within the region. In fact, the Sava region seasonally imports rice from the Sofia region but these imports were not captured by our survey[11] (Fews Net, 2013).

Second, although we found that the probability of flow-ins in destination markets declines during the harvest season (as captured by the harvest season dummy), no clear and consistent evidence exists that the probability of flow-ins inclines as weeks elapse after the main harvest (**Table 7**). Our findings suggest that markets import rice relatively consistently across non-harvest seasons. One

[11] The fact that we failed to capture these imports may be a limitation of our study. Because the survey was conducted only in the regional capital, it may not capture all flows in the region, particularly when several large markets exist within the region, such as the *Sava* region.

possible reason for this occurrence is that deficit markets use their own production as a buffer to avoid food shortages during the lean season. In Madagascar, individual farmers and/or traders do not engage in public storage. Another possible reason is that they engage in imports during that period and set aside their own production for use during lean periods because the price of rice is inexpensive in surplus regions during the harvest season.

5. Conclusion

This paper offers the first comprehensive investigation of the physical flow of rice across regions in Madagascar using originally collected detailed nationwide weekly data that enable us to track the origin and destination regions of rice during a one-year period. We hope that this study contributes to providing insights into the future planning of transportation systems and agricultural policies in the country. This study may also be important in providing basic knowledge when addressing issues related to market structure and spatial integration. Without this information, one is limited when addressing the gaps that exist as part of a broader effort to develop an efficient rice market in Madagascar.

The analysis of flow of the three main local rice varieties shows that for the two varieties (*vary gasy* and *tsipala*) that represent 84% of the observations, rice is primarily traded within the region of production and inter-regional flow is only seasonal. For *makalioka*, which represents 16% of the observations, more inter-regional flows than intra-regional flows exist because the producing regions are limited.

The observed flow of rice in Madagascar is mostly consistent with the natural and common notion that commodity flows from surplus to deficit regions and between proximate regions. We confirm that rice-deficit regions import rice from rice-surplus regions during non-harvest seasons, in particular from adjacent origin regions. In contrast, we did not find that rice trade becomes inactive during the rainy season, which contradicts our common view that transportation during the rainy season in Madagascar is troublesome. This might be because the point locations of origin–destination are region capitals primarily connected by weather-resistant road infrastructure. We also find that although the probability of flow-ins declines during the harvest season (presumably because the local supply is sufficient), this probability does not increase steadily over time after the main harvest season (perhaps because deficit regions import consistently during non-harvest months).

We note some limitations in our findings and interpretations. The first limitation is the regional representativeness of our data. As discussed in Section 4.3, some inter-regional links possibly have been overlooked because they did not concern the flow within regions and the flows between district capitals. The second limitation is related to the number of samples per market. Although we randomly selected five retailers per market every week, this sample might not be sufficient to fully capture the reality of flow. Our data may not have captured some inter-regional flows, particularly in large markets. Furthermore, given the small number of sample retailers, although we collected information on the quantity of rice purchased, we were reluctant to estimate the quantity of flow – critical information for understanding the rice market in Madagascar. The third limitation is related to the effectiveness of the occurrence of trade. Rice observed in the market does not indicate that the produce was just shipped from the producing regions. The produce might have been stored by a wholesaler for some time, thus biasing the assumption that inter-regional flow provides a market outlet for producers.

The results of this study enabled the identification of potential information gaps that need to be addressed. One area to be further explored is the production and marketing capacity of producers to supply markets and enabling them to take advantage of a high price in deficit regions. Another area of future research could focus on the current inter-regional flows and whether they are or are not optimal. This information is possibly useful in maximizing benefits for consumers, who are frequently the most vulnerable entity.

References

Arimoto, Y., Sakurai, M., Tanaka, M., Ralandison, T. (2011) "Rice Trading in Madagascar: Report on Rice Trader Survey", PRIMCED Discussion Paper Series, No. 38, Hitotsubashi University, Japan.

Butler, J. S., and Moser, Christine (2010) "Structural Model of Agricultural Markets in Developing Countries," *American Journal of Agricultural Economics*, 92(5):1364–1378.

Fews Net (2013) "Madagascar livelihood zone map and descriptions".

Ministry of Agriculture of Madagascar (2013) "2012 Agricultural statistics report"

Ministry of Agriculture of Madagascar (2005) "2004–2005 Agricultural census report"

Ministry of Agriculture of Madagascar (2003) "Series of monograph of the 22 regions in Madagascar" (in French)

Minten, Bart, and Dorosh, Paul. (2006) "Rice Markets in Madagascar in Disarray: Policy Options for Increased Efficiency and Price Stabilization." Africa Region Working Paper Series No. 101: IFPRI.

Miyake, Hajime, and Sakurai, Takeshi (2012) "Improvement of Transportation Infrastructure and Integration of Agricultural Market: An Analysis of Rice Market in Madagascar," *Economic Research (Keizai Kenkyu)*, 63(3): 209–226. (in Japanese)

Moser, C., Barrett, C., Minten, B. (2009) "Spatial integration at multiple scales: rice markets in Madagascar," *Agricultural Economics*, 40(3):281–294.

National Statistics Institute (INSTAT) (2010) "2010 Household survey report" (in French)

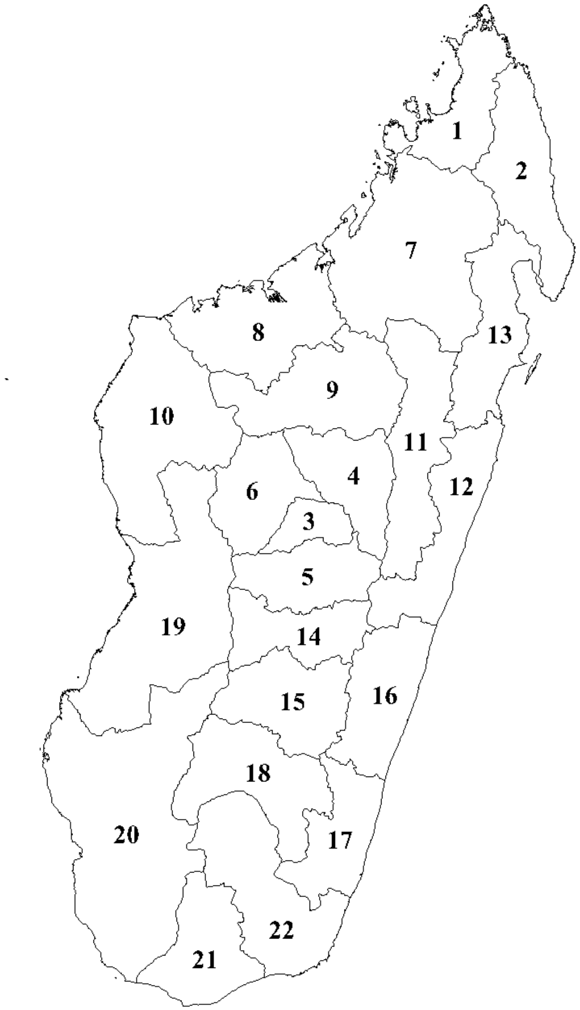
National Statistics Institute (INSTAT) (2005) "2005 Household survey report" (in French)

Ralandison, T., Arimoto, Y., Tanaka, M., Sakurai, T. (2014) “Mode of matching buyers and sellers as a determinant of efficiency in the Madagascar rice markets”, *Journal of Rural Economics*, 16:97–104.

Sakurai, Takeshi and Arimoto, Yutaka (2014) “Characterization of rice market in Madagascar: focusing on price and quality relationship” in *An Evidence-Based Study of the Innovative Anti-Poverty Practices and Market Institution (Interim Report)*, ed. Kazushi Takahashi. Chiba: IDE-JETRO.

