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## **Does a Market-Oriented Variety Change Rice Farming in SSA?: Evidence from a New Aromatic Rice Variety in Northern Ghana**

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Since around 2000 rice demand has been increasing in SSA due to urbanization, and urban consumers prefer aromatic rice imported from Asian countries. Recently a new aromatic rice variety was introduced in Ghana. If farmers are to respond to urban demand, they should be more likely to choose this market-oriented variety. This study examines the impact of this new aromatic variety on farmers. Results show that farmers who adopt this variety achieve higher yield but no higher profit. Larger production costs and little price advantage in the local market may be the reasons.

**Key words:** Technology adoption, Market-oriented rice variety, Rice quality in SSA

### **1. Introduction**

Recently, the importance of rice in the diets is increasing in Sub-Saharan Africa (SSA). Due to recent economic growth and urbanization since 2000, high-quality rice imported mainly from Thailand and Vietnam has become popular in urban market in SSA. Such a phenomenon is more typical in coastal countries in West Africa (Demont, 2013). In urban market in those countries, locally produced rice is differentiated from high-quality imported rice and sold at a lower price due to its inferior quality. Thus, in order for domestically produced rice to compete with imported rice in urban markets, its quality attributes need to be better tailored to urban consumer preferences (Demont and Ndour, 2015). Since one of the most distinguishable quality attributes of high-quality imported rice is aroma<sup>1)</sup>, this study focuses on it.

Will farmers choose aromatic varieties if they are available? This paper tries to answer this question by taking the case of Ghana, which is one of the most typical coastal countries in West Africa. From the view point of rice producers, the rising urban demand implies that they have a big opportunity to increase their income by supplying their rice to urban market, but the problem is until recently there had been no aromatic rice varieties available to domestic farmers in Ghana.

In 2009, Ghanaian government officially released a new

aromatic rice variety called “Jasmine 85”. This variety (hereafter, Jasmine variety in this paper) has unique characteristics as an improved variety: it is aromatic and high-yielding at the same time. Moreover, its grain shape is very similar to popular imported rice from Thailand and Vietnam. Therefore, we can consider it as the first market-oriented aromatic rice variety available to rice farmers in Ghana<sup>2)</sup>.

While high-yielding has been the most important criterion in the improvement of staple food crops including rice because household food security has been the central concern in SSA, Jasmine variety is one of the earliest improved rice varieties intentionally fit with consumer preferences in SSA. Therefore, to see the impact of Jasmine variety is of great interest. Particularly, it is very important to know its impact in the early stage of the introduction since it will predict how such market-oriented varieties contribute to the change of smallholders’ welfare. The results will provide us with relevant policy implications for SSA countries.

For this purpose, this study investigates the impact of the adoption of Jasmine variety on rice farmers by utilizing data collected in Northern Ghana. The data covers rice production in 2012, just three years after the official introduction of this variety. Therefore, this situation is suitable to see the early-stage impact of such a market-oriented rice variety.

In the literature on rice technology adoption in SSA,

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1) Aromatic rice has price premiums on non-aromatic rice (Diagne, Demont, and Ndour, 2017).

2) Our qualitative interviews in the study site confirm that local rice traders and urban markets prefer long shaped and aromatic local varieties to other round shaped local varieties.

positive impacts of modern varieties on rice yield and profit have been identified (Faltermeier and Abdulai, 2009; deGraft-Johnson *et al.*, 2014; Abdulai and Huffman, 2014). However, we do not know whether the adoption of a market-oriented rice variety leads to an improvement of rice production<sup>3)</sup>. This study provides an answer to this question and will contribute to rice policy in SSA.

## 2. Data

This study utilizes the data collected in 90 villages (called communities in Ghana) around Tamale, the capital city of Northern Region, Ghana, from April to May 2013. Data collection was implemented by Japan International Cooperation Agency Research Institute (JICA-RI) and Savanna Agricultural Research Institute (SARI). Among the 90 villages, 60 villages are those surveyed in May 2010 and 30 villages are those newly selected for this survey. The 60 villages surveyed in May 2010 consist of 20 villages randomly selected from the set of 58 villages where Lowland Rice Development Project (LRDP) was conducted from 1998 to 2003 funded by the Agence Française de Développement (AFD) and 40 villages randomly selected around the 20 LRDP project villages from 1/50,000 scale topographic sheets. The newly selected 30 villages include 15 villages where JICA have implemented Sustainable Development of Rainfed Lowland Rice Production project from 2010. The 15 villages are all the project villages in the Northern Region as of 2012. Another 15 villages are randomly selected around the 15 project villages from 1/50,000 scale topographic sheets.

From each 90 village, 10 rice producing households are randomly selected as sample households. Thus, total sample size is 900. Due to missing values for key variables, we drop 93 observations from the analysis. In addition, since some observations have an extremely high value for rice yield, we drop 54 observations whose yield is more than 10 t/ha. Finally, 753 sample households remain for the analysis.

## 3. Estimation methods

The choice of rice varieties by farmers is not random but intentional. To deal with the selection bias caused by non-random adoption of Jasmine variety, this study applies endogenous treatment effect model. Endogenous treatment

effect model is a variant of endogenous switching model, which estimates average treatment effect (ATE). The equations for estimating the impact of the adoption of Jasmine variety are specified as follows (Cameron and Trivedi, 2010);

$$y_i^j = \mathbf{x}_i' \boldsymbol{\beta} + \delta \text{Jasmine}_i + \varepsilon_i \quad (1)$$

$$\text{Jasmine}_i = \begin{cases} 1 & \text{if } \mathbf{x}_i' \boldsymbol{\theta} + \gamma z_i + u_i > 0 \\ 0 & \text{if } \mathbf{x}_i' \boldsymbol{\theta} + \gamma z_i + u_i \leq 0 \end{cases} \quad (2)$$

$$\begin{bmatrix} \sigma^2 & \rho\sigma \\ \rho\sigma & 1 \end{bmatrix} \quad (3)$$

Equation (1) is for the outcome of Jasmine variety adoption, where  $y_i^j$  is the outcome for household “i” about “j”, such as rice yield, income, profit, and input use. “Jasmine” is the indicator of the adoption of Jasmine variety, which takes value 1, if household i adopts Jasmine variety, and otherwise 0. Coefficient  $\delta$  is the impact of the adoption of Jasmine variety on the outcome. “ $\mathbf{x}$ ” is the vector of control variables, which include household head’s characteristics: age (years), formal primary education (dummy=1 if finished primary school), polygamous marriage (dummy=1 if polygamously married), and household’s characteristics: healthy family labor over 15 years old (number), off farm activity (dummy=1 if at least one member of household i is engaged in an off farm activity), average distance from home to rice plots (km), years of continuous use of rice plots (average years of all the plots of household i), clay soil plot (dummy=1 if at least one plot of household i has clay soil), flat land slope (dummy=1 if at least one plot of household i on flat land), family land tenure (dummy=1 if at least one plot cultivated by household i is owned by the household i).  $\boldsymbol{\beta}$  is the vector of parameters to be estimated.  $\varepsilon$  is error term.

Equation (2) is to estimate the probability of adopting Jasmine variety. “Jasmine” and “ $\mathbf{x}$ ” are the same as above. “ $z$ ” is the availability of Jasmine variety in the village (dummy=1 if Jasmine variety is available). This variable is used as an instrumental variable.  $\boldsymbol{\theta}$  and  $\gamma$  are parameters to be estimated.  $u$  is error term.

The two error terms in equations (1) and (2) have bivariate normal distribution with mean zero and covariance matrix given as equation (3). If  $\rho \neq 0$ , the decision to adopt Jasmine variety is endogenous for rice inputs and output. The endogeneity is tested by Wald test.

## 4. Descriptive Statistics

Tables 1 and 2 show the availability of Jasmine variety in

3) Vandecasteele *et al.* (2018) indicate that better connections of rural farmers with urban demand through cities are an important factor promoting agricultural transformation in SSA.

the village<sup>4)</sup> and the number of the adopters in the sample households respectively. According to the tables, 37 percent of villages have access to Jasmine variety and 10 percent of sample households adopt Jasmine variety. In the 33 villages with the availability of Jasmine variety, the adoption rate becomes almost 20 percent. Those facts indicate that since the introduction of Jasmine variety in 2009, farmers who have adopted this new aromatic rice variety are still limited. Whether a village has access to the Jasmine variety is beyond the control of individual farmers who live in the villages. Therefore, the availability of Jasmine variety to farmers is considered to be exogenous and determined by random factors for farmers. Recognizing this situation as a natural experiment of the introduction of a new rice variety to rice farmers, this study uses the access to Jasmine variety at the village level as an instrumental variable in the estimations of endogenous treatment effect model.