Figures

Figure 1 Regions of Madagascar



Code	Region name	Region capital
1	DIANA	ANTSIRANANA I
2	SAVA	SAMBAVA
3	ITASY	MIARINARIVO
4	ANALAMANGA	ANTANANARIVO RENIVOHITRA
5	VAKINANKARATRA	ANTSIRABE I
6	BONGOLAVA	TSIROANOMANDIDY
7	SOFIA	ANTSOHIHY
8	BOENY	MAHAJANGA I
9	BETSIBOKA	MAEVATANANA
10	MELAKY	MAINTIRANO
11	ALAOTRA MANGORO	AMBATONDRAZAKA
12	ATSINANANA	TOAMASINA I
13	ANALANJIROFO	FENOARIVO ATSINANANA
14	AMORON' I MANIA	AMBOSITRA
15	HAUTE MAHATSIATRA	FIANARANTSOA I
16	VATOVAVY FITOVINANY	MANAKARA
17	ATSIMO ATSINANANA	FARAFANGANA
18	IHOROMBE	IHOSY
19	MENABE	MORONDAVA
20	ATSIMO ANDREFANA	TOLIARA I
21	ANDROY	AMBOVOMBE
22	ANOSY	TAOLAGNARO

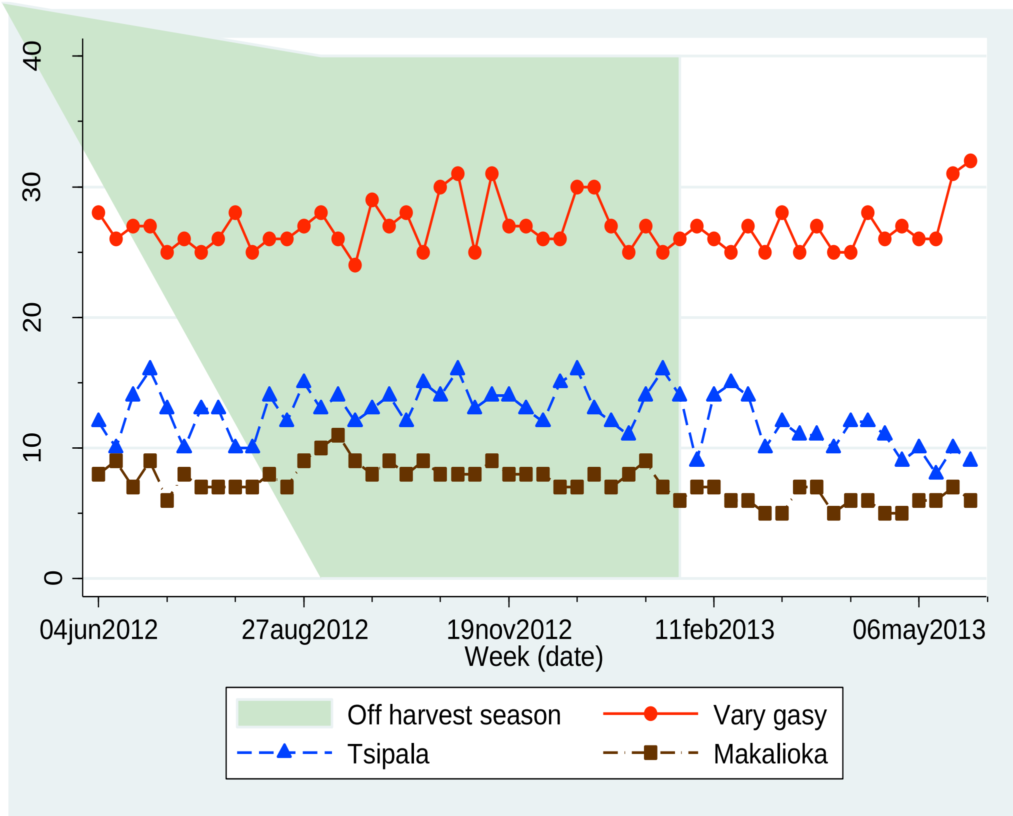


Figure 2 Number of flow-ins by week and rice variety

Note: Figure 2 depicts the number of observed flow-ins. Intra-regional flows are included. Unit of observation is market–origin–week–variety (*N* = 75,504).