**Table 1. Jasmine variety availability in the village**

	Number of Villages	Rate (%)
Available	33	37
Not available	57	63
Total	90	100

Source: Lowland Rice Technology Diffusion Study in 2013.

**Table 2. Jasmine variety adoption rate**

	Number of Farmers	Rate (%)
Jasmine adopter	74	10
Jasmine non-adopter	679	90
Total	753	100

Source: Lowland Rice Technology Diffusion Study in 2013.

Table 3 shows the summary statistics of rice output and inputs for the adopters of Jasmine variety and the non-adopters. According to the table, the rice yield of Jasmine adopters is about 1.8 t/ha<sup>5)</sup>. This yield is statistically significantly higher than that of the non-adopters. However, there are no statistically significant differences in rice

income and profit between the two groups<sup>6)</sup>. Those simple comparisons give us the prediction that rice farmers who adopt Jasmine variety will get higher yield than the non-adopters, but will not earn higher income or profit than the non-adopters. The benefits of higher yield seem to be cancelled out by the higher production costs or low evaluation of Jasmine variety in the local markets (i.e. farm-gate price of Jasmine variety is not different from that of other rice varieties).

**Table 3. Summary statistics of rice output and inputs**

	Jasmine Adopter (a)	Jasmine Non-Adopter (b)	Diff. (a)-(b)
<b>Output</b>			
Rice yield (kg/ha)	1800(1607)	1413 (1162)	***
Rice income (GHC/ha)	501 (833)	377 (648)	
Rice profit (GHC/ha)	-76.0(1076)	-21.8 (853)	
<b>Inputs</b>			
Chemical fertilizer (kg/ha)	157 (186)	107 (140)	***
Herbicide (GHC/ha)	38.1 (31.5)	33.3 (1.30)	
Labor (person-days/ha)			
Family labor, adult male	86.3 (17.3)	59.6 (102)	**
Family labor, adult female	33.0 (54.3)	27.3 (45.0)	
Family labor, child (<15)	13.3 (33.1)	6.52 (19.7)	***
Exchange labor	22.6 (47.4)	17.6 (42.6)	
Hired labor	10.2 (16.1)	7.94 (19.9)	
Number of observations	74	679	

Note: \*\*\* and \*\* indicate 1% and 5% significance level respectively. Numbers in parenthesis are standard deviation. If a household has two plots or more, inputs and output are aggregated at the household level. GHC stands for Ghanaian currency, Cedi.

Source: Lowland Rice Technology Diffusion Study in 2013.

For the agricultural chemical inputs, farmers who adopt Jasmine variety apply 157 kg/ha of chemical fertilizer. This amount is very close to the amount of combination of 100 kg/ha of NPK and 50 kg/ha of Urea, recommended for efficient rice production in this region. That of the non-adopters is 107 kg/ha, which is less than the recommended amount and statistically significantly lower than that of the adopters. In contrast to the application of chemical fertilizer, there is no statistically significant difference in the cost of herbicide per hectare between the adopters of Jasmine variety and the non-adopters.

6) Rice income is defined as “the value of rice produced less total paid-out cost (seed, fertilizer, other chemical, tractor and hired and exchange labor)/ ha”. Note that exchange labor is not really paid, but we assume that its unit cost is the same as hired labor. Rice profit is defined as “rice income less imputed family labor costs (family male, female and child labor costs)/ha”.

4) Village level information about the availability of Jasmine variety is collected by interview with village chairman and informants who know well the situation of rice production in the village.

5) This is much lower than Ghana's national average yield of rice, which fluctuates around 2.5 t/ha since 2008 according to FAOSTAT. Since this yield is lower than that reported in deGraft-Johnson *et al.* (2014) who use the data collected in 2010 from the same households that are in the dataset used for this study, we consider that 2012 was an unfavorable year of rice production. This will explain the negative profit for both groups.

Table 3 also compares labor inputs between the two groups. According to the table, farmers who adopt Jasmine variety use male family labor and child family labor more than the non-adopters, while there are no statistically significant differences in the usage of female family labor, exchange labor, and hired labor.

From the simple comparisons of rice output and inputs between the adopters and non-adopters, rice production of Jasmine adopters is more intensified than non-adopters, particularly with respect to the use of chemical fertilizer and family labor. As a result, the adopters get higher rice yield. However, we cannot simply conclude like this because the adoption of Jasmine variety is an endogenous choice. Therefore, we adopt the endogenous treatment effect model and estimate an unbiased impact of Jasmine adoption on the intensification. The results are given in the next section.