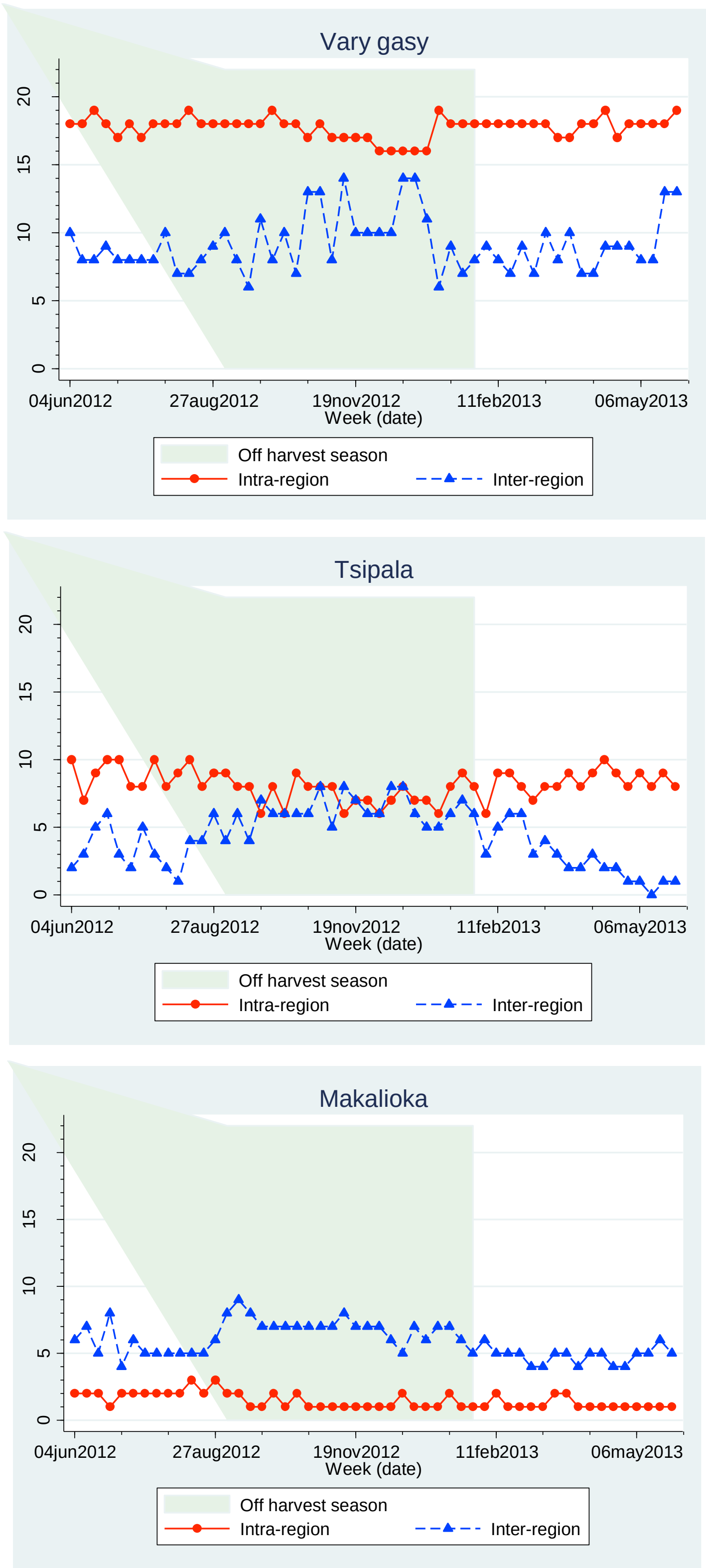


Figure 3 Number of regions with flow-ins by type of flow

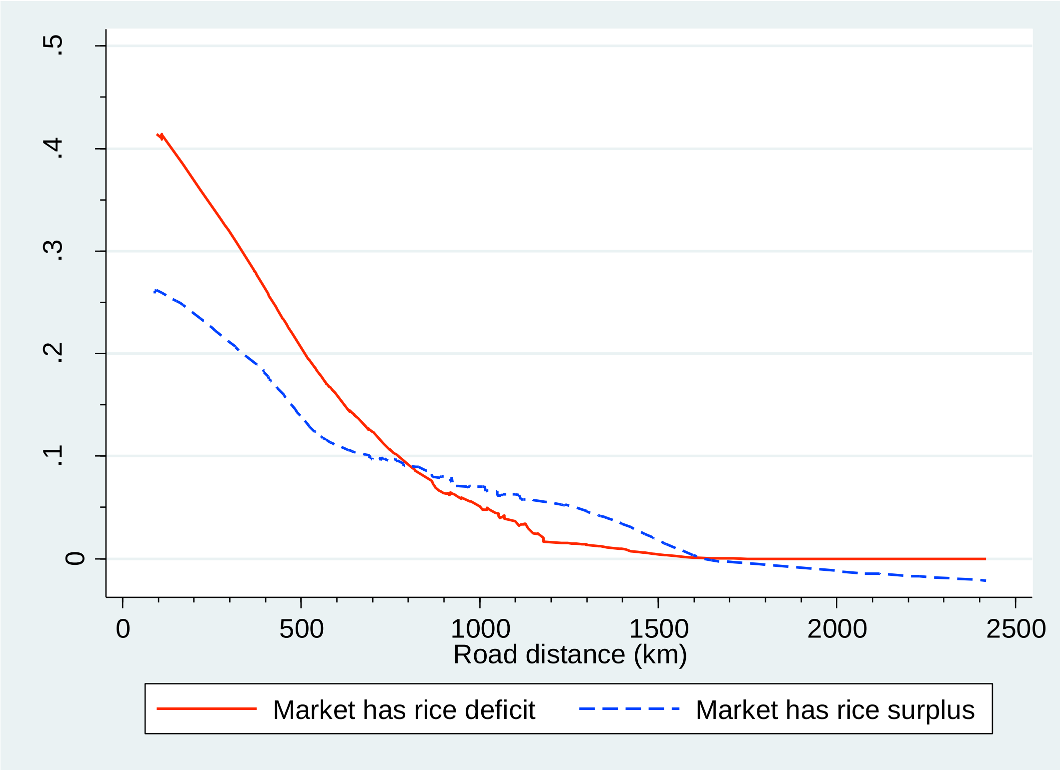
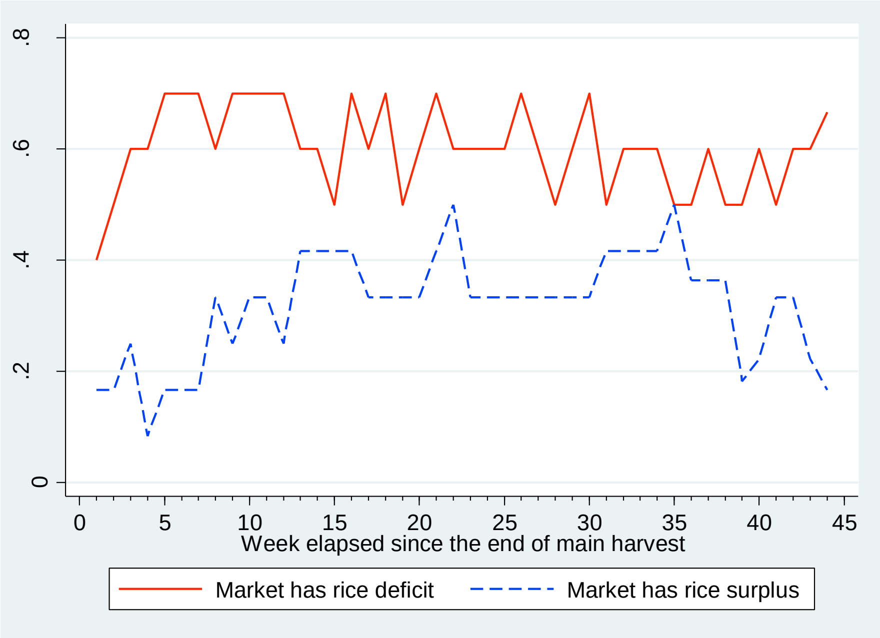
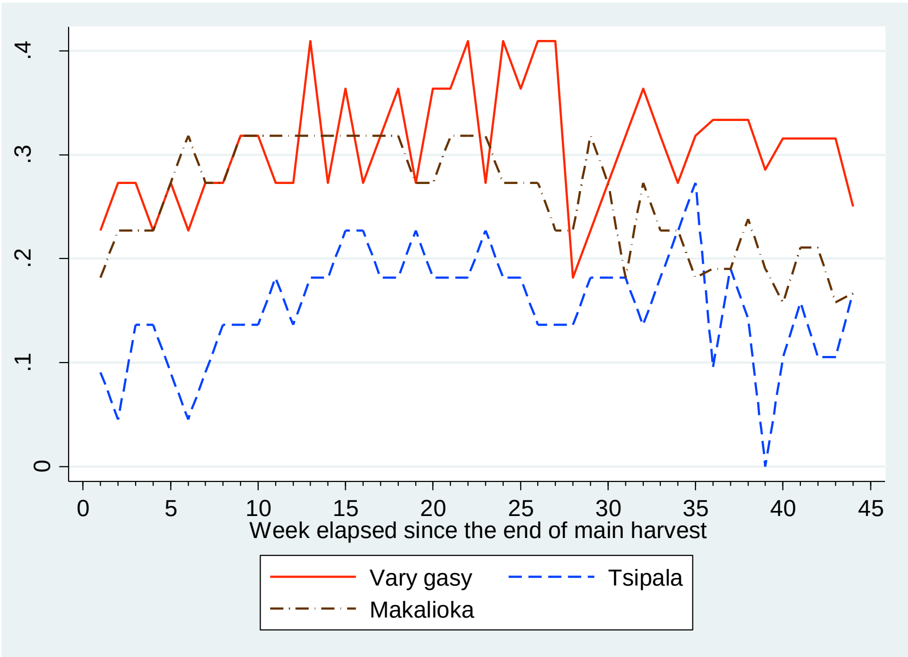


Figure 4 Mean adjusted lowess smoother of flow-ins on road distance

Note: The unit of observation is directed market–origin pairs (excluding intra-regional flow) (N = 22 × 21 = 462).



(a) By market's rice sufficiency (any variety)



(a) By variety

Figure 5 Probability of flow-ins by week elapsed since the last main harvest

Note: The unit of observation is market–week (elapsed). Eight observations with elapsed weeks higher than 45 are truncated given single observations. The remaining total number of observations is 942.

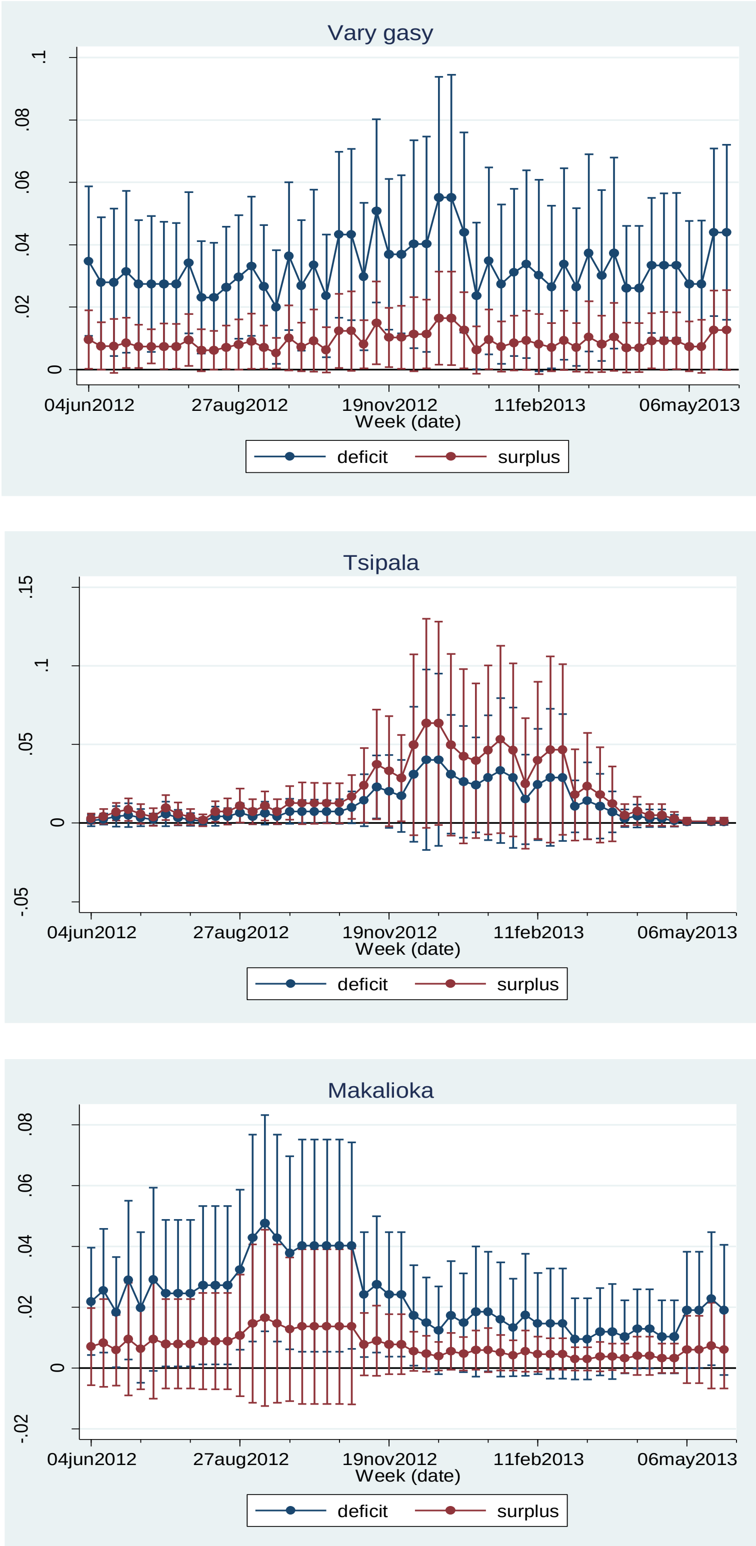


Figure 6 Average predicted probability of flow-ins by weeks

Note: Prediction is based on estimates in Table 6, columns (6)–(8). Prediction is calculated over market's rice-sufficiency status (deficit or surplus).