### 5. Results

This section provides the estimation results of endogenous treatment effect model. Table 4 shows the impact of the adoption of Jasmine variety on rice outputs. The results indicate that Jasmine adopters have statistically significantly higher rice yield than non-adopters. However, there is no evidence that Jasmine adopters get higher income or profit than non-adopters. Table 5 shows the

impact of the adoption of Jasmine variety on input use for rice production. The results show that farmers who adopt Jasmine variety use chemical fertilizer and herbicide more intensively for rice production than non-adopters. As for labor inputs, farmers who adopt Jasmine variety tend to apply more female family labor for rice productions per hectare than non-adopters. The intensive labor use is also confirmed regarding hired labor and exchange labor.

### 6. Discussion

The regression results shown above imply that farmers who adopt Jasmine variety intensify rice production by using more chemical and labor per unit of land than non-adopters, which is like the Green Revolution in Asia. This kind of agricultural intensification should result in more production per unit of land, and consequent higher income and profit. However, our analysis shows, in spite of the significantly higher yield for Jasmine variety adopters, income and profit do not differ between the two groups.

Why does Jasmine variety have no impact on income and profit? One possible reason is the higher cost associated with intensified production. This may have happened particularly because of the lower rice production in 2012. Jasmine adopters used more inputs expecting a higher output and profit, but since the yield was not so high as

**Table 4. Impact of Jasmine adoption on rice outputs (endogenous treatment effect model)**

Explanatory Variables	Rice Yield (kg/ha)		Rice Income (GHC/ha)		Rice Profit (GHC/ha)	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Jasmine adoption	1425	582***	497	757	-123	266
Control Variables						
Household head age (years)	-2.2	4.4	0.7	2.3	1.3	3.3
Formal primary education (dummy)	-170	191	-220	99**	-122	124
Polygamous marriage (dummy)	92	107	67	60	127	75*
Family adult and healthy labor (number)	-4.6	21	-7.7	11	-26	15*
Off farm activity at least one member (dummy)	71	132	38	73	-4.6	74
Average distance from home to rice plots (km)	1.1	1.6	0.8	0.8	1.5	0.7*
Average years of continuous use of rice plots (years)	0.6	5.5	0.2	3.1	0.9	3.4
At least one plot has clay soil (dummy)	103	107	33	58	126	71
At least one plot is on flat land (dummy)	170	111	62	59	45	79
At least one plot is owned by the household (dummy)	143	113	71	70	230	110*
Constant	1050	236***	181	138	-328	189*
Number of Observations	753		753		753	
Wald (chi 2)	1.9		12.9		19.2	
Endogeneity test: Prob>chi2	0.168		0.298		0.057	

Note: \*\*\*, \*\*, and \* indicate 1%, 5%, and 10% significance level respectively. Coef., S.E., and GHC stand for coefficient, standard error, and Ghanaian Cedi respectively. If a household has two plots or more, inputs and output are aggregated at the household level. Descriptive statistics of the explanatory variables are available upon request to the authors.

Source: Lowland Rice Technology Diffusion Study in 2013.

Table 5. Impact of Jasmine adoption on input use for rice production (endogenous treatment effect model)

Explanatory Variables	Chemical Fertilizer (kg/ha)		Herbicide (GHC/ha)		Male Family Lab. (man-days/ha)		Female Family Lab. (man-days/ha)		Child Family Lab. (man-days/ha)		Exchange Lab. (man-days/ha)		Hired Lab. (man-days/ha)	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Jasmine adoption	185	66.5***	53.8	8.9***	99.6	205	63.3	10.4***	21.8	18.9	62.9	16.2***	31.5	4.1***
Control Variables														
Household head age (years)	0.6	0.5	0.0	0.1	-0.3	0.5	0.2	0.2	0.0	0.1	-0.3	0.2	0.0	0.1
Formal primary education (dummy)	-3.6	19.8	-1.1	5.5	-22.1	20.7	-1.9	8.2	-3.8	3.3	8.1	10.9	4.0	2.9
Polygamous marriage (dummy)	21.0	10.0**	-1.5	3.1	-13.5	8.0*	4.1	4.0	2.3	1.4*	-2.6	2.4	1.6	2.1
Family adult and healthy labor (number)	-1.9	2.0	0.2	0.6	3.7	1.8**	0.3	0.6	-0.4	0.3	-0.1	0.8	0.0	0.4
Off farm activity at least one member (dummy)	10.9	14.3	7.1	3.4**	-1.9	18.2	7.1	4.9	3.9	2.5	-6.1	3.8	1.6	2.2
Average distance from home to rice plots (km)	-0.1	0.3	0.0	0.1	-0.0	0.1	-0.1	0.1	-0.0	0.0**	-0.0	0.1	-0.0	0.0
Average years of continuous use of rice plots (years)	-0.2	0.6	0.0	0.2	-0.1	0.4	-0.0	0.2	0.0	0.1	0.2	0.2	0.0	0.1
At least one plot has clay soil (dummy)	-10.4	0.3	2.8	2.9	-25.3	10.5**	2.2	3.3**	0.0	1.9	3.0	3.9	-1.0	1.7
At least one plot is on flat land (dummy)	21.8	13.4	-1.7	3.2	-6.2	12.5	8.3	4.0	0.1	1.8	4.7	3.1	-2.0	1.8
At least one plot is owned by the household (dummy)	-20.9	18.5	-0.3	3.8	-27.2	21.4	-8.9	6.3	-5.7	2.7**	-4.1	4.4	-1.9	1.9
Constant	76.9	32.0**	25.2	7.0***	96.9	35.8***	8.1	9.0	8.5	5.4	24.1	8.3***	5.2	4.1
Number of Observations	753		753		753		753		753		753		753	
Wald (chi 2)	2.34		21.07		14.37		53.89		25.31		52.23		84.58	
Endogeneity test: Prob>chi2	0.126		0.000		0.213		0.000		0.008		0.000		0.000	

Note: \*\*\*, \*\*, and \* indicate 1%, 5%, and 10% significance level respectively. Coef., S.E., GHC, and Lab. stand for coefficient, standard error, Ghanaian Cedi, and labor, respectively. If a household has two plots or more, inputs and output are aggregated at the household level. Descriptive statistics of the explanatory variables are available upon request to the authors.

Source: Lowland Rice Technology Diffusion Study in 2013.

expected, they could not earn a good economic return. If this is the case, Jasmine adopters will be better off in normal or good years than non-adopters.

Another possible reason is the inefficient local rice market, where rice price does not reflect its quality properly. In fact, in our casual interviews with farmers and traders they commented that rice quality is hardly evaluated in the local market<sup>7)</sup>. According to our data, farmers' actual selling price of paddy is 0.68 GHC/kg on average for the aromatic variety and 0.70 GHC/kg on average for other local varieties. If this inefficient pricing continues, Jasmine variety will only have yield advantage and its adopters cannot enjoy quality premiums in the urban market. Farmer will shift to non-aromatic varieties if their yield is better than Jasmine variety.

## 7. Conclusion

Jasmine variety is the first market-oriented aromatic rice variety available to rice farmers in Ghana. This paper examined whether this rice variety changes rice farming.

First, we confirmed some farmers already adopted this new rice variety even just three years after the official release in Ghana. Since the availability of Jasmine variety is limited to some villages and exogenous to individual rice farmers, we assume the situation is a natural experiment and hence we adopt endogenous treatment effect model to deal with the endogeneity in the varietal choice.

The regression analysis shows that farmers who adopt Jasmine variety intensify rice production, that is, they use more chemical and labor input per unit of land. This change is the same as that observed in the case of the Green Revolution in Asia. Jasmine variety gives better yield than other varieties even in a seemingly unfavorable year. In spite of the advantage in production, income and profit do not significantly differ. Hence, we conclude that the adoption of Jasmine variety does not have a positive impact on rice producers' welfare.

We consider two reasons for the insignificant welfare impact. One is high production cost associated with the

intensification. But the high production cost may be excelled by increased production in favorable years. Another reason is low output price. Although Jasmine variety is considered to be market-oriented one and in fact it has a price premium in urban consumer market, its farm-gate price is the same as other varieties in the study site. If this inefficient pricing continues, farmers may abandon Jasmine variety. Therefore, for rice farmers in Ghana to compete with imported rice in urban markets, an improvement of market system and an introduction of cost saving technology will be required.

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7) As mentioned earlier, quality premium exists in urban retail markets of milled rice. But most farmers in the study site sell paddy to traders who come to village to buy paddy or to local paddy collectors who work for the traders from outside. At the time of data collection for this study, we could not observe any quality premium in the farm-gate price, at which transactions between farmers and buyers take place. However, quality-based pricing of paddy has recently been emerging in the study site. The assessment of its impact is left for future study.