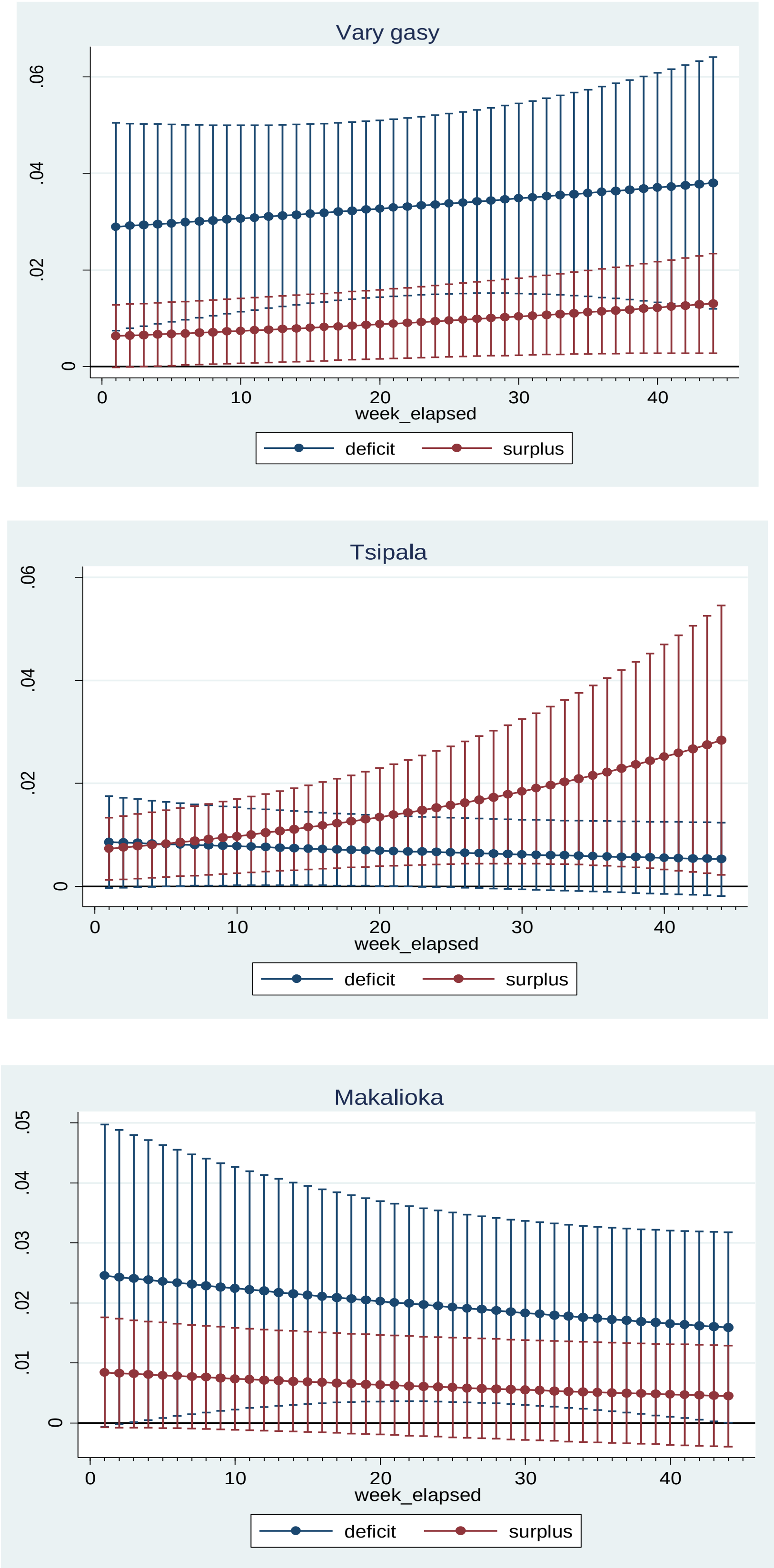


Figure 7 Average predicted probability of flow-ins by weeks elapsed since the main harvest

Note: Prediction is based on estimates in Table 7 columns (6)–(8). Prediction is calculated over market's rice-sufficiency status (deficit or surplus).

Tables

Table 1 Number of flows

	As origin of production					As market (region of production)				
	Vary gasy	Tsipala	Makalioka	Total	%	Vary gasy	Tsipala	Makalioka	Total	%
Analamanga	6	1	0	7	*0.3%*	111	69	54	234	*9.6%*
Vakinankaratra	55	50	1	106	*4.4%*	104	53	53	210	*8.6%*
Itasy	109	35	2	146	*6.0%*	53	28	0	81	*3.3%*
Bongolava	100	82	3	185	*7.6%*	52	52	3	107	*4.4%*
Haute Mahatsiatra	116	25	10	151	*6.2%*	58	57	26	141	*5.8%*
Amoron'I Mania	51	41	0	92	*3.8%*	78	71	0	149	*6.1%*
Vatovavy Fitovinany	47	0	1	48	*2.0%*	113	3	50	166	*6.8%*
Ihorombe	104	22	54	180	*7.4%*	53	3	0	56	*2.3%*
Atsimo Atsinanana	52	1	2	55	*2.3%*	64	2	51	117	*4.8%*
Atsinanana	2	0	0	2	*0.1%*	62	0	52	114	*4.7%*
Analanjirofo	61	0	0	61	*2.5%*	53	0	16	69	*2.8%*
Alaotra Mangoro	116	3	289	408	*16.8%*	44	0	52	96	*4.0%*
Boeny	15	100	0	115	*4.9%*	1	68	0	69	*2.8%*
Sofia	104	99	2	205	*8.4%*	57	8	0	65	*2.7%*
Betsiboka	46	21	0	67	*2.8%*	60	84	0	144	*5.9%*
Melaky	53	0	0	53	*2.2%*	51	0	0	51	*2.1%*
Atsimo Andrefana	54	52	16	122	*5.0%*	63	60	22	145	*6.0%*
Androy	2	0	0	2	*0.1%*	79	0	0	79	*3.3%*
Anosy	94	68	0	162	*6.7%*	52	52	0	104	*4.3%*
Menabe	106	49	1	156	*6.4%*	54	39	0	93	*3.8%*
Diana	52	0	0	52	*2.1%*	84	0	2	86	*3.5%*
Sava	53	0	0	53	*2.2%*	52	0	0	52	*2.1%*
Total	1,398	649	381	2,428	*100.0%*	1,398	649	381	2,428	*100.0%*
	57.6%	*26.7%*	*15.7%*	*100.0%*		*57.6%*	*26.7%*	*15.7%*	*100.0%*	

Note: The unit of observation is market–origin–week–variety (□ $= 22 \times 22 \times 52 \times 3 = 75{,}504$). Intra-regional flows are included.

Table 2 Flow of *vary gasy*

Origin \ Destination	Analamanga	Vakinankaratra	Itasy	Bongolava	Haute Matsiatra	Amoron'I Mania	Vatovavy Fitovinany	Ihorombe	Atsimo Atsinanana	Atsinanana	Analanjirofo	Alaotra Mangoro	Boeny	Sofia	Betsiboka	Melaky	Atsimo Andrefana	Androy	Anosy	Menabe	Diana	Sava
Analamanga	3														3							
Vakinankaratra	1	**52**			2																	
Itasy	**52**		**52**											**5**								
Bongolava	**38**		1	**52**		**9**																
Haute Matsiatra		3			**52**		**50**		**8**									3				
Amoron'I Mania						**51**																
Vatovavy Fitovinany							**47**															
Ihorombe							**13**	**52**	**4**								**4**	**31**				
Atsimo Atsinanana									**52**													
Atsinanana										2												
Analanjirofo										**9**	**52**											
Alaotra Mangoro	**14**	2				1	3			**51**	1	**44**										
Boeny	2				2	**8**									3							
Sofia	1				2	**9**							1	**52**	**8**						**31**	
Betsiboka															**46**							
Melaky																**51**				2		
Atsimo Andrefana																	**52**	2				
Androy																		2				
Anosy								1										**41**	**52**			
Menabe		**47**															**7**			**52**		
Diana																					**52**	
Sava																					1	**52**

Unit of obs.: market–origin–week (max: 22 x 22 x 52)

Table 3 Flow of *tsipala*

Origin \ Destination	Analamanga	Vakinankaratra	Itasy	Bongolava	Haute Matsiatra	Amoron'I Mania	Vatovavy Fitovinany	Ihorombe	Atsimo Atsinanana	Atsinanana	Analanjirofo	Alaotra Mangoro	Boeny	Sofia	Betsiboka	Melaky	Atsimo Andrefana	Androy	Anosy	Menabe	Diana	Sava
Analamanga							1															
Vakinankaratra		50																				
Itasy	9		26																			
Bongolava	29		1	52																		
Haute Matsiatra					25																	
Amoron'I Mania						41																
Vatovavy Fitovinany																						
Ihorombe					16		2	3	1													
Atsimo Atsinanana									1													
Atsinanana																						
Analanjirofo																						
Alaotra Mangoro	2	1																				
Boeny	6					9							52		33							
Sofia	23		1			21							16	8	30							
Betsiboka															21							
Melaky																						
Atsimo Andrefana																	52					
Androy																						
Anosy					16														52			
Menabe		2															8			39		
Diana																						
Sava																						

Unit of obs.: market–origin–week (max: 22 x 22 x 52)

Table 4 Flow of *makalioka*

Origin \ Destination	Analamanga	Vakinankaratra	Itasy	Bongolava	Haute Matsiatra	Amoron'I Mania	Vatovavy Fitovinany	Ihorombe	Atsimo Atsinanana	Atsinanana	Analanjirofo	Alaotra Mangoro	Boeny	Sofia	Betsiboka	Melaky	Atsimo Andrefana	Androy	Anosy	Menabe	Diana	Sava
Analamanga																						
Vakinankaratra		1																				
Itasy	2																					
Bongolava				3																		
Haute Matsiatra							9		1													
Amoron'I Mania																						
Vatovavy Fitovinany							1															
Ihorombe							7		47													
Atsimo Atsinanana									2													
Atsinanana																						
Analanjirofo																						
Alaotra Mangoro	52	52			26		33		1	52	16	52					5					
Boeny																						
Sofia																					2	
Betsiboka																						
Melaky																						
Atsimo Andrefana																	16					
Androy																						
Anosy																						
Menabe																	1					
Diana																						
Sava																						

Unit of obs.: market–origin–week (max: 22 x 22 x 52)

Table 5 Bivariate relations of flow-ins and potential factors

Market' rice sufficiency (unit of obs. = market; *N* =22)				
	Deficit (*n* =10)	Surplus (*n* =12)	Difference	*p* -value
Percentage of observations with flow-in				
Any variety	80.0%	75.0%	5.0%	0.791
Vary gasy	80.0%	75.0%	5.0%	0.791
Tsipala	30.0%	58.3%	-28.3%	0.198
Makalioka	60.0%	25.0%	35.0%	0.110
Number of weeks with flow-in (max=52)				
Any variety	30.6	15.9	14.7	0.125
Vary gasy	25.0	8.2	16.8	0.072
Tsipala	5.0	9.4	-4.4	0.456
Makalioka	20.9	7.0	13.9	0.135

Origin is adjacent (unit of obs. = market-origin, *N* =462)				
	Not adjacent (*n* =362)	Adjacent (*n* =100)	Difference	*p* -value
Percentage of observations with flow-in				
Any variety	5.8%	26.0%	-20.2%	**0.000**
Vary gasy	4.1%	25.0%	-20.9%	**0.000**
Tsipala	2.2%	12.0%	-9.8%	**0.004**
Makalioka	1.4%	10.0%	-8.6%	**0.006**
Number of weeks with flow-in (max=52)				
Any variety	0.6	6.3	-5.7	**0.000**
Vary gasy	0.3	3.8	-3.6	**0.003**
Tsipala	0.2	1.5	-1.3	**0.033**
Makalioka	0.2	2.3	-2.1	**0.038**

Market is rainy season (unit of obs. = market-week; *N* =1,144)				
	Dry (*n* =650)	Rainy (*n* =494)	Difference	*p* -value
Percentage of observations with flow-in				
Any variety	43.1%	43.9%	-0.9%	0.774
Vary gasy	30.8%	30.0%	0.8%	0.768
Tsipala	14.2%	14.4%	-0.2%	0.917
Makalioka	26.5%	24.5%	2.0%	0.449

Market is harvest season (unit of obs. = market-week; N=1,144)				
	Off-harvest (*n* =849)	Harvest (*n* =295)	Difference	*p* -value
Percentage of observations with flow-in				
Any variety	46.3%	35.3%	11.0%	**0.001**
Vary gasy	31.4%	27.5%	4.0%	0.192
Tsipala	16.3%	8.5%	7.8%	**0.000**
Makalioka	24.9%	27.8%	-2.9%	0.328

Note: *p*-values of Welch's two sample *t*-test on the equality of means are reported. Those lower than 5% are emphasized in bold letters.

Table 6 Estimates of logistic regression of flow-ins from origin *j* to market *i*

Dep. var.= dummy if flow-in (Odds ratio)	All varieties (1)	Vary gasy (2)	Tsipala (3)	Makalioka (4)	All varieties (5)	Vary gasy (6)	Tsipala (7)	Makalioka (8)
Market *i* has surplus (dummy)	0.348*	0.178**	1.542	0.254	0.360*	0.195**	1.626	0.250
	[0.153,0.792]	[0.0542,0.585]	[0.444,5.360]	[0.0485,1.326]	[0.159,0.812]	[0.0654,0.579]	[0.469,5.632]	[0.0468,1.332]
Origin *j* has surplus (dummy)	4.298**	4.655*	8.555*	3.156	4.114**	4.002*	8.621*	3.103
	[1.571,11.76]	[1.368,15.84]	[1.642,44.58]	[0.430,23.14]	[1.478,11.45]	[1.200,13.35]	[1.621,45.85]	[0.394,24.41]
Distance between *i*-*j* (100 km)	0.701***	0.615***	0.766**	0.754***				
	[0.624,0.786]	[0.509,0.742]	[0.632,0.927]	[0.648,0.877]				
Regions *i*-*j* is adjacent (dummy)					12.12***	18.00***	5.870**	13.03**
					[5.382,27.29]	[6.509,49.75]	[1.754,19.65]	[2.781,61.09]
Market *i* is rainy season (dummy)	1.193	1.688*	0.495	1.233	0.958	1.250	0.481	0.927
	[0.773,1.840]	[1.029,2.768]	[0.208,1.182]	[0.606,2.510]	[0.637,1.442]	[0.761,2.051]	[0.217,1.065]	[0.452,1.903]
Origin *j* is rainy season (dummy)	1.063	0.721	0.459	3.292*	0.934	0.698	0.438	2.247
	[0.557,2.029]	[0.328,1.585]	[0.191,1.104]	[1.238,8.755]	[0.527,1.656]	[0.337,1.449]	[0.189,1.016]	[0.857,5.890]
Market *i* is harvest season (dummy)	0.874	0.739	0.733	1.343	0.903	0.803	0.724	1.357
	[0.654,1.167]	[0.450,1.212]	[0.417,1.288]	[0.983,1.836]	[0.667,1.224]	[0.487,1.323]	[0.411,1.276]	[0.969,1.900]
Origin *j* is harvest season (dummy)	1.617**	1.248	2.751**	1.668**	1.469**	1.169	2.457**	1.457*
	[1.186,2.205]	[0.759,2.052]	[1.503,5.038]	[1.180,2.358]	[1.118,1.929]	[0.784,1.744]	[1.408,4.286]	[1.043,2.035]
Variety (Reference: Vary gasy)								
Tsipala	0.455*				0.454*			
	[0.219,0.945]				[0.218,0.945]			
Makalioka	0.623				0.622			
	[0.282,1.378]				[0.281,1.376]			
N	72072	24024	23562	24024	72072	24024	23562	24024
pseudo R-sq	0.197	0.285	0.172	0.165	0.198	0.256	0.165	0.202
Log likelihood	-4263.9	-1670.8	-1059.0	-1369.2	-4259.6	-1738.5	-1068.5	-1308.6

Note: The unit of observation is (directed) market–origin–week–variety (*N*=72,072). Intra-regional flows are excluded. Effect sizes are reported in the odds ratio. The 95% confidence interval is reported in brackets using robust standard errors clustered by (non-directed) market–origin pairs. Week fixed-effects are included but are not reported. Samples are omitted in some specifications given perfect predictions. * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 7 Estimates of logistic regression of flow-ins from origin *j* to market *i* with weeks elapsed since the main harvest

Dep. var.= dummy if flow-in (Odds ratio)	All varieties (1)	Vary gasy (2)	Tsipala (3)	Makalioka (4)	All varieties (5)	Vary gasy (6)	Tsipala (7)	Makalioka (8)
Market *i* has surplus (dummy)	0.292**	0.139**	0.751	0.291	0.287**	0.151**	0.712	0.272
	[0.117,0.728]	[0.0328,0.593]	[0.213,2.652]	[0.0651,1.301]	[0.113,0.725]	[0.0381,0.601]	[0.196,2.583]	[0.0565,1.312]
Origin *j* has surplus (dummy)	4.044**	4.462*	7.848*	2.895	3.873*	3.787*	7.884*	2.828
	[1.445,11.31]	[1.205,16.53]	[1.465,42.04]	[0.387,21.66]	[1.358,11.05]	[1.058,13.55]	[1.454,42.74]	[0.354,22.58]
Week elapased since main harvest	0.996	1.003	0.990	0.983	1.000	1.007	0.988	0.989
	[0.977,1.014]	[0.976,1.030]	[0.958,1.024]	[0.957,1.011]	[0.982,1.017]	[0.983,1.032]	[0.958,1.020]	[0.959,1.020]
Week elapased since main harvest*	1.010	1.010	1.040*	0.994	1.012	1.010	1.046*	0.996
market i has surplus (dummy)	[0.994,1.026]	[0.985,1.036]	[1.001,1.080]	[0.971,1.017]	[0.996,1.029]	[0.985,1.036]	[1.007,1.086]	[0.975,1.017]
Distance between *i*-*j* (100 km)	0.702***	0.610***	0.780*	0.753***				
	[0.623,0.790]	[0.505,0.737]	[0.643,0.947]	[0.643,0.882]				
Regions *i*-*j* is adjacent (dummy)					11.48***	16.99***	5.281**	13.47**
					[5.010,26.31]	[5.920,48.77]	[1.527,18.26]	[2.716,66.78]
Market *i* is rainy season (dummy)	0.939	1.206	0.365*	1.136	0.833	1.059	0.349*	0.884
	[0.594,1.483]	[0.693,2.097]	[0.150,0.889]	[0.518,2.490]	[0.544,1.275]	[0.626,1.790]	[0.151,0.805]	[0.420,1.862]
Origin *j* is rainy season (dummy)	1.106	0.875	0.447	3.633*	0.986	0.844	0.418	2.659*
	[0.559,2.188]	[0.370,2.068]	[0.184,1.083]	[1.255,10.51]	[0.523,1.862]	[0.370,1.924]	[0.173,1.009]	[1.013,6.975]
Market *i* is harvest season (dummy)	0.755	0.718	0.295	1.319	0.796	0.792	0.301	1.402
	[0.502,1.138]	[0.428,1.203]	[0.0563,1.547]	[0.801,2.170]	[0.508,1.247]	[0.435,1.444]	[0.0541,1.669]	[0.824,2.386]
Origin *j* is harvest season (dummy)	1.579*	1.378	3.135***	1.238	1.373	1.171	2.738***	1.050
	[1.040,2.398]	[0.707,2.687]	[1.641,5.988]	[0.762,2.011]	[0.927,2.034]	[0.664,2.064]	[1.514,4.951]	[0.642,1.716]
Variety (Reference: Vary gasy)								
Tsipala	0.471*				0.470*			
	[0.225,0.985]				[0.224,0.985]			
Makalioka	0.603				0.602			
	[0.269,1.350]				[0.269,1.346]			
N	59850	19950	18795	19950	59850	19950	18795	19950
pseudo R-sq	0.194	0.291	0.170	0.165	0.191	0.253	0.164	0.203
Log likelihood	-3627.3	-1406.9	-918.7	-1133.0	-3639.4	-1481.0	-925.9	-1080.4

Note: The unit of observation is (directed) market–origin–week–variety (N=72,072). Intra-regional flows are excluded. Samples are limited to off-main harvest weeks. Effect sizes are reported in the odds ratio. The 95% confidence interval is reported in brackets using robust standard errors clustered by (non-directed) market–origin pairs. Week fixed-effects are included but are not reported. Samples are omitted in some specifications given perfect predictions. * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Appendix

Table A1. Regional variables

Region	Population (persons) Total	Urban	Rural	Per capita rice consumption (kg) Urban	Rural	Total rice consumption (ton) Urban	Rural	Total	Total rice production (ton)	Difference	Rice sufficiency status
Analamanga	3,014,120	1,047,386	1,509,593	116	102	121,811	154,355	276,166	188,389	-87,777	Deficit
Analanjirofo	1,043,934	186,579	831,124	137	117	25,599	97,078	122,677	79,742	-42,935	Deficit
Atsimo Atsinanana	763,381	76,328	729,354	114	121	8,709	88,406	97,115	57,797	-39,318	Deficit
Sava	939,800	106,011	1,034,665	132	132	13,951	136,162	150,113	118,849	-31,264	Deficit
Atsinanana	1,341,983	301,070	983,779	81	69	24,417	67,924	92,341	66,595	-25,745	Deficit
Diana	611,178	199,300	356,196	164	164	32,586	58,238	90,824	70,881	-19,943	Deficit
Ihorombe	244,106	50,885	220,502	162	172	8,228	37,878	46,106	27,554	-18,552	Deficit
Vatovavy Fitovinany	1,321,930	152,655	1,238,205	71	75	10,762	92,734	103,497	96,248	-7,249	Deficit
Androy	593,565	148,415	729,354	45	37	6,708	27,059	33,767	26,882	-6,885	Deficit
Melaky	214,624	63,606	220,502	168	191	10,686	42,160	52,846	50,568	-2,279	Deficit
Anosy	671,722	84,809	576,698	93	76	7,870	43,927	51,797	63,022	11,225	Surplus
Menabe	482,822	139,934	491,890	150	123	21,018	60,641	81,659	100,323	18,664	Surplus
Atsimo Andrefana	1,272,567	322,273	1,085,550	72	59	23,042	63,707	86,749	106,494	19,745	Surplus
Sofia	1,180,537	122,972	1,051,626	178	202	21,864	212,802	234,666	256,960	22,294	Surplus
Betsiboka	301,279	46,645	339,234	130	148	6,068	50,229	56,298	94,604	38,306	Surplus
Amoron i Mania	873,194	84,809	610,622	86	92	7,310	55,916	63,227	108,850	45,623	Surplus
Boeny	675,820	207,781	508,851	100	114	20,799	57,970	78,769	165,951	87,182	Surplus
Bongolava	410,476	55,126	424,043	140	123	7,740	52,343	60,083	160,068	99,986	Surplus
Haute Matsiatra	1,371,170	224,743	1,017,703	91	96	20,384	98,059	118,443	245,566	127,123	Surplus
Itasy	785,311	76,328	746,315	112	99	8,564	73,620	82,184	231,874	149,690	Surplus
Alaotra Mangoro	1,100,271	169,617	882,009	163	139	27,597	122,170	149,766	339,563	189,796	Surplus
Vakinankaratra	1,988,354	373,158	1,373,899	88	77	32,689	105,813	138,502	392,155	253,653	Surplus

Source: Authors' calculation based on Population Explorer (2013). http://www.populationexplorer.com/ accessed in November 2014 for the variable "population;" INSTAT's 2010 household survey for the percentage of urban and rural populations; INSTAT's 2005 household survey for rice consumption per capita in urban and rural areas; and the Ministry of Agriculture (2013) for rice production per region.

Table A2. Seasonal variables

Region	Rainy season Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Harvest season Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Analamanga	1	1	1	0	0	0	0	0	0	0	0	1	0	0	1	1	**1**	**1**	0	0	0	0	0	0
Vakinankaratra	1	1	1	1	0	0	0	0	0	0	1	1	0	0	**1**	**1**	**1**	0	0	0	0	0	0	0
Itasy	1	1	1	0	0	0	0	0	0	0	0	1	0	0	1	1	**1**	**1**	0	0	0	0	0	0
Bongolava	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	**1**	**1**	0	0	0	0	0	0	0
Haute Matsiatra	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	**1**	**1**	0	0	0	0	0	0
Amoron'I Mania	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	**1**	**1**	0	0	0	0	0	0
Vatovavy Fitovinany	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	**1**	**1**	0	0	0	0	0	1
Ihorombe	1	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	**1**	**1**	0	0	0	0	0	1
Atsimo Atsinanana	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	**1**	**1**	0	0	0	0	0	1
Atsinanana	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	**1**	**1**	0	0	0	0	1
Analanjirofo	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	**1**	**1**	0	0	0	0	1
Alaotra Mangoro	1	1	1	1	0	0	0	0	0	0	1	1	0	0	1	1	**1**	**1**	0	0	0	0	0	0
Boeny	1	1	1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	**1**	**1**	0	0	0
Sofia	1	1	1	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	**1**	**1**	0	0	0
Betsiboka	1	1	1	1	0	0	0	0	0	0	0	1	0	0	**1**	**1**	**1**	**1**	0	0	0	0	0	0
Melaky	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	**1**	**1**	0	0	0	0	0	0	0
Atsimo Andrefana	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**1**	0	0	0	0	0
Androy	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Anosy	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	**1**	**1**	**1**	0	0	0	0	0	0
Menabe	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	**1**	**1**	0	0	0	0	0	0	0
Diana	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	**1**	**1**	0	0	0	0	1
Sava	1	1	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	**1**	1	0	0	0	0	1

Source: Fews Net (2013) "Madagascar livelihood zone map and descriptions," Ministry of Agriculture of Madagascar (2003) "Series of monograph of the 22 regions in Madagascar"

Note: "1" indicates rainy season or harvest season for that month. The main harvest season is emphasized using square and bold letters.

Table A3. Region-pair variables

	Analamanga	Vakinankaratra	Itasy	Bongolava	Haute Matsiatra	Amoron'I Mania	Vatovavy Fitovinany	Ihorombe	Atsimo Atsinanana	Atsinanana	Analanjirofo	Alaotra Mangoro	Boeny	Sofia	Betsiboka	Melaky	Atsimo Andrefana	Androy	Anosy	Menabe	Diana	Sava
A. Road distance (km)																						
Analamanga		169	95	218	395	259	579	545	688	369	474	320	570	754	329	651	865	918	1,028	730	1,204	1,390
Vakinankaratra	169		161	226	226	90	410	376	519	538	643	489	739	923	498	659	696	749	859	561	1,373	1,559
Itasy	95	161		123	387	251	571	537	680	464	569	415	665	849	424	556	857	910	1,020	722	1,299	1,485
Bongolava	218	226	123		452	316	636	702	745	587	692	538	788	972	547	433	922	975	1,085	787	1,422	1,608
Haute Matsiatra	395	226	387	452		136	296	150	405	764	869	715	965	1,149	724	885	470	523	633	596	1,599	2,003
Amoron'I Mania	259	90	251	316	136		320	286	429	628	733	579	829	1,013	588	749	606	659	769	460	1,463	1,649
Vatovavy Fitovinan	579	410	571	636	296	320		446	109	948	1,053	899	1,149	1,333	908	1,069	766	819	929	892	1,783	1,969
Ihorombe	545	376	537	702	150	286	446		275	914	1,019	865	1,115	1,299	874	1,135	320	373	483	746	1,749	1,935
Atsimo Atsinanana	688	519	680	745	405	429	109	275		1,057	1,162	1,008	1,258	1,442	1,017	1,178	595	648	758	1,001	1,892	2,078
Atsinanana	369	538	464	587	764	628	948	914	1,057		105	459	939	1,123	698	1,020	1,234	1,287	1,397	1,099	1,573	1,759
Analanjirofo	474	643	569	692	869	733	1,053	1,019	1,162	105		564	1,044	1,228	803	1,125	1,339	1,392	1,502	1,204	1,678	1,864
Alaotra Mangoro	320	489	415	538	715	579	899	865	1,008	459	564		890	1,074	649	971	1,185	1,238	1,348	1,050	1,524	1,710
Boeny	570	739	665	788	965	829	1,149	1,115	1,258	939	1,044	890		474	241	636	1,435	1,488	1,598	1,300	924	1,110
Sofia	754	923	849	972	1,149	1,013	1,333	1,299	1,442	1,123	1,228	1,074	474		425	820	1,619	1,672	1,782	1,484	450	636
Betsiboka	329	498	424	547	724	588	908	874	1,017	698	803	649	241	425		395	1,194	1,247	1,357	1,059	875	1,061
Melaky	651	659	556	433	885	749	1,069	1,135	1,178	1,020	1,125	971	636	820	395		1,357	1,408	1,518	407	1,270	1,456
Atsimo Andrefana	865	696	857	922	470	606	766	320	595	1,234	1,339	1,185	1,435	1,619	1,194	1,357		582	692	1,066	2,069	2,255
Androy	918	749	910	975	523	659	819	373	648	1,287	1,392	1,238	1,488	1,672	1,247	1,408	582		110	1,129	2,122	2,308
Anosy	1,028	859	1,020	1,085	633	769	929	483	758	1,397	1,502	1,348	1,598	1,782	1,357	1,518	692	110		1,239	2,232	2,418
Menabe	730	561	722	787	596	460	892	746	1,001	1,099	1,204	1,050	1,300	1,484	1,059	407	1,066	1,129	1,239		1,934	2,120
Diana	1,204	1,373	1,299	1,422	1,599	1,463	1,783	1,749	1,892	1,573	1,678	1,524	924	450	875	1,270	2,069	2,122	2,232	1,934		448
Sava	1,390	1,559	1,485	1,608	2,003	1,649	1,969	1,935	2,078	1,759	1,864	1,710	1,110	636	1,061	1,456	2,255	2,308	2,418	2,120	448	
B. Adjacent																						
Analamanga		1	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Vakinankaratra	1		1	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0
Itasy	1	1		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bongolava	1	1	1		0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0
Haute Matsiatra	0	0	0	0		1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Amoron'I Mania	0	1	0	0	1		1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0
Vatovavy Fitovinan	0	0	0	0	1	1		0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ihorombe	0	0	0	0	1	0	0		1	0	0	0	0	0	0	0	1	0	1	0	0	0
Atsimo Atsinanana	0	0	0	0	1	0	1	1		0	0	0	0	0	0	0	0	0	1	0	0	0
Atsinanana	0	1	0	0	0	1	1	0	0		1	1	0	0	0	0	0	0	0	0	0	0
Analanjirofo	0	0	0	0	0	0	0	0	0	1		1	0	1	0	0	0	0	0	0	0	1
Alaotra Mangoro	1	1	0	0	0	0	0	0	0	1	1		0	1	1	0	0	0	0	0	0	0
Boeny	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1	0	0	0	0	0	0
Sofia	0	0	0	0	0	0	0	0	0	0	1	1	1		1	0	0	0	0	0	1	1
Betsiboka	1	0	0	1	0	0	0	0	0	0	0	1	1	1		1	0	0	0	0	0	0
Melaky	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1		0	0	0	1	0	0
Atsimo Andrefana	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0		1	1	1	0	0
Androy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		1	0	0	0
Anosy	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1		0	0	0
Menabe	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0		0	0
Diana	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0		1
Sava	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	

Source: Authors based on a Madagascar Roadmap from the National Hydrographic and Geographic Institute in Madagascar (FTM), 2003

Note: The distance is calculated using the optimal itinerary connecting two region capitals.

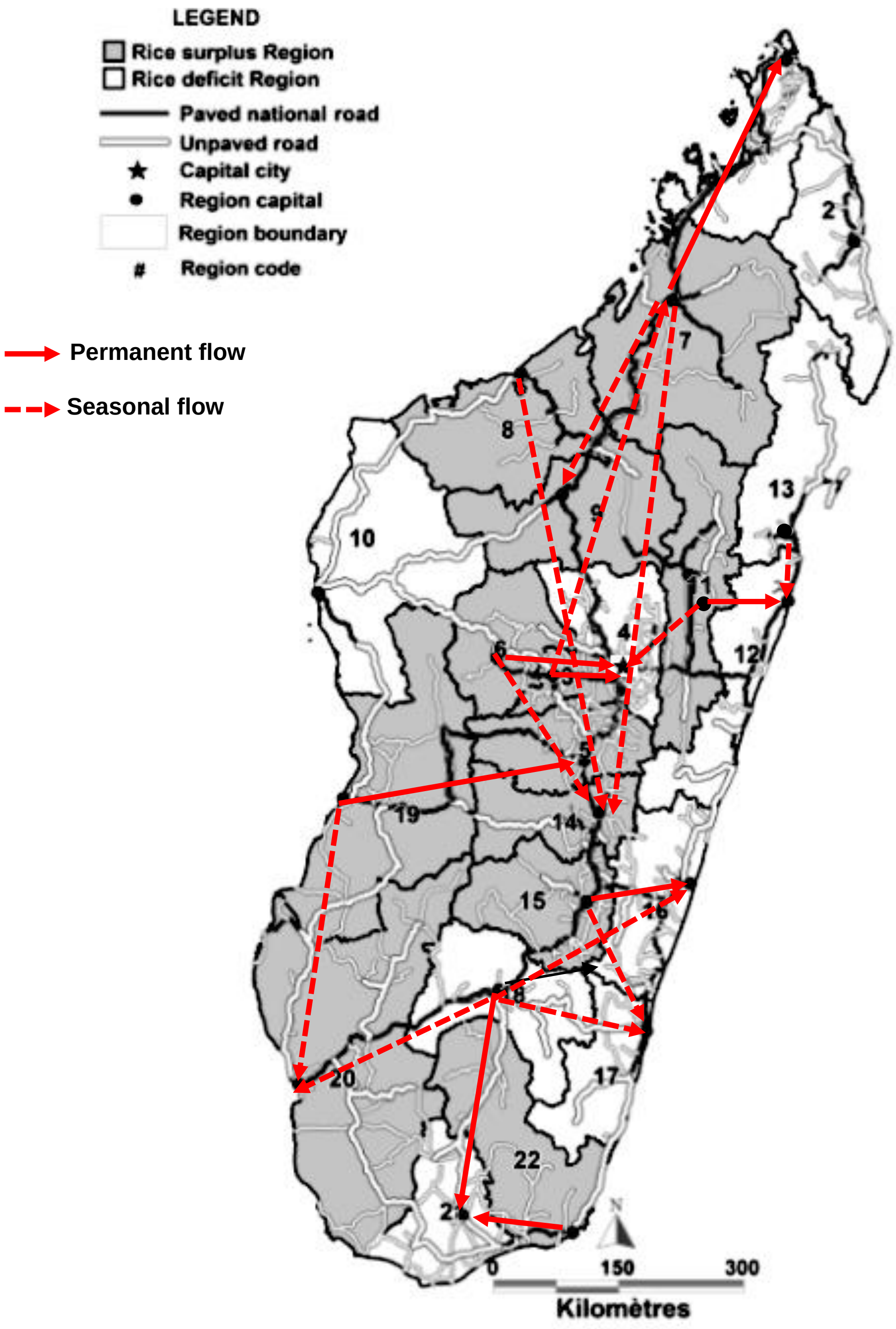


Fig. A1 Localization of inter-regional flows of *vary gasy*

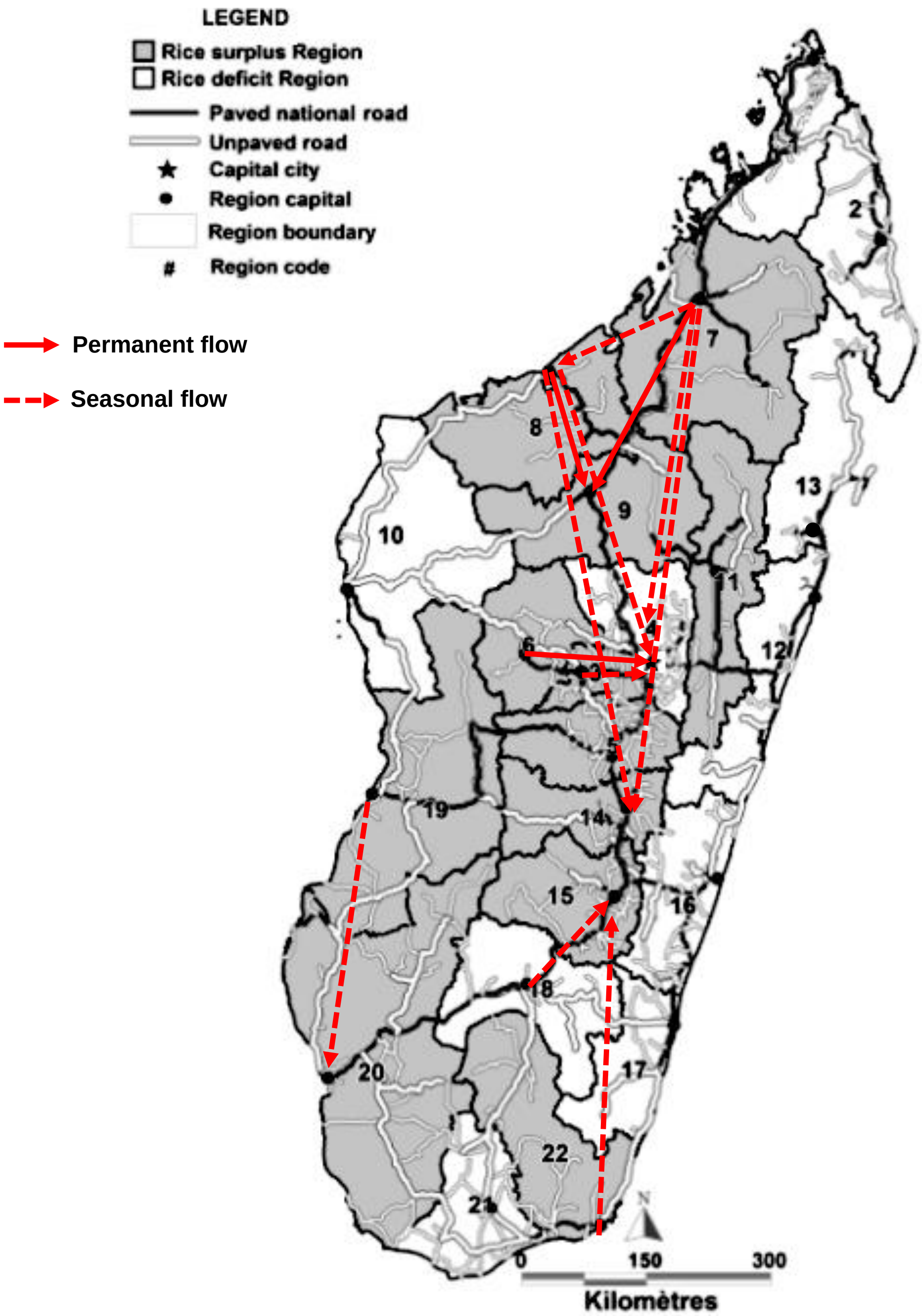


Fig. A2 Localization of inter-regional flows of *tsipala*

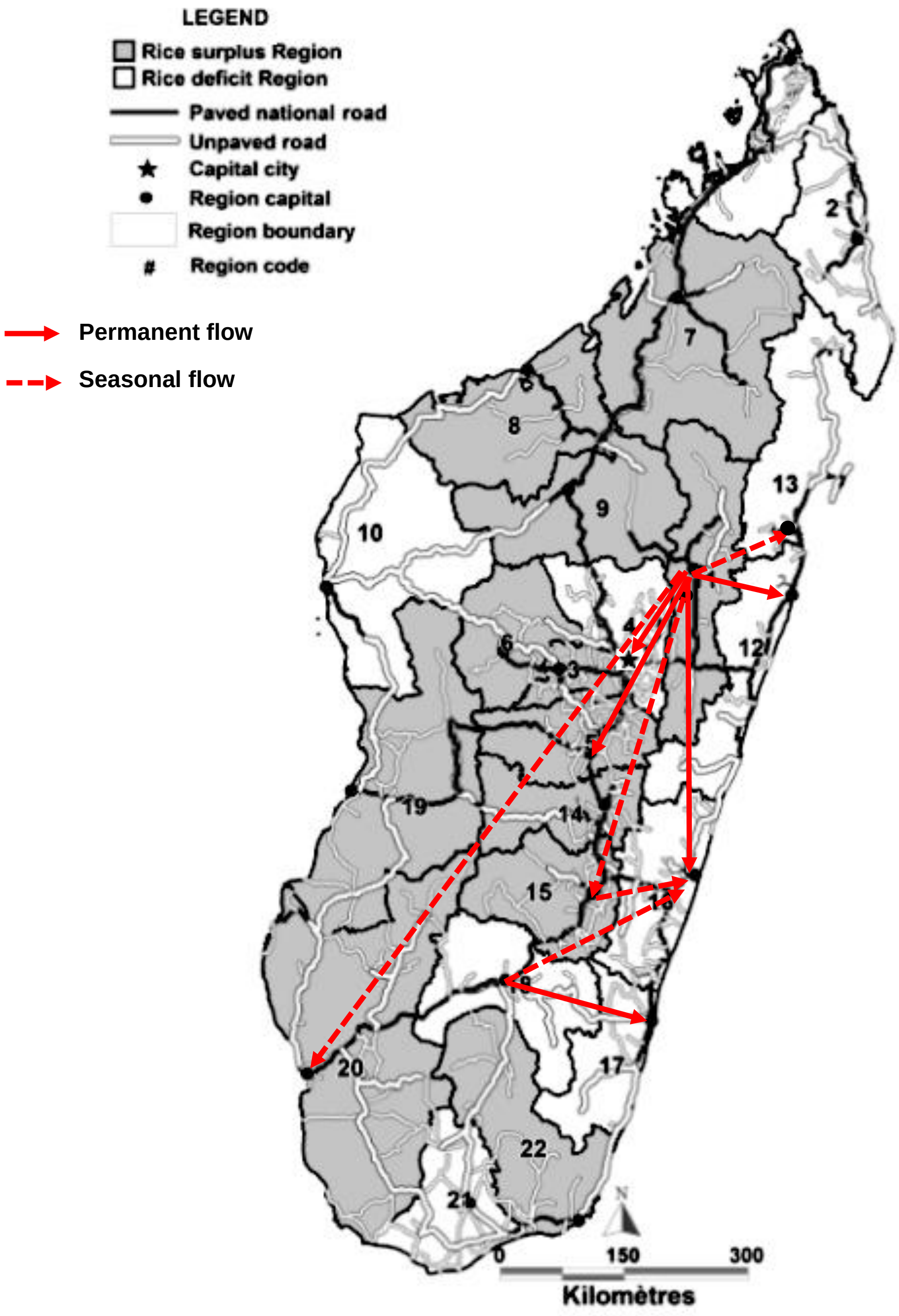


Fig. A3 Localization of inter-regional flows of *makalioka*